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BANGLADESH RICE RESEARCH INSTITUTE

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Preface

The present volume of BRRI Annual Report is a summary of research works carried out by 19 research divisions and eleven regional stations of the institute during July 2020 to June 2021. This document consists of the significant portions of the research covering eight programme areas.

The programme areas such as variety development, crop-soil-water management, rice farming systems, pest management, socio-economics and policy, farm mechanization, technology transfer and regional stations representing the broader conceptual frameworks of BRRI activities.

With a target to sustain Bangladesh's achievements as a rice surplus country, BRRI scientists have been engaged in developing various location specific, climate smart, stress tolerant rice varieties and some nutritionally enriched premium quality ones.

Another group of BRRI scientists dedicated their time to develop and disseminate resource-saving profitable environment friendly technologies along with some management tools such as alternate wetting and drying (AWD) techniques, low cost water distribution system, rice transplanter, low cost machinery like harvester, weeder etc., integrated crop management (ICM) practices, rice based farming systems and popularization of BRRI machinery to the end users.

Furthermore, BRRI developed high yielding rice varieties along with management technologies were demonstrated in different agro-ecological zones of the country.

Above all, the present report includes various research results out of activities that attempted to minimize yield gap. It also includes research initiatives dedicated to finding out coping strategies to face the effects of changing climate like increased flash floods, salinity, excessive heat and drought as well as severe cold.

I acknowledge all the efforts that helped bring out the publication and special thanks for those who contributed with different capacities.

I hope the report will be useful for the scientists, extension agents, policy makers and other partners home and abroad to be updated on continuous research activities at BRRI.

(Dr Md Shahjahan Kabir)
Director General
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Weather information

Introduction: Weather is an instantaneous state of atmosphere, describing for example the degree to which it is hot or cold, wet or dry, calm or stormy, clear or cloudy. It influences growth and development of crops as well as pest and disease incidences. We present here the available weather parameters *viz* maximum and minimum temperature (℃), rainfall (mm), pan evaporation (mm), humidity (9 am and 2pm), sunshine hours and solar radiation (gm-cal/cm^2/day) during the reporting year (July 2020 - June 2021) as recorded from BRRI he adquarter-Gazipur and six regional stations Rangpur, Cumilla, Bhanga, Habiganj, Barishal and Sonagazi by Plant Physiology Division.

Temperature: The mean maximum temperature was higher in April and May for most of the stations during the reporting period. The highest mean monthly maximum temperature was recorded at Cumilla (37.20 ℃) followed by Barishal (36.65 ℃), Gazipur (36.15 ℃), Bhanga (35.52 ℃) and Sonagazi (34.10 ℃) during April. However, in Rangpur the highest mean monthly maximum temperature was recorded during August (32.56 ℃) and for Habiganj in May (34.69 ℃) (Fig 1). Mean monthly minimum temperature was recorded lowest for Rangpur from October to June compared to all station. The lowest mean monthly minimum temperature was recorded at Rangpur (11.35 ℃) followed by Bhanga (12.89 ℃), Barishal (12.96 ℃), Sonagazi (12.99 ℃), Gazipur (13.19 ℃) and Habiganj (14.11 ℃) during January for all station except Habiganj in February (Fig. 1).

Rainfall and Wet days: Total rainfall during the reporting period was recorded highest at Sonagazi (2184.50 mm) and lowest at Bhanga (921.20 mm). Mean monthly highest total rainfall was recorded at Rangpur (695.08 mm) in September followed by Sonagazi (581.50) in June, Barishal (466.20 mm) in August, Cumilla (404.75 mm) in June, Habiganj (400.60 mm) in July, Gazipur (356.40 mm) in June and Bhanga (273.30 mm) in July (Fig. 2). However, no rainfall recorded during December to March for all the station. Wet days or rainy days was recorded highest in Gazipur (126 days) followed by Barishal (112 days), Sonagazi (105 days), Rangpur (94 days), Bhanga (94 days), Habiganj (73 days) and Cumilla (71 days) (Fig. 2).

Relative humidity and Pan evaporation: Relative humidity was recorded twice daily i.e. 9 am and 2 pm. Mean monthly relatively humidity was recorded highest and lowest in Cumilla (94.40%) and Gazipur (78.10%) at 9 am, respectively. However, at 2 pm, it was highest in Sonagazi (69.92%) and lowest in Cumilla (63.49%). In general, relative humidity was recorded relatively higher at the morning irrespective of stations and gradually declined at noon (Fig. 3). Mean monthly maximum RH was recorded at Habiganj (96.61%) in January and lowest in Gazipur (65.19%) in March at 9 am. However, at 2 pm, it was highest at Habiganj (86.74%) in August and lowest in Gazipur (47.35%) in March (Fig. 3). Mean pan evaporation was recorded highest at Rangpur (3.22 mm) and lowest in Barishal (2.08 mm). Mean monthly pan evaporation was recorded highest at Sonagazi (5.53 mm) in April and lowest at Bhanga and Rangpur (1.26 mm) in December and January, respectively (Fig. 3).

Solar radiation and sunshine hours: Mean solar radiation ranged from 290.35 to 341.39 gm-cal/cm^2/day. Solar radiation was relatively lower during the months of December and January. The highest mean mo nthly solar radiation prevailed in April at Habiganj (461.30 gm-cal/cm^2/day) followed by Cumilla (454.60 gm-cal/cm^2/day) in May, Gazipur (447.38 gm-cal/cm^2/day), Sonagazi (526.12 gm-cal/cm^2/day), Bhanga (421.52 gm-cal/cm^2/day), Barishal (415.79 gm-cal/cm^2/day) in May and Rangpur (361.71 gm-cal/cm^2/day) in August (Fig. 4). However, it was lowest in January at Habiganj (149.51 gm-cal/cm^2/day). The mean sunshine hours per day was ranged from 4.97 to 6.19 hours.

The mean monthly sunshine hour was highest at Rangpur (9.36 hours) in February followed by Cumilla and Habiganj (8.79 hours), Gazipur (8.33 hours), Sonagazi (7.72 hours), Bhanga (7.56 hours) and Barishal (7.36 hours) in April, respectively (Fig. 4). However, lowest mean monthly sunshine hours recorded at Sonagazi (2.47 hours) in June (Fig. 4).

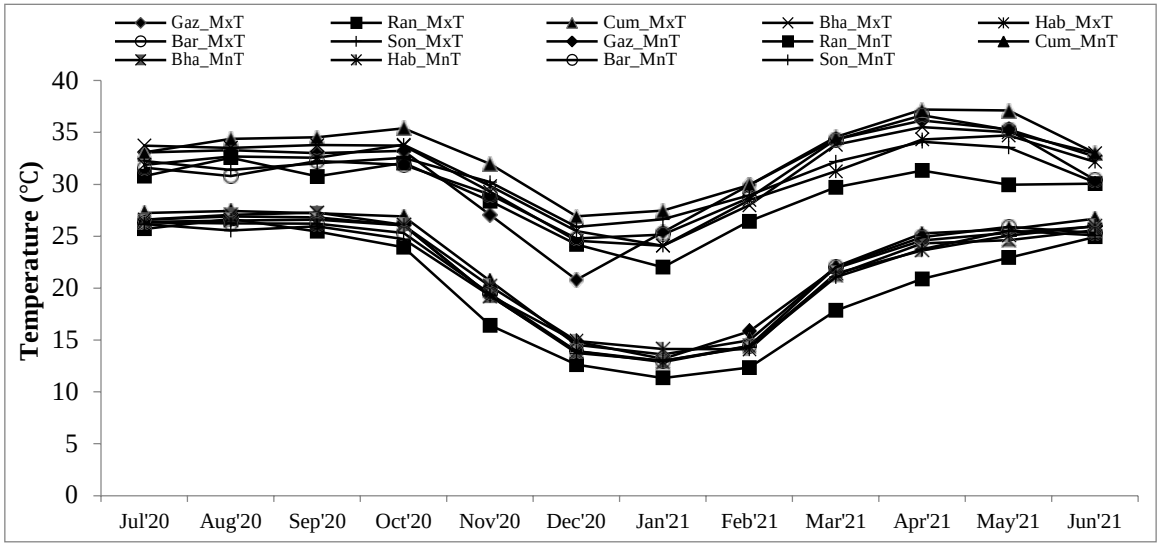

Fig. 1: Mean monthly maximum and minimum temperatures of seven different stations of BRRI during the reporting period from July 2020 to June 2021.

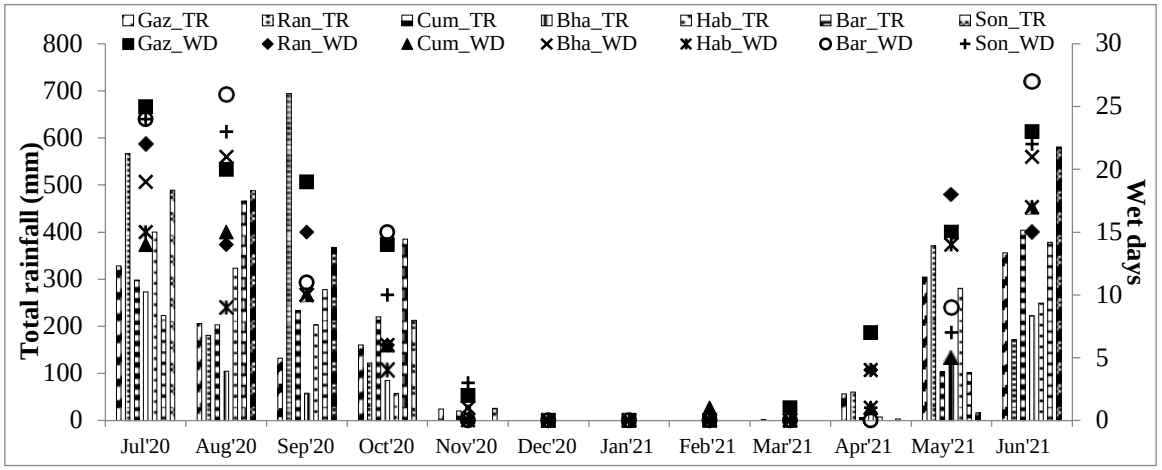

Fig. 2: Monthly total rainfall and wet days of seven different stations of BRRI during the reporting period from July 2020 to June 2021. Bars represents monthly total rainfall in the primary axis and markers represents wet days in the secondary axis, respectively.

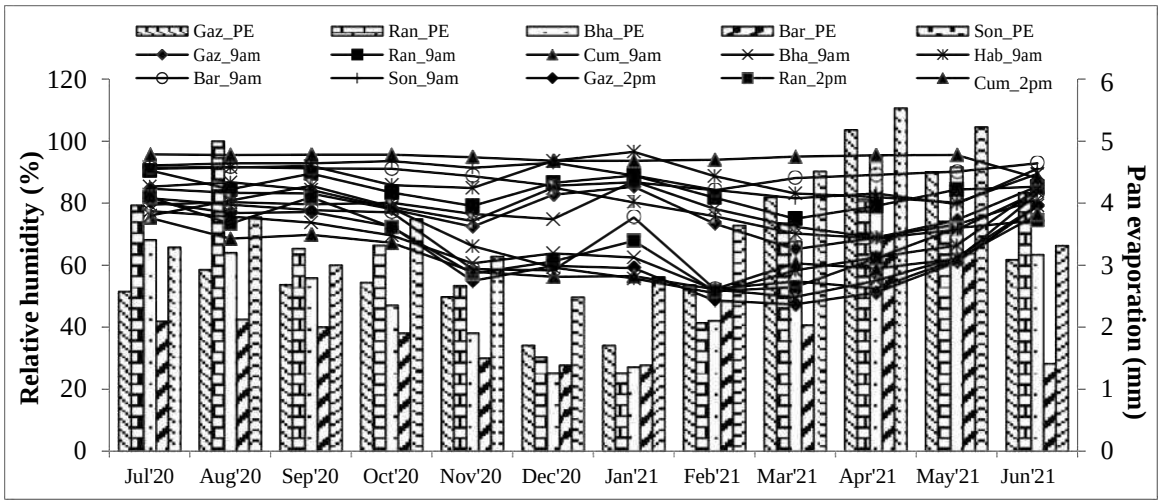

Fig. 3: Relative humidity at two-time point (9 am and 2 pm) and pan evaporation of seven different stations of BRRI during the reporting period from July 2020 to June 2021. Line represents mean monthly relative humidity in the primary axis and bar represents pan evaporation for 5 stations in the secondary axis, respectively.

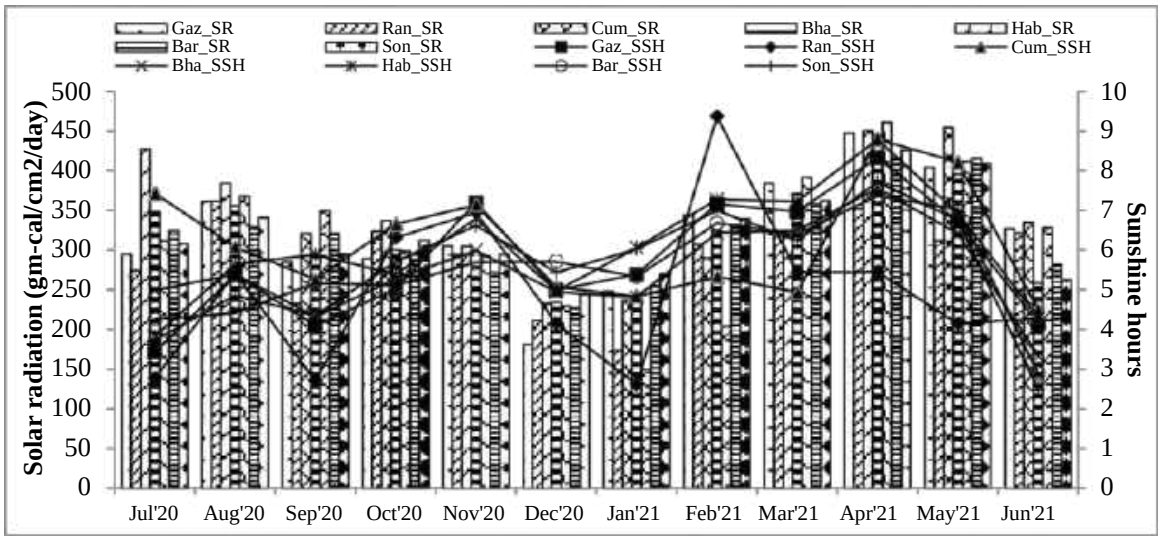

Fig. 4: Solar radiation and sunshine hours of seven different stations of BRRI during the reporting period from July 2020 to June 2021. Bar represents mean monthly solar radiation in the primary axis and line represents sunshine hours in the secondary axis, respectively.

Abbreviation and acronyms

AEZ	=	agroecological zone
ALART	=	advanced line adaptive research trial
ARIMA	=	auto regressive integrated moving average
As	=	arsenic
AT	=	active tillering
AWD	=	alternate wetting and drying
AYT	=	advanced yield trial
B. Aman	=	broadcast Aman
BADC	=	Bangladesh Agricultural Development Corporation
B. Aus	=	broadcast Aus (upland rice)
Bak	=	bakanae
BARI	=	Bangladesh Agriculture Research Institute
BB	=	bacterial blight
B	=	Blast
BC	=	back cross
BCR	=	benefit-cost-ratio
BI	=	blast
BLB	=	bacterial leaf blight
BINA	=	Bangladesh Institute of Nuclear Agriculture
BMDA	=	Barind Multi Purpose Development Authority
BPH	=	brown plant hopper
BR	=	Bangladesh rice
BS	=	breeder seed
BRRI	=	Bangladesh Rice Research Institute
BWDB	=	Bangladesh Water Development Board
BShB	=	bacterial sheath blight
CAB	=	Commonwealth Agriculture Bureau
ck	=	check
cm	=	centimetre
CDB	=	Carabid beetle
CMS	=	cytoplasmic male sterile
CV	=	common variance, co-efficient of variation
DAE	=	Department of Agricultural Extension (Bangladesh)
DAP	=	drought animal power
DAS	=	days after seeding
DAT	=	days after transplanting
DH	=	dead heart
DHB	=	dark-headed borer
DMRT	=	Duncan’s multiple range test
DNA	=	deoxyribonucleic acid
DNI	=	Direct normal irradiance
DHI	=	Diffuse horizontal irradiance
DTF	=	days to flowering
DWSR	=	Direct wet seeded rice
DWR	=	deepwater rice
ET	=	evapotranspiration
FS	=	foundation seed

FMPHT	=	Farm Machinery and Postharvest Technology
GABA	=	gamma amino buteric acid
GH	=	grasshopper
GM	=	gall midge
GMB	=	green mirid bug
GLH	=	green leafhopper
GoB	=	Government of Bangladesh
GRS	=	Genetic Resources and Seed
GSR	=	green super rice
GQN	=	Grain Quality and Nutrition
HA	=	Habiganj Aman
HAT	=	hours after treatment
HB	=	Habiganj Boro
HNRP	=	Hill Nerica Rice Productivity
ht	=	height
IIRON	=	International Irrigated Rice Observational Nursery
INGER	=	International Network for Genetic Evaluation of Rice
INM	=	integrated nutrient management
IPM	=	integrated pest management
IPNS	=	integrated plant nutrition system
IRRI	=	International Rice Research Institute (Philippines)
IRSSTN	=	International Rice Soil Stress Tolerance Nursery
IURON	=	International Upland Rice Observational Nursery
LCC	=	leaf colour chart
LBB	=	lady bird beetle
LHC	=	long-horned cricket
Lit/ha	=	litre per hectare
LR	=	leaf roller
LSc	=	leaf scald
LSD	=	least significant difference
LV	=	local variety
LIV	=	local improved variety
MAS	=	marker assisted selection
MER	=	micronutrient enriched rice
ML	=	monogenic line
MLT	=	multi-location trial
MMT	=	million metric tons
MR	=	moderately resistant
MT	=	maximum tillering
MV	=	modern variety
meq	=	milli equivalent
NGO	=	non-government organization
NIL	=	near isogenic line
NIR	=	net irrigation requirement
NSB	=	National Seed Board (Bangladesh)
OC	=	oil cake
OHLH	=	orange headed leafhopper
OT	=	observational trial
OYT	=	observational yield trial
PAcp	=	phenotypic acceptance

PI	=	panicle initiation
PQR	=	premium quality rice
PVART	=	proposed variety adaptive research trial
PVS	=	participatory varietal selection
PVT	=	proposed variety trial
PYT	=	preliminary yield trial
QTL	=	quantitative trait loci
RCB design	=	randomized complete block design
RF	=	rainfall
RH	=	rice hispa
RLF	=	rice leaf folder
RLR	=	rice leaf roller
RPT	=	rice production training
RS	=	Regional station
RTV	=	rice tungro virus
RWM	=	rice whorl maggot
RWS	=	relative water supply
RYT	=	regional yield trial
SAAO	=	Sub Assistant Agricultural Officer
SB	=	stem borer
SCA	=	Seed Certification Agency (Bangladesh)
SD	=	standard deviation
SES	=	standard evaluation system
ShB	=	sheath blight
ShR	=	sheath rot
SPDP	=	seed production and dissemination trial
SPIRA	=	Strengthening Physical Infrastructure and Research Activities
SR	=	solar radiation, stem rot
STB	=	soil test based
STPD	=	staphylinid
SYT	=	secondary yield trial
T. Aman	=	transplanted Aman
T. Aus	=	transplanted Aus
TGW	=	1000-grain weight
TLS	=	truthfully labelled seed
TOC	=	Training and operation cell
TRB	=	Transforming Rice Breeding
TSP	=	triple super phosphate
USG	=	urea super granule
WMM	=	Workshop Machinery and Maintenance
WBPH	=	white-backed plant hopper
WS	=	wet season
WSR	=	wet-seeded rice
WTR	=	weed tolerant rice
wt	=	weight
YSB	=	yellow stem borer

Plant Breeding Division

2 Summary
2 Variety development

SUMMARY

For the development of rice varieties under different ecosystems 546 crosses were made and 285 crosses were confirmed during 2020-21. In pedigree nursery, 1928 individual plants were selected from F_2 to F_6 generations based on phenotypic performances of segregating progenies of each cross and 167 fixed lines were bulked. A total of 4,84,452 individual plants were advanced from F_{2-6} generation following single seed decent (SSD) method under rapid generation advance (RGA) condition. From line-stage testing (LST), 9,361 genotypes were selected based on yield and other agronomic performances. A total of 850 genotypes from observational yield trial (OYT) and 562 advanced breeding lines were selected from yield trials PYT, SYT, RYT, AYT & PVT. A total of 101 germplasm from different biotic and abiotic screening nurseries were selected to use as parents in the breeding programe.

National Seed Board (NSB) of Bangladesh has released four promising genotypes *viz.*BR9011-67-4-1, IR83484-3-B-7-1-1-1, HHZ5- DT20-DT2-DT1 (GSR IR1-5-D20-D2-D1) and BR8631-12-3-5-P2 as BRRI dhan97, BRRI dhan98,
BRRI dhan99 and BRRI dhan100, respectively. BRRI dhan98 has been released for cultivation in T. Aus rice growing areas. BRRI dhan98 produced 0.79 t/ha higher yield than the check variety BR26 (4.30 t/ha) with similar growth duration. BRRI dhan97 and BRRI dhan99 have been released for salinity prone areas of Bangladesh. BRRI dhan97 produced 0.70 t/ha higher yield than the salinity tolerant check variety BRRI dhan67 with similar growth duration. BRRI dhan99 produced 1.2 t/ha higher yield than the salinity tolerant check variety BRRI dhan67 with growth duration five days longer than BRRI dhan67. BRRI dhan100 has been released for cultivation throughout the country in Boro season. BRRI dhan100 was named as the Bangabandhu dhan100 by the government with the consent from the Father of the Nation Bangabandhu Sheikh Mujibur Rahman Memorial Trust on 28 June 2021 in the Mujib year 2020-21. The average yield of BRRI dhan100 (Bangabandhu dhan100) was 7.7 t/ha and zinc content of the milled rice was 25.7 mg/kg which was higher than that of BRRI dhan74 (24.2 mg/kg).

VARIETY DEVELOPMENT

Development of upland rice (Aus). Efforts were made to develop varieties with multiple traits *viz*. quick seedling emergence, vigorous growth, short duration (90-100 days), tolerance to lodging, drought and pre-harvest sprouting tolerance, medium bold to medium slender grains and good eating quality. Twenty crosses were made using 11 parents. A total of 15,750 individuals obtained from 14 crosses of F_3 generation and 4,102 individuals obtained from 20 crosses of F_5 generation advanced through Field RGA. Out of 2,584 lines, 175 lines comprising 11 crosses were selected from LST during T. Aman, 2020 based on identical flowering, grain type traits and phenotypic acceptability under field condition. Five entries were selected considering growth duration, yield, uniformity of morpho-agronomic traits and superiority in one or more traits over the standard checks from 44 advanced materials in OYT. Five genotypes such as BR10756-2B-8-72, BR10757-2B-9-26, BR10759-2B-11-3, BR10759-2B-11-20 and SVIN434 among 24 tested entries were selected on the basis of yield and growth duration (earliness) in PYT. Another three genotypes *viz*., BR10409-15-2-8, BR10417-15-2-11 and BR10418-32-1-58 among 10 tested entries were selected in SYT.

Improvement of jhum rice under upland rice programme was implemented to develop high yielding rice variety with low (10-19%) to intermediate (20-25%) and high (>25%) grain amylose content and drought tolerance along with good eating quality for jhum cultivation acceptable to tribal people of Chottogram hill districts. Fifteen crosses were made involving 10 parents including six local Jhum cultivars and four BRRI varieties having low to intermediate level amylose content. Seventeen F_1s were confirmed out of 40. There were three observational yield trials. From OYT-1, nine were selected out of 13 genotypes for further trial. In OYT-2, seven entries were selected from 14 tested local germplasm. Ten Binni accessions

were evaluated in OYT-3 and six were selected. Nine entries including six local Jhum cultivars were evaluated in Preliminary yield trial (PYT) and six were selected.

Investigators. M A Hossain and N Jahan

Development of transplant Aus rice (T. Aus). The project aimed to develop short duration (105-110 days), high yield potential genotypes having tolerance to lodging and heat (high temperature) at reproductive phase, pre-harvest sprouting and good grain quality. Teenty-nine crosses were made using 40 parents and 3938 F_1 seeds were obtained; 14 crosses were confirmed as true hybrid; 26800 progenies from 57 crosses in T Aus season were advanced through modified FRGA. Out of 7009 lines of 37 crosses, 1556 uniform lines were identified from LST based on uniformity in heading, plant height and acceptable grain type in the field condition. Selection applied for selecting LST lines was 22% (Fig. 1). Finally, 713 fixed lines were selected from 1556 lines on the basis of trait genotyping with 12-SNP indica panel. Thirty seven genotypes were selected from 110 entries in observational yield trial (OYT), one advanced line out of three from RYT#1 for favourable ecosystem a nd two advanced lines out of four from RYT#2 were selected for non-saline tidal ecosystem in Barishal region on the basis of homogeneity with respect to plant height, phenotypic acceptability at vegetative and maturity stages and physicochemical properties. One genotype, BR9006-40-2-3-1 out of two from ALART#1 was recommended for PVT compared to popular cultivar BRRI dhan48 and BRRI dhan82. For non-saline tidal ecosystem, two genotypes under ALART#2 were evaluated along with the check BRRI dhan27 and BRRI dhan48. Among the two genotypes, one genotype BR8781-16-1-3-P2 was proposed for PVT. The National Technical Committee (NTC) recommended the B. Aus variety BRRI dhan83 for cultivation in T. Aus growing areas of Bangladesh. The proposed line BR9011-67-4-1 was released as a T. Aus variety BRRI dhan98 by National seed Board (NSB)

(Table 1). The advanced line produced 0.8 t/ha higher yield than the check variety BR26 with benefit of high amylose (27.9%).

Improvement of rice for shallow flooded and deep water environment. The major objectives of the this project were to develop high yielding (4.0-5.0 t/ha) rice varieties for deep (>1.0 m), shallow flooded area (up to 1.0 m depth), shallow deep area (30 cm water) and medium deep area (50-60 cm water) along with submergence, facultative elongation and hypoxia tolerance. In total, 37 crosses were made and 19 F_1s crosses were confirmed through QC SNP panel analysis. A total of 6,365 progenies of 20 F_2 crosses, 5,035 progenies of 18 F_3 crosses were advanced through RGA. Twelve fixed lines were selected from F_6 population for OYT. In Yield trials, 18 genotypes were selected out of 25 genotypes. In OYT the genotype BR8791-5R-1 gave highest yield (3.2 t/ha) which is significantly higher than the check variety BRRI dhan91 (2.5 t/ha) whereas in PYT the genotype BR11186-5R-377 (4.1 t/h) gave highest yield which was significantly higher than the check variety BRRI dhan91 (1.8 t/ha). In SYT, four advanced materials were selected for semi deep water conditions. ALART for shallow deep flood areas was conducted in three locations where two materials (BR10-230-7-19-B and BR10247- 14-18-7-3 -1B) were selected having moderate elongation and better yield than checks. ALART for very deep

Table 1. Performance of BRRI dhan98 under proposed variety trial, T Aus 2019-20.

Designation	Plant height (cm) *	Growth duration (day) *	Grain yield (t/ha) *	Grain characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Elongation ratio	Protein (%)	Amy-lose (%)
BRRI dhan98 (BR9011-67-4-1)	106	112	5.09	51.6	3.2	LS	1.5	9.5	27.9
BR26 (Ck.)	105	111	4.30	47.4	3.6	LS	1.5	9.8	22.7

*Mean of ten locations (Feni, Chottogram; Barishal; Cumilla; Sonagazi; Jashore; Habiganj; BRRI RS, Rangpur; BRRI RS, Rajshahi; BINA, Mymensingh and BRRI HQ Farm Gazipur)

Investigators: M Khatun, S K Debsharma and J A Nupur

flooded areas were conducted in nine locations, however two advanced genotypes BRBR9390-6-2-2B and BR10260-5-11-21-6B and two local pure lines Dudlaki and Khoiya motor having faster elongation were selected based on data of two locations (other damaged due to flood). The heritability obtained for grain yield under stress of all trials conducted was ranging from 71 % to 94% indicating acceptable level of precision in these experiments.

Investigators. A S M Masuduzzaman, Sharmistha Ghosal, N Jahan and K M Iftekharuddaula

Development of rainfed lowland rice (RLR). The project aimed to develop genotypes superior to standard varieties and adaptable to rainfed lowland environment in T. Aman season. In T. Aman, 2087 F_1 seeds were obtained from 23 single crosses and four crosses were confirmed as true hybrid. A total of 21,267 individual progenies of 88 crosses from F_2-F_6 generations were advanced through RGA method. A total 705 genotypes were selected from 8955 progenies of Line Stage Testing (LST) trial. Sixty-nine genotypes were evaluated in International Rainfed Lowland Observational Nursery (IRLON) and among them six were advanced for evaluation in Secondary Yield Trial (SYT). Two Preliminary Yield Trials (PYT) containing 31 tested genotypes, only six were forwarded for secondary yield evaluation. Two genotypes were selected for advancing in Regional Yield Trial (RYT) among 13 tested genotypes of two SYTs. Two lines were also selected for advancing RYT from Advanced Yield Trial (AYT). In RYT, three genotypes out of 14 were selected for re-trial. None of the materials were identified as promising to advance from ALART.

Investigators. M A Kader, R R Majumder, M E Haque, K Fatema and A S M Masuduzzaman

Development of rice varieties for favourable Boro environment. The aim of this project was to develop improved genotypes with high yield potential (≥8.0 t/ha), earliness (135-145 days) and acceptable grain quality for favourable irrigated ecosystem in Bangladesh. In the reporting year, 30 crosses were made and thirteen crosses were confirmed as true F_1. A total of 14,496 individual panicles were collected from 15,451 individual plants of 32 cross combinations of F_2-F_7 generations. Out of 3,456 RGA-derived lines, 407 uniform lines were identified from LST based on uniformity in heading, grain type and plant height. Then, final selection was made based on the presence of desired trait markers, 228 genotypes were selected for Observational yield trial (OYT). From OYT, 46 breeding lines out of 794 having 4.2-9.2 t/ha yield with 143-158 days growth duration were selected. Considering yield, growth duration, disease and insect-pest reaction, and grain quality traits, 19 entries out of 120 tested in the AYT were selected for further evaluation. In RYT, three breeding lines, BR8899-14-4-1-2-2-1, IR15A3500 and SVIN109 out of 20 breeding lines with medium duration (149 - 154 days) yielded almost similar to that of BRRI dhan89 with at least one week shorter duration. These three lines were selected for further advancement as they yielded 7.5-9.5 t/ha across at least four locations out of 10 trial sites (Table 2). In another set of RYT, the average yield of BRH11-9-11-4-5B-HR3 was 0.2 t/ha higher than the check variety BRRI dhan63 (Table 3). The grain size of BRH11-9-11-4-5B-HR3 was medium slender with thousand grain weight of 17.4 g only, thus it was also selected for further advancement. As part of nucleus seed maintenance of Boro rice varieties, 42 varieties were grown in the varietal display and panicles from 10 single plants from each variety were collected and preserved after necessary postharvest processing. In addition, 62 parental lines fingerprinted with 1k-RiCA SNP chip set were maintained as nucleus stock.

Investigators. Wazifa Afrin, Md Emam Ahmed, Fahmida Akhter, Md Rafiqul Islam, Md Salauddin Ahmaed, M R A Sarker, KM Iftekharuddaula, A S M Masuduzzaman and P S Biswas

Development of cold tolerant rice. The major objective of the project was to develop high yielding and short duration (6.0-7.0 t/ha yield and 135-145 days growth duration for haor areas) and high yielding medium duration (6.5-7.5 t/ha yield with 145-150 days growth duration for Northern regions) rice varieties tolerant to cold stress at seedling and reproductive stage. Thirty-nine crosses

Table. 2 Agronomic performances of the three selected genotypes out of 20 breeding lines tested in RYT (MD), development of favourable Boro rice during Boro 2020-21.

Designation	GD	PH	Yield (t/ha)*										
			L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Avg
BR8899-14-4-1-2-2-1	151	95	5.8	8.0	6.9	6.1	8.7	8.1	7.1	4.7	7.5	5.5	7.1
IR15A3500	150	96	5.7	7.5	7.3	6.7	8.7	8.1	7.4	4.9	7.6	6.1	7.2
SVIN109	151	100	5.7	9.5	7.6	6.9	8.9	8.4	6.9	5.3	5.7	6.1	7.3
BRRI dhan81 (Ck)	148	94	5.4	8.5	6.3	5.0	8.7	6.4	6.6	5.2	5.0	6.1	6.4
BRRI dhan29 (Ck)	154	94	6.0	9.2	6.7	6.6	7.6	7.7	7.7	5.0	5.4	6.0	6.9
BRRI dhan89 (Ck)	158	106	6.7	7.0	7.4	6.8	8.4	7.7	7.7	5.7	7.0	6.2	7.2
LSD (0.05)	0.91	1.7	0.20	0.57	0.16	0.27	0.23	0.19	0.18	0.18	0.38	0.14	0.11
H^2b (%)	60.7	27.1	92.4	91.3	62.8	55.7	78.5	73.8	70.7	85.2	96.8	23.6	5.52

*BLUE, GD=Growth duration; PH=Plant height
L1=Barishal, L2=Bhanga, L3=Cumilla, L4=Gazipur, L5=Habiganj, L6=Kushtia, L7=Rajshahi, L8=Rangpur, L9=Sathkhira, L10=Sonagazi

Table. 3 Agronomic performances of the breeding lines tested in RYT(YM), development of favourable Boro rice during Boro 2020-21.

Designation	DM	PH	Barishal	Bhanga	Gazi	Kush	Raj	Rang	Sona	Avg.
BRH11-9-11-4-5B-HR3	148	91	6.5	9.3	5.9	7.5	6.3	6.6	6.7	7.0
BRH13-2-4-6-4B	148	92	6.4	8.6	6.0	7.1	6.1	6.0	6.6	6.7
BRRI dhan63 (Ck)	146	86	6.3	8.3	5.9	7.9	6.4	6.8	6.7	6.8
LSD (0.05)	2.2	5.2	0.32	1.98	0.74	0.37	0.49	0.87	0.30	0.79
H^2b (%)	0.74	0.86	-	-	-	0.88	-	0.43	-	0.46

*BLUE, GD=Growth duration; PH=Plant height

were made. Thirteen crosses were confirmed as true F_1 through F_1 verification using QC genotyping with purity SNP panel. From 7,220 individuals in RGA nursery, 6,667 individual plants were harvested from 16 crosses of F_2-F_6 generation. Out of 6,317 RGA-derived lines, 1,190 uniform lines were selected from LST based on uniformity in heading. Then based on availability of trait markers, 384 lines were selected for further yield trial (Fig. 1). From OYT#1 with 212 breeding lines, 28 genotypes showing yield 4.7-10.7 t/ha with 147-159 days growth duration and from OYT#2 with 668 breeding lines, 24 genotypes showing 5.3-11.4 t/ha with 132-158 days growth duration under non-stress condition along with yield reduction less than 20% under natural cold stress condition at booting stage were selected for advanced yield trial. From AYT, out of 82 entries, 14 genotypes were selected considering significant yield advantage over check varieties. From RYT, out of 21 entries, two breeding lines, BR10717-5R-82 and BR11001-5R-37 having growth duration of 149 days and 6.35 t/ha and 6.16 t/ha yield were selected for further evaluation (Table 4). From RYT (Haor) conducted in the haor areas of Nikli, Tahirpur, and Habiganj, two genotypes IR100722-B-B-B-B-11 and IR100723-B-B-B-B-61 were selected based on 1.0-ton yield advantage over the check variety BRRI dhan28 (Table 5) and least yield reduction under cold stressed condition (Table 6 and 7). The grain quality performance of these lines showed acceptable ranges for different quality traits (Table 8). Also, these lines have good quality grains of long slender type in appearance (Fig. 2).

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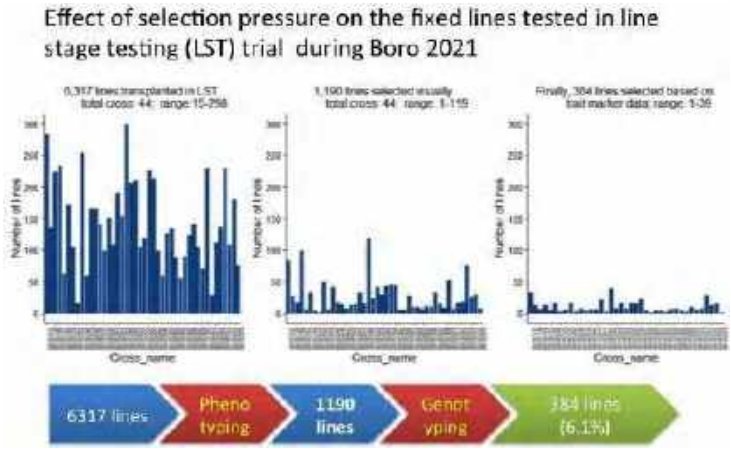

Fig. 1. Selection process of homogeneous lines with key target traits from LST.

Table. 4. Agronomic performances of the selected genotypes out of 21 tested in RYT under cold tolerant rice during Boro2020-21.

Designation	GD	PH	Yield (t/ha)*							
			Gaz	Hab	Raj-1	Raj-2	Ran-1	Ran-2	Ran-3	Avg
BR10717-5R-82	149	106	5.8	5.1	6.4	6.2	5.9	7.8	7.8	6.3
BR11001-5R-37	149	102	7.0	5.5	5.8	6.2	5.7	6.3	6.1	6.2
BRRI dhan28 (Ck)	150	103	5.3	5.7	6.2	7.0	3.8	4.9	7.2	5.9
BRRI dhan67 (Ck)	153	108	6.1	6.6	5.9	5.8	5.6	7.1	8.3	6.4
BRRI dhan69 (Ck)	156	100	6.8		7.6	7.7	7.4	7.3	6.1	7.1
BRRI dhan89 (Ck)	159	106	6.7	6.4	7.1	7.1	7.2	7.6	6.8	7.1
LSD (0.05)	4.4	2.86	0.94	0.66	0.52	0.71	0.93	1.73	1.26	0.55
Heritability (%)	83	46.8	71.6	53.2	81.7	81.6	89.5	88.5	37.3	37

***BLUE**

GD=Growth duration; PH=Plant height

Gaz=Gazipur, Hab=Habiganj, Raj-1=Rajshahi-1 (Alimganj), Raj-2=Rajshahi-2 (Godagari), Ran-1=Rangpur-1 (Mithapukur), Ran-2=Rangpur-2 (Dorsona), Ran-3=Rangpur-3 (Chirir Bondar)

Table. 5. Yield and other agronomic performance of seven breeding lines/varieties tested under regular planting schedule (non-stress*) in different haor areas of Bangladesh during Boro 2020-21.

Designation	PH (cm)	GD (days)	Yield (t/ha)										
			Habi1	Habi2	Habi3	Habi4	Nik1	Nik2	Nik3	Tah1	Bis	Tah2	AVG
BRRI dhan28	109.1	145	6.9	7.2	6.1	5.2	7.1	7.1	6.8	8.3	6.0	5.6	6.6
BRRI dhan67	115.2	149	6.8	7.4	6.0	6.8	6.9	6.9	7.2	8.5	7.8	6.3	7.0
BRRI dhan69	99.6	157	-	-	-	-	8.5	7.5	8.3	9.4	7.9	8.2	8.0
IR100722-B-B-B-B-11	118.7	151	7.7	6.4	8.0	7.7	7.6	7.9	6.7	8.2	9.0	6.9	7.6
IR100723-B-B-B-B-61	113.1	151	7.4	7.2	7.7	7.6	7.2	8.0	7.6	8.3	8.6	6.4	7.6
TP16199	125.7	156	4.2	6.3	5.7	4.7	6.4	6.0	6.8	8.3	6.8	7.9	6.3
LSD (0.05)	8.78	2.31	0.67	0.51	0.50	0.54	0.72	0.56	0.52	0.65	0.99	1.01	0.52
H2b (%)	28.5	84.4	80.9	77.6	84.7	84.4	63.7	33.9	71.1	50.9	39.6	68.1	31.5

* Seeding was done on 19 November 2020 (Habiganj); 23 November 2021 (Tahirpur-Biswamvarpur) and 21/11/2021 (Nikli) so that the crop at the reproductive stage (pre-booting to booting stage) is not exposed to average temperature below 18˚C- 20˚C

PH = Plant height; GD = Growth duration; t/ha = Ton per hectare; LSD = Least squared difference; H2b = Broad sense heritability

Nik = Nikli (Kishoreganj); Habi = Habiganj and Tah = Tahirpur (Sunamganj), Bis = Biswamvarpur (Sunamganj)

Table. 6. Yield and other agronomic performance of seven breeding lines/varieties tested under early planting schedule (Cold-stress*) in different haor areas of Bangladesh during Boro 2020-21.

Designation	PH (cm)	GD (cm)	Yield (t/ha)								
			Habi1	Habi2	Habi3	Nik1	Nik2	Nik3	Tah1	Bis	AVG
BRRI dhan28	93.3	160	5.2	6.0	4.7	3.6	4.2	3	4.5	2.7	4.2
BRRI dhan67	102.7	162	-	-	-	8.3	5.2	5.4	6.3	6.4	6.3
BRRI dhan69	89.3	167	6.5	5.9	NA	7.4	6	5	5.9	6.7	6.2
IR100722-B-B-B-B-11	98.3	163	-	-	-	7.8	5.2	6.1	5.7	5.7	6.1
IR100723-B-B-B-B-61	98.7	162	6.8	6.8	5.7	6.2	5.2	5.9	6.4	7.3	6.3
TP16199	106.8	165	6.9	5.4	5.8	7.1	7.4	6.5	6.8	7.7	6.7
LSD (0.05)	7.19	2.63	0.44	0.73	1.13	1.18	1.16	0.66	0.87	0.96	0.73
H2b (%)	68.3	70.9	86.7	70.8	46.3	99.8	49.1	72.8	71.5	87.8	46.7

* Seeding was done on 26 October 2020 (Habiganj); 28 October 2021 (Tahirpur-Biswamvarpur) and 21 October 2021 (Nikli) so that the crop at the reproductive stage (pre-booting to booting stage) is exposed to average temperature below 18°C- 20°C
PH = Plant height; GD = Growth duration; t/ha = Ton per hectare; LSD = Least squared difference; H2b = Broad sense heritability
Nik = Nikli (Kishoreganj); Habi = Habiganj and Tah = Tahirpur (Sunamganj), Bis = Biswamvarpur (Sunamganj)

Table. 7. Yield reduction pattern of six breeding lines/varieties tested under regular planting schedule (non-stress*) and cold-stress condition in different haor areas of Bangladesh during Boro 2020-21.

Designation	Habi1	Habi2	Habi3	Nik1	Nik2	Nik3	Tah1	Tah2	AVG
BRRI dhan28	24.6	16.7	23.0	49.3	40.8	55.9	45.8	55.0	36.4
BRRI dhan67	.	.	.	-20.3	24.6	25.0	25.9	17.9	10.0
BRRI dhan69	.	.	.	12.9	20.0	39.8	37.2	15.2	22.5
IR100722-B-B-B-B-11	.	.	.	-2.6	34.2	9.0	30.5	36.7	19.7
IR100723-B-B-B-B-61	8.1	5.6	26.0	13.9	35.0	22.4	22.9	15.1	17.1
TP16199	-64.3	14.3	-1.8	-10.9	-23.3	4.4	18.1	-13.2	-6.3

Table 8. Grain quality parameters of selected entries, RYT (Haor), Boro 2020-21.

Designation	Milled rice (%)	Head rice (%)	Chalkiness	Length (L) mm	Breadth (B) mm	L/B ratio	Size & shape	Amylose (%)	Protein
IR100722-B-B-B-B-11	72.8	59	Tr	7.4	1.9	3.9	LS	25.7	10.2
IR100723-B-B-B-B-61	72.2	67.3	Wb9	6.5	2.1	3.1	LS	25.5	7.2
BRRI dhan28	71.7	65.6	Tr	5.8	1.8	3.2	MS	28	8.6

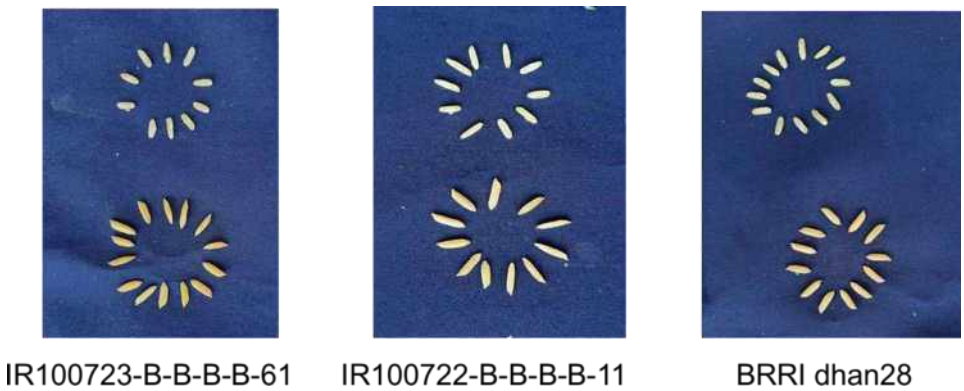

Fig. 2. Appearance of grains of IR100722-B-B-B-B-11 and IR100723-B-B-B-B-61.

Development of salt tolerant rice (STR). The objective of this project is to develop high yielding salt tolerant rice varieties based on product profile. Salinity is one of the major constraints for the Rainfed lowland and Boro rice ecosystem in the southern coastal zone of Bangladesh. In T. Aman season, 14 crosses were made using 19 well-characterized elite parents. A total of 43 F_1s were confirmed as true hybrid through F_1 verification by quality check (QC) genotyping with purity SNP panel during T. Aman season. The Field Rapid Generation Advance was done at BRRI HQ farm, Gazipur. In T. Aman season, 71,335 segregating progenies derived from 103 crosses were advanced in F_2-F_6 generations using FRGA technique. Yield trials were condueted in Gazipur, Koyra, Khulna and Assasuni, Debhata, Kaliganj and BRRI Farm, Satkhira in T. Aman season. In LST, out of 7179 breeding lines, 972 lines were selected on the basis of strong culm with good plant ideotype, acceptable grain type and uniformity at heading in field condition (Fig.3). A total of 450 LST lines were genotyped using trait-specific SNP panel (Fig. 4) to identify promising breeding lines with trait of interest (ToI). Each line assayed against QTLs and genes of interest to assess the presence or absence of useful traits. (Fig.5). In T. Aman season, out of 1436 breeding lines, 100 lines harbored the 7-10 QTLs/genes that regulate ToI that are designated as Genetically Important Lines (GILs) (Fig. 6). Out of 816 genotypes, 226 genotypes were selected from OYT. Three PYTs (PYT-1 to PYT-3) were conducted using 63 breeding lines. Forty-two genotypes were selected from these trials depending on grain yield, salinity tolerance and phenotypic acceptability. Thirty-four genotypes, out of 46 genotypes were selected from SYT/AYT and three genotypes such as (i) IR108158-B-2-AJY1-1(IR16T1032), ii) IR15T1464, iii) TP30649 (IR15T1456) were selected from RYT for conducting ALART.

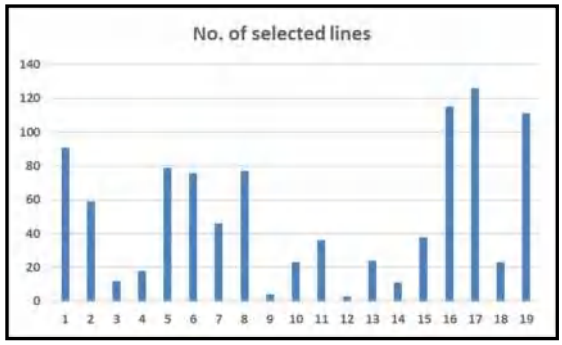

Fig. 3. Number of selelcted lines of LST per cross.

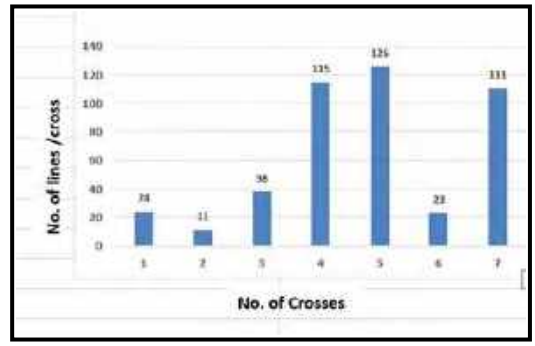

Fig. 4. No. of LST lines per cross genotyped using trait-specific SNP panel.

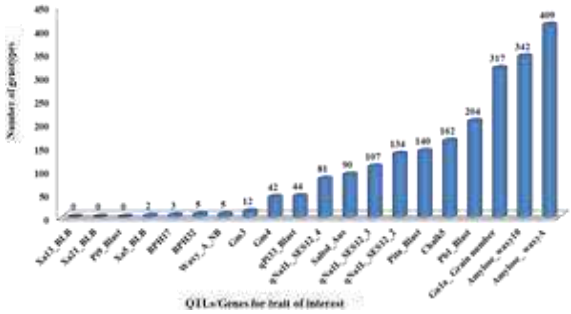

Fig. 5. Selected LST genotypes with QTL/genes for trait of interest, T. Aman, 2020-21.

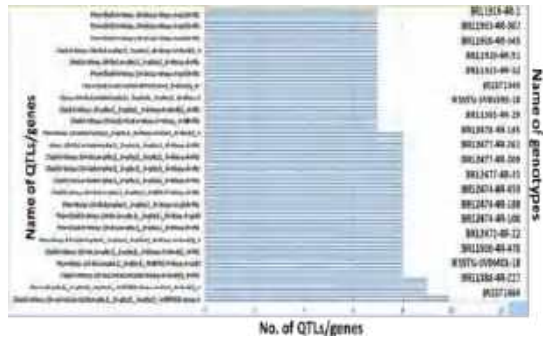

Fig 6. Identified Genetically Important Lines (GILs) in the STR Breeding program, T. Aman, 2020-21.

In Boro Season, 20 crosses were made using 21 elite parents. en total 20 F_1s were confirmed as true hybrids through F_1 verification by quality check (QC) genotyping with purity SNP panel. Tottaly 80,128 segregating progenies from 113 crosses (F_2-F_5 generation) were harvested from FRGA nursery and grown in the subsequent generation. In LST trial, 450 lines out of 3823 lines were selected on the basis of desirable plant type, grain quality and uniformity at flowering under field condition. A total of 128 genotypes were selected out of 410 from two OYT's based on growth duration, grain yield, and homogeneity in different morpho-agronomic traits. Out of 371 genotypes, 96 genotypes were selected from four PYT's. Fifteen genotypes were selected from two AYT's. Five genotypes from RYT-1 and five genotypes from RYT-2 were selected. In RYT3, eighteen genotypes were evaluated in five locations and six genotypes such as BR11716-4R-102, BR11715-4R-186, BR11723-4R-27, BR11716-4R-105, BR11723-4R-12 and BR11712-4R-227 were selected based on grain yield, degree of salt-tolerance and grain quality traits like amylose and protein content (Table 9).

The mean grain yield of selected lines ranged from 8.0 t/ha (BR11716-4R-102) to 8.5 t/ha (BR11712-4R-227) which were higher than the check varieties. The lower SES score (score 3-4) indicates salt-tolerance and the higher score (score 7-9) shows the sensitivity of the genotypes. The selected lines showed salt-tolerance that varied from high (BR11716-4R-105, BR11723-4R-12 and BR11712-4R-227) to moderate (BR11716-4R-102, BR11723-4R-27, BR11716-4R-105). All yield trials were conducted in Gazipur, Khulna and Satkhira region during Boro season where salinity level (EC) varied from 3.09 dS/m to 28.5 dS/m (Fig. 7) in the field. All the selected lines have high amylose content (>25.0%) and the protein content of the selected lines ranged from 7.2% to 11.3%. However, the highest protein content (11.3%) obtained in BR11723-4R-27 among 18 breeding lines, and the lowest amount of protein (7.1%) found in BR11716-4R-108.

Table 9. Grain yield, agronomic performance and salt-stress response of different rice genotypes at green house and field condition in regional yield trial (RYT3), Boro 2020-21

Designation	GD (days)	PH (cm)	Grain yield (t/ha)					Surv (%)	SES Score		PAcp	Sterility (%)	Grain quality traits	
			Gaz	Sat	Bha	Cum	Mean		Physio. (Green house)	Koyra (At field)	Sat. Farm		Protein content (%)	Amylose content (%)
BR11723-4R-172	162	104	7.4	8.0	7.8	7.7	7.8	50	5	5	5	37.2	10.7	27.7
BR11716-4R-102	163	104	6.8	9.1	8.7	7.7	8.0	70	5	7	4	28.5	7.9	28.1
BR11715-4R-186	161	102	9.6	8.4	7.2	8.4	8.1	50	7	7	4	26.5	8.3	28.7
BR11716-4R-108	164	105	8.0	7.8	6.6	7.8	7.6	80	5	4	5	-	7.1	28.0
BR11716-4R-120	164	102	8.2	8.9	8.3	7.0	7.9	60	7	5	5	-	8.5	26.3
BR11712-4R-218	161	106	9.0	7.9	7.4	6.4	7.8	50	7	5	4	30.1	10.6	28.0
BR11723-4R-27	163	103	9.3	9.1	8.0	7.6	8.3	50	5	5	4	-	11.3	26.8
BR11716-4R-129	162	103	8.2	8.6	8.1	6.5	7.9	60	5	5	5	32.1	7.4	27.1
BR11723-4R-48	162	104	8.2	10.1	8.9	7.8	8.4	60	5	7	4	32	11.0	27.5
BR11716-4R-105	151	106	10.0	8.8	9.1	6.5	8.5	80	5	5	5	16	7.6	27.7
BR11723-4R-12	164	104	9.5	8.1	9.7	6.6	8.4	70	5	4	3	24	7.6	27.9
BR11716-4R-147	160	106	8.6	8.7	7.9	5.9	7.8	80	5	7	4	38	8.1	29.0
BR11712-4R-227	162	104	10.8	9.4	8.6	7.8	8.5	30	7	4	3	34	7.2	28.8
BR11716-4R-123	161	106	8.8	9.2	8.0	7.1	8.2	29	7	5	6	36	8.0	28.0
BR11716-4R-114	162	102	7.4	7.8	8.5	7.8	7.6	55	7	7	5	12	10.7	27.2
SVIN355	151	105	8.7	7.0	7.4	7.8	7.4	70	5	7	9	-	8.2	27.1
SVIN415	150	100	8.1	6.4	5.3	5.7	7.1	40	7	9	7	-	8.2	25.6
BR10672-1-3-7-12	153	106	6.6	7.3	7.8	5.5	7.6	10	8	5	6	-	8.3	29.2
BRRI dhan67	150	107	7.4	6.6	9.4	6.3	7.1	-	-	7	5	-	-	-
BRRI dhan89	152	107	9.0	6.6	5.0	7.9	8.0	-	-	9	5	32	-	-
BRRI dhan97	153	107	8.1	7.7	9.5	7.3	7.9	70	4	3	5	-	-	-
Binadhan-10	150	113	7.7	8.0	8.0	7.2	8.0	100	3	5	5	-	-	-
LSD (<0.05)	0.30	1.91	0.7	0.9	1.0	0.8	-	-	-	-	-	-	--	-
H (%)	99	62	7.4	8.0	7.8	7.7	7.8	-	-	-	-	-	-	-

GD=Growth duration, PH=Plant height, Gaz=Gazipur, Sat=Satkhira, Bha=Bhanga, Cum=Cumilla, Surv= Survivability, Physio= Physiology

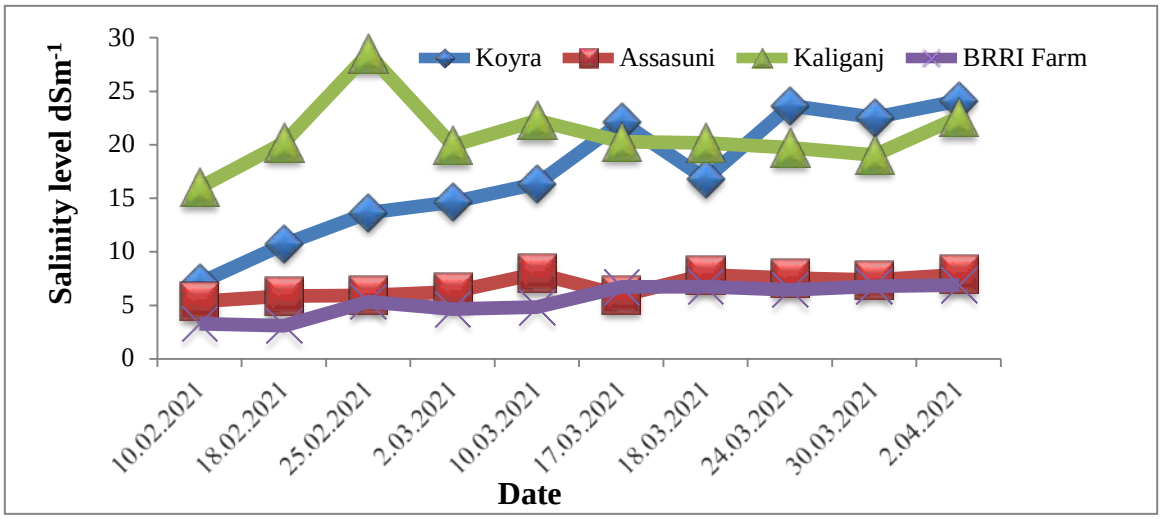

Fig. 7. Salinity dynamics of different experimental fields in coastal saline areas in Boro 2020-21.

The proposed genotype IR83484-3-B-7-1-1-1 was evaluated under PVT by NSB team in eight locations of coastal area of Bangladesh in Boro, 2018-19 and released as BRRI dhan97. The advanced lines produced 0.7 t/ha higher yield than the salinity tolerant check BRRI dhan67 (Table 10).

Development of premium quality rice (PQR). T. Aman. Efforts were made to develop aromatic and non-aromatic fine quality rice with national and international standards (Kalizira/ Chinigura /Kataribhog /Radhunipagol/Jasmine type), anti-oxidant enriched (black and red) rice and photosensitive rice for domestic use and export. In T. Aman 2020, total 43 crosses (27 crosses for PQR, six for anti-oxidant enriched rice and 10 for photosensitive rice) were made and 24 crosses (24 for PQR, six for anti-oxidant enriched rice and seven for photosensitive rice) were confirmed as true hybrid using quality control SNP panel analysis. A total of 8,816 progenies (4,000 progenies of 12 F_2 crosses and 4,816 progenies of 14 F_3 crosses) were advanced through RGA under PQR, 2,500 progenies of five F_2 crosses 1,595 progenies from 10 F_3 crosses, 3,583 progenies from 18 F_4 crosses and 2,922 progenies from 14 F_5 crosses were advanced through RGA under Antioxidant program, whereas from pedigree nurseries, 23 PS were selected from five F_2 population, 55 PS were selected from five F_3 population, 16 PS were selected from three F_5 population under photosensitive program. In total 51 genotypes were selected out of 144 from different yield trials. From Observational Trial (OT) 13 genotypes were selected from 71 genotypes based on growth duration, yield, homogeneity and morpho-agronomic traits. From PYT#1 & 2, total genotypes were selected out of 22 genotypes. In total 22 genotypes were selected out

Table 10. Performance of the variety BRRI dhan97 under proposed variety trial, Salinity, Boro 2018-19.

Designation	Plant height (cm) *	Growth duration (day) *	Grain yield (t/ha) *	Grain characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Elongati-on ratio	Protein (%)	Amy lose (%)
BRRI dhan97 (IR83484-3-B-7-1-1-1)	100	152	4.9	60.0	2.3	MB	1.9	8.6	25.2
BRRI dhan28 (Sus. Ck.)	94	146	2.8	63.5	3.1	MS	1.5	8.5	28.0
BRRI dhan67 (Tol. Ck.)	100	150	4.2	61.1	2.8	MB	1.3	8.8	24.6

*Mean of eight locations (Kaliganj, Debhata, Tala, Satkhira; Dumuria, Batiaghata, Paikgacha, Khulna; Rampal, Bagerhat and Kalapara, Patuakhali, Barishal)

Investigators. M Akhlasur Rahman, Hasina Khatun, M Asif Rahman, R Farzana Disha, Avijt Biswas, AA Shoily and SMM Islam

of 41 genotypes from SYT#1, SYT#2 & SYT#3. In OYT, the genotype BR11802-11-3-1 produced highest yield (4.5 t/ha). In PYT#1 the aromatic Chinigura type genotype BR10824-5-6-4-1 produced highest yield (2.9 t/ha) which is significantly higher than the check variety Chinigura, Kalijira, BINA dhan13 and BRRI dhan34. In PYT#2, the Kataribhog type genotype BR11213-12-2-3 produced highest yield (2.6 t/ha) which was significantly higher than the check varieties Kataribhog, Dinajpur Karatibhog and BRRI dhan37. In SYT#1 the Bashmati type aromatic genotype BR8493-12-7-4-P1 produced highest yield (3.2 t/ha). In RYT#1 the non-aromatic Kalijira type genotype BR9590-45-1-3-2-P2 showed highest yield (3.7 t/ha) followed by aromatic genotype BR8493-3-5-1-P1 which produced 3.5 t/ha yield. In RYT#2, the non-aromatic Kataribhog type genotype BR9844-7-4-4-2-4-2 produced highest yield with 111 days growth duration and the yield was significantly higher than the check varieties Dinajpur Kataribhog and BRRI dhan37. In ALART, a non-aromatic Kataribhog type genotype BR8528-2-2-3-HR2 produced highest yield followed by the aromatic genotype BR9178-7-2-4-4 producing 3.1 t/ha yield (Table 11). Under photosensitive rice program, 39 genotypes out of 121 were selected from different yield trials. In PYT, the photosensitive genotype TL Aus-Gaz8-45-6-P2-1 produced significantly higher yield (5.2 t/ha) than the check varieties BR22 (4.3 t/ha) and BR23 (4.2 t/ha). In SYT#1, the genotype BR8845-21-1-5-10-3-P2 produced significantly higher yield (4.0 t/ha) while in SYT#2, a strongly photosensitive genotype TL Aus Kushtia-3 (PR-2) produced higher yield (4.2 t/ha). However the yield was not significantly higher than the check varieties BR22 (3.8 t/ha) and BR23 (4.0 t/ha). The heritability obtained for grain yield under stress of all trials conducted was ranging from 66 % to 96% indicating acceptable level of precision in these experiments.

Investigators. Sharmistha Ghosal, K M Iftekharuddaula, R J Promee and T L Aditya

Boro. The project aims to develop of aromatic and non-aromatic fine quality rice with international (Basmati/Banglamati/SoruBalam type) standards in Boro season for domestic use and export quality. Totally 15152 F_1 seeds were obtained from 25 crosses. In Boro 2020-21 season, 18 F_1 crosses were confirmed out of 20 crosses as true hybrid. In total 12831 progenies of 24 crosses from F_3-F_5 generations were advanced through RGA method. A total 199 genotypes were selected from 3186 progenies of LST trial. From two PYT's, 28 genotypes were selected out of 52 tested genotypes. In two SYT's, four genotypes were selected out of 12 tested genotypes. In RYT, two genotypes were selected out of five genotypes for conducting ALART in Boro 2021-22. None of the genotypes were recommended for advancing from ALART by Adaptive Research Division.

Investigators. R R Majumder, M E Haq, K Fatema, U R Shaha and M A Kader.

Development of zinc enriched rice (ZER). The project aims to develop high yielding rice varieties with improved nutritional quality with high zinc (Zn≥24 mg/kg) in polished grain. The project also prioritizes development of stress tolerant zinc enriched rice varieties in a combination of submergence + zinc, drought + zinc, salinity + zinc and cold + zinc enriched rice with improved grain yield. The experiments were conducted in both T. Aman and Boro seasons. In T. Aman season, 49 single crosses were made producing 7038 seeds. A total of 18 crosses wereselected and confirmed as true F_1s. In pedigree selection, 1832 progenies and 167 fixed lines were selected from 82 crosses

Table 11. Performance of genotypes in regional yield trial (RYT), PQR, T. Aman 2019-20.

Designation	PAcp	PH (cm)	GD (Day)	Grain Yield (t/ha)									
				L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean
BR9178-7-2-4-4	3	138	151	3.5	3.2	3.3	2.5	3.3	3.4	2.2	3.2	3.4	3.1
BR8528-2-2-3-HR2	3	117	136	3.5	3.0	3.2	4.3	3.3	4.5	3.0	5.3	5.5	4.0
BR8882-30-2-5-2	5	131	149	2.2	3.0	3.1	2.9	2.7	2.8	2.4	3.8	3.9	3.0
D. Kataribhog (L. Ck.)	7	145	150	2.6	2.9	3.4	2.5	2.6	2.9	2.1	3.3	3.4	2.9
BRRI dhan37 (Std. Ck.)	5	133	155	4.4	2.8	3.3	3.6	3.1	3.1	3.0	3.4	3.4	3.3
LSD (0.05)		6	1.4										0.27

of F_2-F_6 generations. From two OYT's, 48 genotypes were selected from 175 genotypes. A total of 23 genotypes were selected from 100 genotypes of three PYT's based on yield performances. Only two promising genotypes were selected out of 13 genotypes of two SYT's. One promising genotype out of eight was selected from RYT. None of the entries were recommended for promoting from ALART by ARD. In proposed variety trial (PVT), the zinc enriched rice genotype was not identified promising to release as variety and hence it was not recommended by SCA. In Boro season, 100 single crosses were made producing 19,556 seeds. A total of 50 crosses were confirmed as true F_1s. From F_2, F_3, F_5 and F_6 generations 4790 progenies and 182 fixed lines were isolated. From OYT, 53 out of 131 genotypes were selected. From RYT none of the genotypes was selected for advancing. None of the genotypes were selected for advancing from ALART by Adaptive Research Division. The promising zinc enriched line IR99285-1-1-1-P2 was evaluated under PVT, Boro 2020-21 at 10 different locations of Bangladesh by SCA for releasing a zinc enriched variety in Boro season. Zinc enriched BR8631-12-3-5-P2 was released as BRRI dhan100 by National Seed Board (NSB) of Bangladesh for cultivation throughout the country for Boro season. The average yield of BRRI dhan100 was 7.7 t/ha with 148 days growth duration and zinc content of the milled rice of the variety was 25.7 mg/kg which was higher than that of BRRI dhan74 (24.2 mg/kg) (Table 12).

Investigators. M A Kader, R R Majumder, S M T Islam, M E Haq, K Fatema and U R Shaha.

Development of disease resistant rice. Efforts were made for developing varieties resistant to bacterial blight (BB), rice tungro virus (RTV) and blast diseases. The experiments were conducted in both T. Aman and Boro seasons. Nine crosses for BB and ten for blast in T. Aman and 13 crosses for BB and 11 for blast were made in Boro season. Twelve crosses for BB and thirteen for blast in T. Aman and nine crosses for BB and four for blast in Boro season were confirmed as true F_1. A total of 37,807 progenies for BB and 22,048 progenies for blast were advanced from F_{2-6} generation through Green-house RGA and FRGA. Out of 3495 lines, 198 uniform lines from T. Aman season and 1940 uniform lines out of 10491 were identified from LST in Boro season based on uniformity in heading, plant height and grain type. Forty one genotypes for BB were selected from observational yield trial (OYT) in T. Aman season whereas 45 entries out of 540 for BB during Boro season showed better yield potential and agronomic performance over the check varieties and tolerance to BB. From PYT, nine advanced lines were promoted based on growth duration, grain yield and BB score compared to the check varieties in T. Aman season and 23 genotypes out of 80 for BB were selected in Boro season. From RYT trial, three genotypes for T. Aman season were selected compared to yield, growth duration, BB resistance and better grain quality characters and three BB resistance genotypes performed better but yield was not >10% higher than the check variety. Therefore, the high yielding background of BB resistant promising lines will be used as genetic resource to develop high yielding disease resistance varieties. The promising BB resistant line BR8938-19-4-3-1-1 was evaluated under PVT, Boro 2020-21 for releasing a BB resistant variety in Boro season.

Investigators. M Khatun, S K Debsharma, J A Nupur, M A I Khan and A Ara

Table 12. Performance of BRRI dhan100 in proposed variety trial, Boro 2019-20.

Designation	Plant height (cm)*	Growth duration (day) *	Grain yield (t/ha) *	Grain characteristics						
				Head rice yield (%)	L-B ratio	Size and shape	Elongation ratio	Protein (%)	Amy (%)	Zinc content (mg/kg rice)
BRRI dhan100 (BR8631-12-3-5-P2)	101	148	7.69	64	2.8	MS	1.4	7.8	26.8	25.7
BRRI dhan74 (Ck)	95	148	7.41	68	2.4	MB	1.5	8.3	28.0	24.2
BRRI dhan84 (Ck)	96	144	6.49	53	3.3	LS	1.4	9.7	25.9	27.6

*Mean of ten locations (Feni, Chottrogram; Shahjanpur, Bogura; Narendrapur, Jashore; BRRI, Gazipur; BINA, Mymensingh; BRRI, Faridpur; Laksham, Cumilla; BRRI, Rangpur; Babuganj, Barishal; Sadar, Dinajpur)

Development of insect resistant rice. The main thrust of the project was to develop varieties resistant to gall midge (GM), brown plant hopper (BPH) and white backed plant hopper (WBPH). The experiments were conducted in both T. Aman and Boro seasons. In the T. Aman season, 28 crosses were made using 26 parents and 25 crosses were confirmed as true hybrids using quality check (QC) genotyping with purity SNP panel. In total 39,484 segregating progenies from 57 crosses of F_2-F_5 generations were advanced using Field Rapid Generation Advanced (FRGA) technique. Out of 4192 $F_{5:6}$ LST lines derived from 20 different crosses, 564 genotypes were selected based on strong plant architecture, grain type and uniformity in heading under field condition as well as 16 trait SNP markers. The yield trials (OYT, PYT and AYT) were conducted at three locations of BRRI Gazipur, Cumilla and Rajshahi. Seventy nine genotypes were selected from 460 breeding lines in OYT. Twelve selected OYT genotypes had both *bph17* and *bph32* SNP favorable alleles. Total 13 shows the performance and favourable alleles of selected OYT genotypes. Seven lines were selected from 50 lines in PYT. Two genotypes were selected from 44 lines in AYT. Twenty five genotypes were evaluated in two RYT's and none of the entry was selected due to poor performance compared to the check varieties. Four promising lines such as BR9880-40-1-3-34, BR9881-24-2-2-25, BR9880-27-4-1-18 and BR9880-2-2-2-1 were evaluated in ALART that showed moderate resistance to BPH (SES Score 5.0). Two (BR9880-40-1-3-34 and BR9880-27-4-1-18) from ALART were recommended for conducting re-ALART in T. Aman 2021-22 season. In Boro season, 22 crosses were made using 27 parents and 21 crosses were confirmed as true hybrids through F_1 verification using quality check (QC) genotyping with purity SNP panel. A total of 63,897 individual plants were harvested from 67 crosses in F_2-F_5 generations by FRGA technique. In LST, 962 lines having strong plant architecture, grain quality and uniformity in heading under field condition were selected from 4465 $F_{5:6}$ breeding lines that are the descendants of 16 crosses. Sixty five out of 460 genotypes were selected from OYT. Out of 78 genotypes, 25 were selected from AYT for further evaluation. Total 65 parental lines were maintained in insect resistant maintenance breeding programme.

Development of submergence and water stagnation tolerant rice varieties. The projects aimed for the development of high yielding rice varieties tolerant to submergence (flash flooding) and medium stagnant water (MSW) stresses. Totally 2,305 F_1 seeds were obtained from 35 single crosses. Fifteen single F_1s crosses were selected and confirmed through QC SNP panel analysis. Panicles of 3,230 from nine F_2 crosses, 4,890 from 10 F_3, 4,145 from nine F_4 progenies, 6,565 from 22 F_5 progenies, and 3,590 from 13 F_6 progenies were harvested at the time of maturity, processed with proper labels and preserved. The ranges of mortality percentage of different RGA generations were 18-20%. From LST population, 1,419 lines were genotyped with trait markers using custom SNP panel among which 145 lines were selected based on uniformity and traits markers like *Sub1*, *Wx-A group*, *Wx-A_NB*, *xa13*, *Xa21* etc. In yield trial, 1,054 genotypes were tested out of which 129 genotypes were selected based on phenotypic acceptance, growth duration, survivability and higher yield performance. From OYT#1, eleven genotypes out of 56 genotypes, from OYT#2, twenty genotypes out of 60 genotypes, from OYT#3, twenty genotypes out of 46 genotypes, from OYT#4, 8 genotypes out of 24 genotypes, from PYT#2, four genotypes out of eight genotypes, from PYT#3, six genotypes out of 12 genotypes, from PYT#4, three genotypes out of eight genotypes, from AYT#1, three genotypes out of eight genotypes, from AYT#2, five genotype out of fourteen genotypes, from PVS#1, two genotypes out of four genotypes, from PVS#2, one genotype out of three genotypes, were selected. In OYT#1, the genotype BR11692-5R-345 with 89% survivability produced the highest yield of 6.1 t/ha under stress condition. In OYT#2 the genotype BR11690-5R-301 showed higher yield (5.3 t/ha) under stress with 71% survivability. In OYT#3, the genotype BR11694-5R-236 produced highest yield (7.2 t/ha) followed by the genotype BR11694-5R-317 (6.4 t/ha) having a survivability of 94% and 100% survivability, respectively. In OYT#4, the

Table 13. Grain yield, agronomic performance and BPH reaction through screening at greenhouse with favourable alleles for trait of interest of selected genotypes from OYT lines, T. Aman 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)	BPH Score	Available useful traits
BR11035-4R-1	120	115	3.8	7	*Pi-ta, Chalk5, Gn1a, BPH17, BPH32, Pb1, Waxy-A*
BR11035-4R-101	121	113	4.4	7	*Pi-ta, Ckalk5, Gn1a, BPH17, BPH32, Waxy-A*
BR11035-4R-190	121	102	3.4	9	*Pi-ta, Chalk5, Gn1a, BPH17, BPh32, Waxy-A*
BR11039-4R-57	119	116	2.5	5	*Pi-ta, Gn1a, BPH32, Pb1, Waxy-A*
BR11039-4R-106	95	113	4.4	5	*Pi-ta, Chalk5, Gn1a, BPH32, Waxy-A*
BR11039-4R-165	106	115	5.6	5	*Pi-ta, Gn1a, BPH32, Pb1, Waxy-A*
BR11039-4R-192	118	118	4.1	5	*Pi-ta, Chalk5, Gn1a, BPH32, Pi33, Waxy-A*
BR11039-4R-203	96	108	5.0	5	*Pi-ta, Chalk5, Gn1a, BPH32, Pi33, Waxy-A*
BR11039-4R-247	116	114	4.0	5	*Pi-ta, Chalk5, Gn1a, BPH32, Pi33, Waxy-A*
BR11040-4R-181	96	110	3.4	5	*Pi-ta, Gn1a, BPH32, Pi33, Waxy-A*
BR11040-4R-191	122	116	4.1	5	*Pi-ta, Chalk5, BPH32, Pb1, Waxy-A*
BR11040-4R-208	127	119	4.2	5	*Pi-ta, Chalk5, BPH32, GM4, Pb1*
BR11040-4R-240	107	118	3.9	5	*Pi-ta, Gn1a, BPH32, Pi33, Waxy-A*
BR11044-4R-33	115	109	4.3	7	*Pi-ta, BPH17, BPH32, GM4, Waxy-A*
BR11044-4R-47	114	113	3.2	7	*Pi-ta, BPH17, BPH32, GM4, Waxy-A*
BR11044-4R-82	112	111	3.0	5	*Pi-ta, GM4, Waxy-A*
BR11044-4R-101	111	116	3.5	5	*Pi-ta, BPH32, GM4, Waxy-A*
BR11044-4R-211	116	117	3.6	5	*Gn1a, BPH32, Waxy A*
BR11044-4R-279	105	117	4.5	5	*Chalk5, Gn1a, BPH32, GM4, Pi33*
BR11046-4R-23	107	118	3.3	5	*Chalk5, Gn1a, Waxy-A, Pb1*
BR11049-4R-12	110	106	4.0	9	*Gn1a, BPH17, BPH32, Waxy-A, GM4, Pb1*
BR11052-4R-135	104	109	4.1	9	*Chalk5, Gn1a, BPH17, BPH32, Waxy-A*
BR11052-4R-234	103	106	3.9	7	*BPH17, BPH32, Waxy-A, Pi33*
BR11052-4R-241	100	104	4.2	9	*Gn1a, BPH17, BPH32, Waxy-A, Pi33, Pb1*
BR11052-4R-251	128	113	4.6	7	*Pi-ta, Chalk5, BPH17, BPH32, Waxy-A, GM4*
BR11052-4R-273	118	112	5.3	7	*BPH17, BPH32, Waxy-A, GM4, Pi33*
BR11302-4R-239	123	117	4.6	5	*Pi-ta, Chalk5, Gn1a, Waxy-A, GM4, Pi33*
BR11302-4R-287	121	111	5.0	5	*Gn1a, Waxy-A*
BR11295-4R-156	124	126	4.8	5	*Pi-ta, Chalk5, Gn1a, Waxy-A*
BR11295-4R-225	118	129	3.9	5	*Pi-ta, Chalk5, BPH32*
BR11295-4R-277	119	139	3.4	5	*Pi-ta, xa5, BPH32, GM4*
BR11295-4R-435	124	123	5.1	5	*Pi-ta, Chalk5, Gn1a, BPH32, GM4*
BR11295-4R-570	121	125	3.6	5	*Pi-ta, Chalk5, Waxy-A*
BR11296-4R-19	117	129	4.6	5	*Pi-ta, xa5. BPH32, Waxy-A*
BR11296-4R-22	115	114	4.4	5	*BPH32, Waxy-A*
BR11296-4R-92	115	116	4.3	5	*Gn1a, BPH32, Waxy A*
BR11296-4R-124	121	120	5.1	5	*Gn1a, BPH32, Waxy A*
BR11296-4R-136	109	128	4.2	5	*Pi-ta, Gn1a, Waxy-A*
BR11296-4R-167	126	112	4.1	5	*Chalk5, Gn1a, Waxy-A, Pi33*
BR11296-4R-196	111	110	4.6	5	*Gn1a, Waxy-A*
BR11296-4R-264	119	129	4.1	5	*Pi-ta, Chalk5, BPH32, Waxy-A, GM4*
BR11296-4R-295	119	118	4.6	5	*xa5, BPH32, Waxy-A*
BR11296-4R-297	121	126	4.3	5	*Pi-ta, Waxy-A*
BR11296-4R-312	125	127	4.4	5	*Pi-ta, xa5, Gn1a, BPH32, Waxy-A*
BR11296-4R-314	127	131	4.5	5	*Pi-ta, xa5, BPH32*
BR11297-4R-210	133	118	4.2	5	*Pi-ta, Chalk5, Gn1a, Waxy-A, GM4*
BR11298-4R-75	114	130	4.8	5	*Chalk5, Gn1a, Waxy-A, Pb1*

Investigators. Md. Ruhul Amin Sarker, M Akhlasur Rahman, Hasina Khatun and Ribed Farzana Disha.

highest yield was 6.0 t/ha given by the genotype IR100842-B-B RGA-B RGA-B RGA-9 with survivability of 93%. In PYT#2 the genotype BR11185-5R-738-5 produced highest yield (4.1 t/ha) with survivability of 79% and growth duration of 119 days. In PYT#3, the genotype BR11196-5R-83 produced highest yield (4.3 t/ha) with 80% survivability and 119 days growth duration. In PYT#4 the genotype IR 127152-3-22-18-1-B produced the highest yield of 4.8 t/ha which possessed all four *SUB1* genes along with four BB resistance genes. In AYT#2, the genotype IR16F1148 gave highest yield of 4.5 t/ha with 94% survivability and 120 days growth duration under stress. This genotype was also evaluated in PVS#1, where it produced 4.2 t/ha yield under stress which was 1.2 t/ha higher than the check variety BINA dhan11 (3.0 t/ha) with similar growth duration. This genotype was promoted to ALART. From PVS#2, two genotypes viz. BR9158-19-9-6-50-2-HR1 and IR13F441 produced higher yield under stress (4.5 t/ha and 4.3 t/ha respectively) with survivability of 87% and 86% respectively. Yield and survivability were significantly higher than the check varieties BRRI dhan52 (3.4 t/ha) and BRRI dhan79 (3.5 t/ha). These two genotypes were also promoted to ALART. The genotype BR9158-19-9-6-50-2-HR1 also got the highest preference score in PVS function. From AGGRi-network trial, out of 83 genotypes, 34 genotypes were selected of which survivability ranging from 93 to 99%. The heritability obtained for grain yield under stress of all trials conducted was ranging from 51 % to 98%, whereas that for non-stress trials was ranging from 54 % to 89%, indicating acceptable level of precision in these experiments.

Investigators. Sharmistha Ghosal, Z A Riyad, A Rahaman, R Hassan and K M Iftekharuddaula

Development of drought tolerant rice (DTR). The projects aimed to develop of high yielding drought tolerant rice varieties under rainfed lowland rice ecosystem in T. Aman season. In T. Aman 2020-21, tottaly 3,678 F_1 seeds were obtained from 19 crosses using 18 parents. A total of 13,721 individual panicles from 74 crosses of F_2-F_6 were harvested through RGA. From LST, 729 lines were selected from 8,034 progenies of 46 crosses. In PYT total four genotypes were selected from 16 genotypes based on yield performances. In, Boro 2020-21 season, 2704 progenies were selected from 10 crosses of F_3 generation through RGA method. In OYT, 180 drought tolerant genotypes were evaluated, and the trial will be re-evaluated in T. Aman 2021-22 season for evaluation of yield stability.

Investigators. M A Kader, R R Majumder, M E Haq, U R Shaha and K Fatema

Development of water saving and aerobic rice varieties. The objective of the project was to develop short duration water-use-efficient rice genotypes with 10% more yield than the check varieties under transplanted alternate wetting and drying (AWD) and aerobic condition. A total of 14 crosses were made using 11 parents and 2,560 F_2 populations from four crosses were advanced through FRGA. From yield trial conducted under AWD condition, 12 genotypes were selected from 28 genotypes grown. Ten genotypes from PYT, two genotypes from AYT were selected. In PYT, none of the genotypes produced higher yield than the check variety BRRI dhan89 (7.0 t/ha), however the genotype BR11207-5B-288 produced 5.7 t/ha yield followed by the genotype BR11206-5B-75 (5.6 t/ha) with 5-6 days lower growth duration. The yield of these genotypes was significantly higher than the check variety BRRI dhan28 with similar growth duration. In AYT, The genotype IR16L1081 produced highest yield (5.7 t/ha) however it was not significantly higher than the check varieties BRRI dhan28 (5.3 t/ha) and BRRI dhan58 (5.5 t/ha). These genotypes would be used as parent. The heritability obtained for grain yield under stress of the trials conducted was ranging from 59 % to 96% indicating acceptable level of precision in these experiments.

Investigator. Sharmistha Ghosal, Z A Riyadh and K M Iftekharuddaula

Improvement of green super rice (GSR). The project aims at developing of less input but high yield potential genotypes with tolerance to different stresses. Form AYT, four entries out of six in T. Aman season and forty entries were selected from Boro season based on PAcp, growth duration, yield and grain quality. Among these GSR Boro

materials, nine genotypes were evaluated in T. Aus ecosystem for developing high yielding and short duration T. Aus rice varieties and 28 genotypes having low amylose (9.0-22.6%) were provided to upland rice (Aus) program to develop high yielding jhum rice for hilly people of Bangladesh. From RYT, one entry 7FBR336 (8.02 t/ha) out of five was performed better than the check variety BRRI dhan58 (7.88 t/ha) with 2-3 days longer growth duration in Boro season. The proposed genotypes HHZ5-DT20-DT2-DT1 (GSR IR1-5-D20-D2-D1) and HHZ12-SAL2-Y3-Y2 (GSR IR1-12-S2-Y3-Y2) was evaluated under PVT by NSB team in coastal area of Bangladesh in Boro, 2018-19 and released as BRRI dhan99. The variety BRRI dhan99 produced 1.2 t/ha higher yield than the salinity tolerant check BRRI dhan67 with five days longer growth duration (Table 14).

Investigators. M Khatun, M A Rahman, Ribed Farzana Disha and S K Debsharma

Development and validation of high beta-carotene rice and high iron & zinc rice varieties (Healthier Rice). The main objective of the project was to develop high yielding transgenic rice varieties with enhanced provitamin A, iron and zinc content in polished rice grain. Under the above-mentioned objective, six back crosses made and 4135 BC_2F_1 seeds were obtained in T. Aman 2020-21 season with a view to developing provitamin A enriched rice. Two homozygous progenies and 272 heterozygous plants were selected from three backcrosses from BC_3F_5 generations through Marker Assisted Selection (MAS) method. In Boro 2020-21 season, 4440 BC_3F_1 seeds were obtained from six backcrosses. A total of 14 genotypes from Contained Trial (CT) were selected from 70 transgenic lines of provitamin A enriched GR2E BRRI dhan28 based on the yield performances. Among 11 genotypes, five genotypes were selected from three events IRS1030-039, IRS1030-031, IRS1027-059 from the Confined field Trial (CFT) conducted in eight locations of Bangladesh under healthier rice project.

Investigators. M A Kader, R R Majumder, K Fatema, M E Haq and U R Shaha

International network for genetic evaluation of rice (INGER). This project focused on sharing and use of germplasm and breeding lines through international platform for the acceleration of genetic improvement of rice varieties. Totally six entries out of 51 entries of one INGER nursery set of Aus, 50 entries out of 321entries from six INGER nursery sets of T.Aman 2020 and 45 entries from six INGER nursery sets of Boro 2020-21 seasons were selected to be use in different breeding programmes for direct use in the breeding pipeline.

National Coordinator. K M Iftekharuddaula

Key Cooperator. Sharmistha Ghosal

Table 14. Performance of the salinity tolerant variety BRRI dhan99 under proposed variety trial (PVT), GSR, Boro 2018-19.

Designation	Plant height (cm) *	Growth duration (day) *	Grain yield (t/ha)	Grain characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Elongation ratio	Protein (%)	Amy lose (%)
BRRI dhan99 (HHZ5-DT20-DT2-DT1/GSR IR1-5-D20-D2-D1)	93	155	5.4	61.7	3.1	LS	1.5	7.9	27.1
BRRI dhan28 (Sus. Ck.)	94	146	2.8	63.5	3.1	MS	1.5	8.5	28.0
BRRI dhan67 (Tol. Ck.)	100	150	4.2	61.1	2.8	MB	1.3	8.8	24.6

*Mean of eight locations (Kaliganj, Debhata, Tala, Satkhira; Dumuria, Batiaghata, Paikgacha,Khulna; Rampal, Bagerhat and Kalapara, Patuakhali, Barishal)

Biotechnology Division

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26 C4 rice development

SUMMARY

During Boro 20-2021, two doubled haploids lines derived from a cross between BRRI dhan29 and Kanaklata were selected from PYT for developing low glycemic index (GI) rice variety. During Aus season 2020 a total of 152 F_1 seeds were harvested from eight crosses for further anther culture. Twenty two double haploid plants were regenerated from four different crosses. Four and seven double haploid plants were selected from BRRI dhan38/ Bashful and BRRI dhan50/ Bashful cross, respectively. Three double haploid fixed lines from BRRI dhan28/ BRRI dhan61 cross were evaluated during Boro 2020-21 as PYT. Among them two lines were selected for further evaluation. Thirteen crosses were done and 697 F_1 seeds were collected during Boro 2020-21 for further anther culture. Six antioxidant enriched double haploid black rice derived from a cross between BRRI dhan28 and Padi Kool was selected for PYT. A total of 81 (SC_3) and 111 (SC_4) black rice somaclonal variants were grown in T. Aman 2020. among them 41 and 78 antioxidant enriched black rice plants were selected, respectively. On the other hand, 440 (SC_3) and 41 (SC_4) antioxidant enriched plants were selected from 146 and 56 lines, respectively during Boro 2020-21. During Aus 2020, a total of 25 fixed lines and 77 plants were selected from EMS treated somaclonal In variants of BRRI dhan48 (M_1SC_5). Besides, 14 somaclonal variants (SCV_0) of Kalijira were harvested for further evaluation. Seventy two lines from different generation of embryo rescued plants were evaluated in T. Aman 2021. Among them 38 plants were selected (Table 6; Fig. 4). Besides, five backcrosses were done with previously embryo rescued plants and 102 BC_2F_1 seeds were harvested. Two hundred and ten M_2 plants developed from NMU treated 1000 BRH-11-9-11-4-5B seeds were harvested during T. Aman 2020 and these M_2 lines along with the check were transplanted in Boro 2020-21 for generation advancement. But no desired variation was observed. One thousand Kilizira seeds were treated with 20 mM NMU solution at two time point (3 hr and 4 hr) to create variation. Seeds from 215 M_2 plants were harvested during T Aman-2020. During T. Aman 2020, about 600 seeds of BRRI dhan 87 were treated by 20 mM NMU at two-time point (3 hr and 4 hr) and treated seeds sown in the field. From two treatments 520 M_2 plants were selected for further selection. During T. Aman 2020, about 600 seeds were treated by 20 mM NMU. Seeds were sown in seedbed and transplanted later in the field. Two hundred and sixty plants from each treatment totally 520 M_2 plants were collected for further selection. In identification of QTLs for taller seedling height study, genotyping was done using sixty polymorphic primers with 184 F_2 populations from BR11/Sadamota (acc.no.1576) cross. Beside four F_4 plants were selected from mapping QTL population for further evaluation during T. Aman 2021. Eighty one F_4 progenies developed from a cross between BRRI dhan87 and Kalijira were selected from 29 lines on the basis of aroma, growth duration and plant height. Bacterial blight (BB) gene pyramided two lines having three BB resistant genes (*Xa4*, *xa13* and *Xa21*) were evaluated as ALART at 10 locations in Boro 2019-20. *NHX1* and *HKT1* salt tolerant genes were isolated from Pokkali and also *NHX1* salt tolerant gene isolated from *Oryza coarctata*. Twenty one T_4 putative salt tolerant transgenic plants were confirmed by *GlyI* primer. Moreover, three BC_2F_1 plants of BRRI dhan28 containing *AeMDHAR* salt tolerant gene were confirmed by gene specific primer of *AeMDHAR.* In both the genome edited studies for developing blast resistant variety and to develop aromatic rice variety, three PCR reactions were done and the amplicons were subjected to sequence for both rice aroma and blast resistance. A total of 1794 M_3 lines of Kaoun (*Setaria italica*) were developed for high-throughput screening for loss of C4 functions.

DEVELOPMENT OF DOUBLE HAPLOID RICE THROUGH ANTHER CULTURE

Low glycemic index (GI) rice variety

During Boro 2020-21**,** three doubled haploid lines derived from a cross between BRRI dhan29 and

Kanaklata were grown in a secretary yield trial. Among them two lines were selected depending on the growth duration and yield compared with the check variety (Table 1).

Table 1. Agronomic characteristics of anther culture derived lines during Boro 2020-21 (SYT).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)10381-AC32-3	121	140	7.2
BR(Bio)10381-AC32-5	119	142	5.9
BR(Bio)10381-AC1-2	95	142	8.5
BRRI dhan28	107	143	7.1
CV(%)	0.62	-	9.24
LSD(0.05)	1.37	-	1.32

Investigator: Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque.

Premium quality rice variety

A total of 6,789 and 7,596 hybrid anthers from 13 crosses were plated on N6 and M10 media. In total, 22 green plants were regenerated from four crosses (Table 2; Fig. 1). Seven crosses and 11 backcrosses were done and 673 seeds were harvested from them for future anther culture programme. Seventeen doubled haploid lines were evaluated in T. Aman 2020. Among them four and seven plants were selected from BRRI dhan38/ Bashful (acc. No. 3954) and BRRI dhan50/ Bashful (acc. no. 3954) cross, respectively.

Investigator: Nilufar Yasmin Shaikh, Jannatul Ferdous and Md Enamul Hoque

Salt tolerant rice variety

Three double haploid fixed lines from BRRI dhan28/BRRI dhan61 cross were evaluated during Boro 2020-21 as PYT. Among them two lines were selected for further evaluation (Table. 3). Besides, 13 crosses were done and 697 F_1 seeds were harvested for future anther culture programme.

Table 2. Number of doubled haploid plants regenerated in T. Aman 2020.

Cross	No. of Anther plated		No. of calli obtained	No. of plant regenerated
	N6	M10		
BRRI dhan90/ BRRI dhan34	900	1078	16	2 (M10)
BRRI dhan90/ Tulshimala	1284	1460	22	6 (M10)
BRRI dhan90/ Kalizira (P)	635	909	31	5 (N6)
BRRI dhan90/ Kataribhog	487	676	11	8 (M10), 1 (N6)
Total			81	22

Fig. 1. Doubled haploid plant regenerated from different crosses.

Table 3. Agronomic characteristics of doubled haploid lines during Boro 2020-21 (PYT)

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR (Bio) 11310-AC1-2	94	143	6.28
BR (Bio) 11310-AC2-1	93	142	7.01
BR (Bio) 11310-AC2-2	93	143	7.35
BRRI dhan28	95	143	7.07
BRRI dhan61	93	148	6.66
BRRI dhan86	94	143	7.09
		LSD (0.05)	0.39
		CV	5.57

Parentage BR(Bio)11310: BRRI dhn28/ BRRI dhan61
Investigator: Nilufar Yasmin Shaikh, Shahanaz Sultana and Md Enamul Hoque.

High yielding Aus rice variety

During Aus 2020, a total of 152 F_1 seeds were harvested from eight crosses for future anther culture programme.

Investigator: Shampa Das Joya, Jannatul Ferdous, Nilufar Yasmin Shaikh and Md Enamul Hoque

Antioxidant enriched black rice variety

During Boro 2020-21, a total of 16 double haploid lines derived from a cross between BRRI dhan28 and Padi Kool were grown as OT with standard checks to select agronomically desirable and high yield potential materials. (Table 4). Among them six lines were selected depending on the duration and yield with checks for further evaluation.

Investigator: Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque.

High yielding favourable Aus rice variety

During Aus 2020, five BB resistant materials developed through marker assisted selection were evaluated in a PYT with standard checks to select agronomically desirable and high yield potentiald materials. Among them three lines were selected depending on the duration and yield compare with the checks for further evaluation as SYT (Table 5).

Investigator: Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque.

Table 4. Agronomic characteristics of doubled haploid lines during Boro 2020-21 (OT).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)13028-AC 24-2-3	121	150	6.43
BR(Bio)13028-AC24-2-6	118	145	8.12
BR(Bio)13028-AC24-5-1	123	147	4.15
BR(Bio)13028-AC24-1-1	126	158	8.36
BR(Bio)13028-AC24-1-2	122	149	7.41
BR(Bio)13028-AC24-1-3	123	145	7.42
BR(Bio)13028-AC24-2-1	110	146	7.26
BR(Bio)13028-AC24-2-2	119	153	7.91
BR(Bio)13028-AC24-2-3	113	144	7.18
BR(Bio)13028-AC24-2-4	111	143	6.45
BR(Bio)13028-AC24-2-5	117	143	6.99
BR(Bio)13028-AC24-3-1	121	151	7.61
BR(Bio)13028-AC24-3-3	109	144	9.16
BR(Bio)13028-AC24-3-4	123	145	7.19
BR(Bio)13028-AC11-1-3	115	145	5.75
BR(Bio)13028-AC11-3-1	99	144	8.17
BRRI dhan86	88	144	7.75

Table 5. Agronomic characteristics of BB resistant materials in T. Aus/2020 (PYT).

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
BR(Bio)11447-1-28-4-6	110	99	4.52
BR(Bio)11447-1-28-12-3	103	98	4.61
BR(Bio)11447-1-28-14-1	119	99	4.35
BR(Bio)11447-1-28-14-3	119	104	3.27
BR(Bio)11447-3-10-7-1	122	104	4.02
BRRI dhan48 (ck)	104	108	4.76
CV (%)	0.89	2.05	11.76
LSD $_{(0.05)}$	1.8	3.8	0.88

High yielding photosensitive rice variety

During T. Aman 2020, six crosses were done and 106 F_1 seeds was harvested for future anther culture programme.

Investigator: Md Arafat Hossain, SM Hisam Al Rabbi and Md Enamul Hoque.

DEVELOPMENT OF RICE VARIETY THROUGH SOMACLONAL VARIATION

Somaclonal variants using EMS treated rice seed

In Aus 2020, a total of 25 fixed lines and 77 plants were selected from 85 EMS treated somaclonal variants of BRRI dhan48 (M_1SC_5). During T. Aman 2020 a total of 30 EMS treated somaclonal variants of BR11 were grown as observational trial with the standard check but none of them was selected. Besides, 19 fixed lines and 97 plants were selected from 224 EMS treated somaclonal variants of BR11.

Investigator: Shahanaz Sultana, Jannatul Ferdous, Shampa Das Joya and Md Enamul Hoque

Development of premium quality rice (Kalijira type) through somaclonal variation

Matured seeds of kalijira were culture on MS media to get the calli. Calli were then transferred to regeneration medium for regeneration of green plantlets. Finally seeds were harvested from 14 somaclonal variants (SCV_0) of Kalijira rice (Fig. 3).

Investigator: Shahanaz Sultana, Jannatul Ferdous and Md Enamul Hoque

Antioxidant enriched black rice variety

A total of 81 (SC_3) and 111 (SC_4) somaclonal variants of Lansan, Padi Chelum and Padi Kool were grown in T. Aman 2020. Among them 41 and 78 antioxidant enriched black rice plants were selected respectively. On the other hand, 440 (SC_3) and 41 (SC_4) antioxidant enriched plants were selected from 146 and 56 lines during Boro 2020-21, respectively.

Investigator: Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque.

Fig. 3. Regeneration from matured seeds of Kalijira.

DEVELOPMENT OF RICE VARIETY THROUGH WIDE HYBRIDIZATION

Investigator: Nilufar Yasmin Shaikh, Shahanaz Sultana and Md Enamul Hoque

Wide hybridization followed by embryo rescue

Seventy-two (72) lines from different generation of embryo rescued plants were evaluated in T. Aman 2021. Among them 38 plants were selected (Table 6; Fig. 4). Besides, five backcrosses were done with previously embryo rescued plants and 102 BC_2F_1 seeds were harvested (Table 7).

DEVELOPMENT OF RICE VARIETY THROUGH MUTATION BREEDING

Development of variants using NMU of BRH-11-9-11-4-5B having reduced sterility

One thousand BRH-11-9-11-4-5B seeds were treated with 20 mM NMU solution to get M_1 plants. Two-time point 3 hr and 4 hr were used to

Table 6. List of plants selected from embryo rescued rice lines during T. Aman 2020.

Cross	Generation	No. of lines evaluated	No. of plants selected
BRRI dhan28/*O. nivara* (IRGC103821) (Cross number: BR(Bio)13035)	BC_1F_1	8	2
	BC_1F_2	12	3
	BC_1F_4	2	1
	BC_1F_5	14	7
BRRI dhan28/*O. glaberrima* (IRGC105190) (Cross number: BR(Bio)13037)	F_4	13	11
BRRI dhan87/*O. glaberrima* (IRGC105190) (Cross number: BR(Bio)13040)	F_4	6	1
BRRI dhan48/*O. glaberrima* (IRGC105190) (Cross number: BR(Bio)13036)	F_4	17	13
	Total	72	38

Table 7. List of backcross with embryo rescued plants during T. Aman 2020.

Cross	No of seeds harvested (BC_2F_1)
BRRI dhan87*[2]/ *O. glaberrima* (IRGC 105190)	11
BRRI dhan48*[2]/ *O. glaberrima* (IRGC 105190)	14
BRRI dhan48/ *O. glaberrima* (IRGC 105190)// BR86*[1]	15
BRRI dhan28/ *O. glaberrima* (IRGC 105190)// BR86*[1]	38
BRRI dhan28/ *O. nivara* (IRGC 103821)// BR86*[1]	24
Total	102

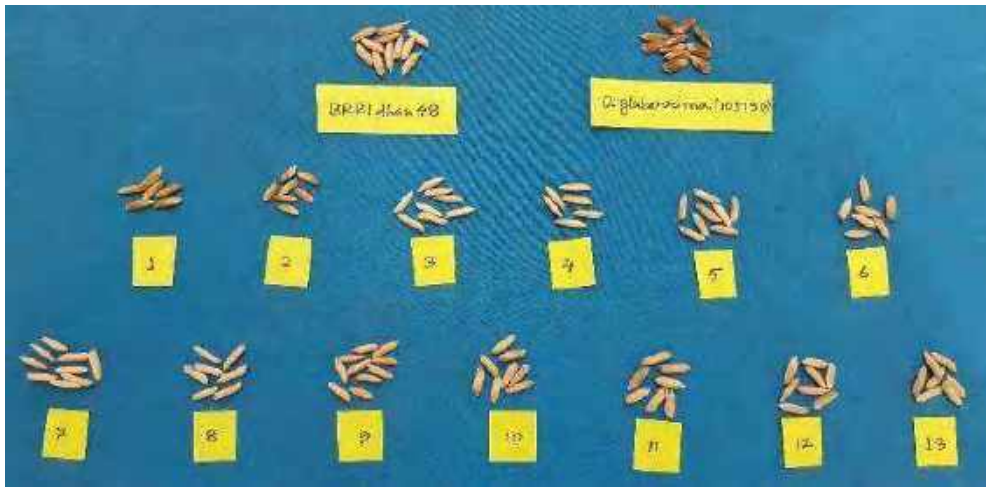

Fig. 4. Seeds of different pedigree lines derived from wide cross of BRRI dhan48/*O. glaberrima* (IRGC 105190)..

plants. Two-time point 3 hr and 4 hr were used to create variation. Seeds from two hundred and ten (210) M_2 plants were harvested during T Aman2020. Two hundred and ten M_2 lines along with check were transplanted in Boro 2020-21 for generation advancement. But no desired variation was observed.

Investigator: Shahanaz Sultana, Jannatul Ferdous, S.M Hisham Al Rabbi, Shampa Das Joya and Md Enamul Hoque.

Development of Kilijira type rice variety through mutation by NMU

One thousand Kilizira seeds were treated with 20 mM NMU solution to get M_1 plants. Two-time point 3 hr and 4 hr were used to create variation. Seeds from 215 M_2 plants were harvested during T Aman 2020.

Investigator: Shahanaz Sultana, Jannatul Ferdous, S.M Hisham Al Rabbi, Shampa Das Joya and Md Enamul Hoque.

High Yielding sheath blight resistant rice variety

During T. Aman 2020, about 600 seeds of BRRI dhan87 were treated by 20 mM NMU at two-time point (3 hr and 4 hr) and treated seeds sown in the field. From two treatments 520 M_2 plants were selected for further selection.

Investigator: Md Arafat Hossain, Shahanaz Sultana, Jannatul Ferdous, S.M Hisham Al Rabbi and Md Enamul Hoque.

ALLELE MINING

Identification of QTLs for taller seedling height

Genotyping was done using 60 polymorphic primers with 184 F_2 individuals developed from a cross between BR11 x Sadamota (acc. no. 1576) (Fig. 5). From the mapping population, 11 pedigree lines were grown in T. Aman 2020 and from them four F_4 plants (cross number: BR (Bio) 13038) were selected during T. Aman 2020 for further evaluation.

Investigator: Nilufar Yasmin Shaikh, Jannatul Ferdous, S M Hisam Al-Rabbi, Md Arafat Hossain and Md Enamul Hoque.

DEVELOPMENT OF RICE VARIETY THROUGH MARKER ASSISTED SELECTION

Marker assisted selection for fragrance gene *BADH2*

Twenty-nine pedigree lines developed from a cross between BRRI dhan87 and Kalijira were evaluated and among them 81 plants were selected on the basis of aroma, growth duration and plant height. All tested aromatic lines were confirmed by using functional marker (ESP + IFAP + INSP + EAP) of fragrance gene *BADH2*. Figwres 6 and 7 show the gel image generated by marker ESP + IFAP + INSP + EAP. The primers combination of ESP and IFAP amplified the fragrance allele-specific at 257 bp. On the other

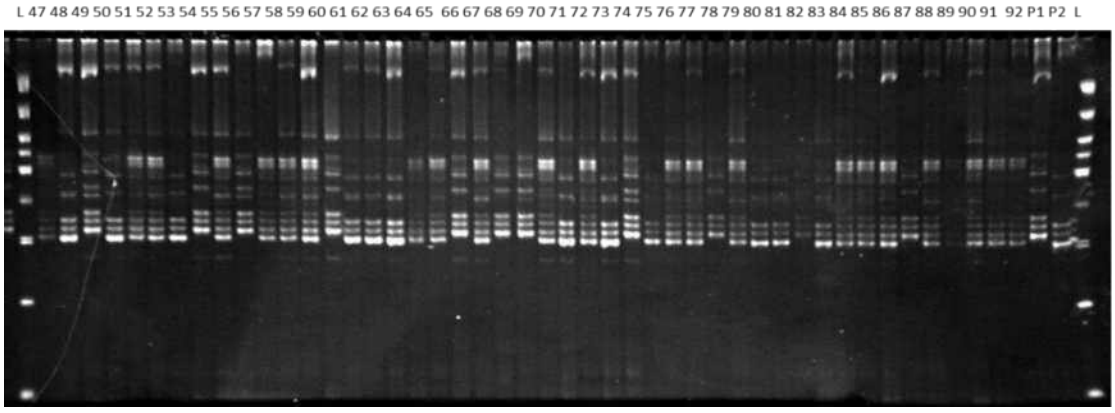

Fig. 5. Gel view of genotyping of F_2 population (BR11 x Sadamota acc. no. 1576) with primer RM252.

hand, the primers combination of INSP and EAP amplified the expected non-fragrance-specific allele (355 bp).

On the other hand, 38 pedigree lines developed from a cross between BRRI dhan28 and Kalijira were evaluated and among them 148 plants were selected on the basis of aroma, growth duration and plant height during T. Aman 2020. The selected aromatic lines were confirmed by using functional marker (ESP + IFAP + INSP + EAP) of fragrance gene *BADH2* in early generation.

Investigator: Jannatul Ferdous, S M Hisam Al-Rabbi and Md Enamul Hoque.

Gene pyramiding for resistance to bacterial blight in rice

Bacterial blight (BB) gene pyramided two lines having three BB resistant genes (*Xa4, xa13* and *Xa21*) were evaluated as ALART at 10 locations in Boro 2020-21 with standard checks by Adaptive Research Division, BRRI.

Investigator: Jannatul Ferdous, Shahanaz Sultana and Md Enamul Hoque.

GENE CLONING

Isolation and cloning of stress tolerant gene

cDNA was synthesized from RNA of salt treated *Oryza coarctata* and Pokkali to isolate and clone salt tolerant gene. Sodium/hydrogen exchanger 1 (NHX1), high-affinity K + transporter (HKT1) from *Oryza coarctata* and Pokkali were targeted to isolate for cloning purpose. NHX1 and HKT1 from Pokkali*;* NHX1 from *Oryza coarctata* were isolated and send for sequencing. (Fig. 8 and 9)

Investigator: Shahanaz Sultana, Jannatul Ferdous, Md Enamul Hoque and Md Nazmul Hasan Nayeem

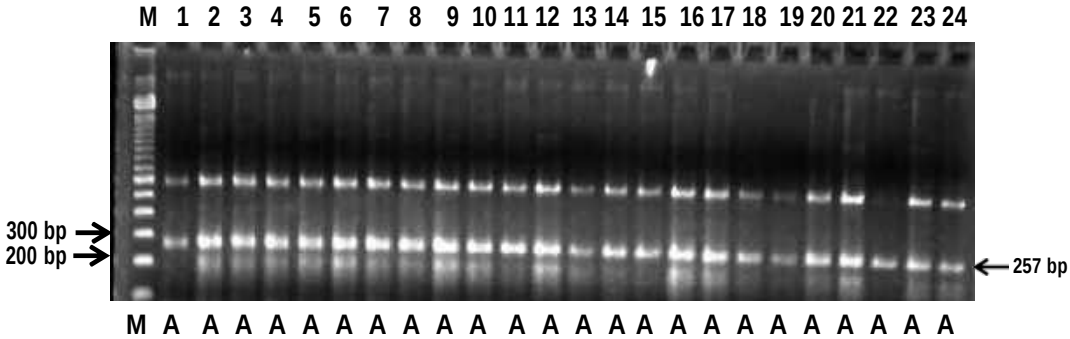

Fig. 6. Identification of aromatic genotypes with simple functional markers for fragrance in F_3 progenies of BRRI dhan87 and Kalijira (BRRI dhan87/Kalijira-2-41). A=Aromatic (all plants).

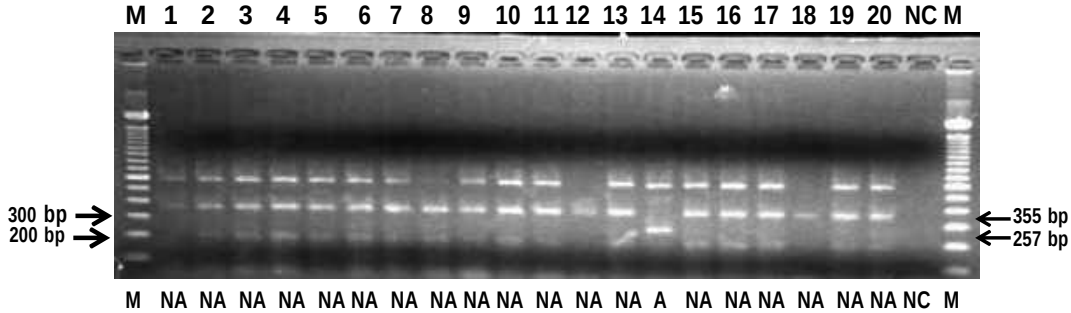

Fig 7. Identification of aromatic genotypes with simple functional markers for fragrance in F_3 progenies of BRRI dhan87 and Kalizira (BRRI dhan87/Kalijira-2-43). A=Aromatic (plant no 14), NA=Non Aromatic, NC=Negative control.

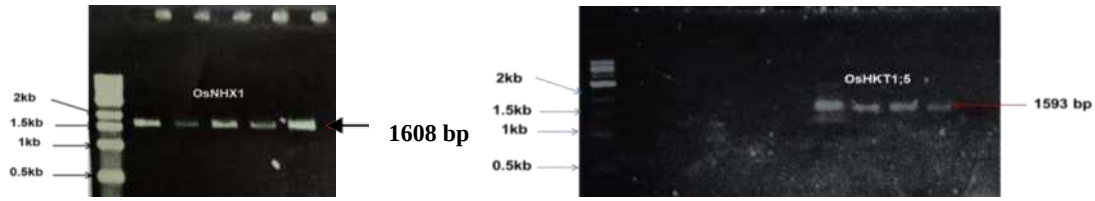

Fig. 8. PCR Amplification of 1608 bp *OsNHX1*and 1593 bp *OsHKT1* gene from local rice cultivar Pokkali.

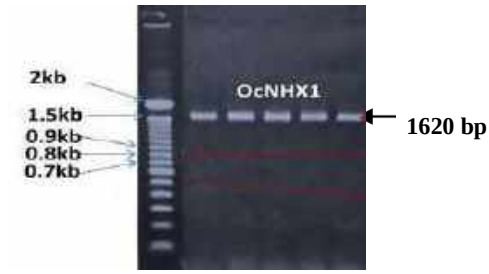

Fig. 9. PCR Amplification of 1620bp of *OcNHX1* gene from *O. coarctata* rice genotypes

RICE TRANSFORMATION

Development of salt tolerant transgenic rice with *GlyI and GlyII*

After transformation with *GlyI and GlyII* genes, plants were confirmed by GlyI and GlyII primers and sequencing. Twenty one T_4 plants were confirmed by *GlyI* specific primer.

Investigator: Shahanaz Sultana, Jannatul Ferdous, Shampa Das Joya and Md Enamul Hoque.

Introgression of salt tolerant gene

AeMDHAR salt tolerant gene (from mangrove plant) containing transgenic plant was crossed with BRRI dhan28 to introgress *AeMDHAR salt* tolerant gene. Three BC_2F_1 plants of BRRI dhan28 were confirmed by gene specific primer (Fig 10).

Investigator: Shahanaz Sultana, Jannatul Ferdous, Shampa Das Joya and Md Enamul Hoque.

GENOME EDITING THROUGH CRISPR

Development of high yielding aromatic rice lines through genome editing

Three PCR reactions were made and the amplicons were subjected to sequence. Two amplicons matched with the reference sequences (Figs. 11 and 12).

Investigator: S M Hisam Al Rabbi, Jannatul Ferdous, Shahanaz Sultana Shampa Das Joya, Md Enamul Hoque

Development of high yielding blast resistant lines through genome editing

Three PCR reactions were made and the amplicons were subjected to sequence. Two amplicons matched with the reference sequences (Figs. 13 and 14).

Investigator: Shahanaz Sultana, S M Hisam Al Rabbi, Jannatul Ferdous, Md Enamul Hoque

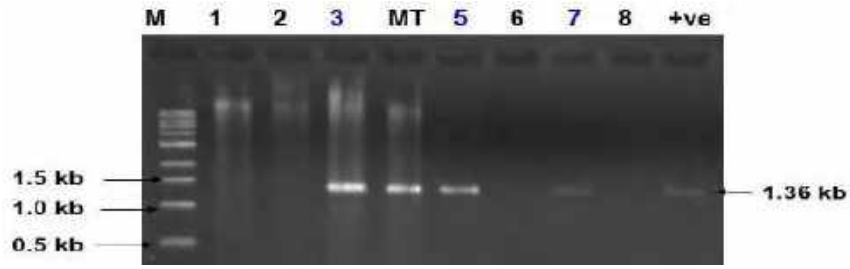

Fig. 10. Amplification of mangrove *AeMDHAR with gene specific primer.*

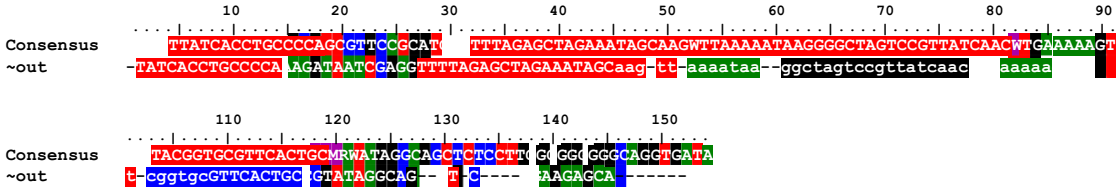

Fig. 11. Comparison of second amplicon for aroma with the reference sequence.

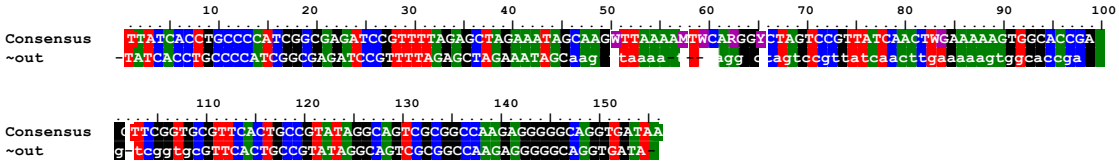

Fig. 12. Comparison of third amplicon for aroma with the reference sequence.

C4 RICE DEVELOPMENT

Identification of *Setaria* mutants losing C4 properties.

In tltal of 1794 M_3 lines of Kaoun (*Setaria italica*) have been developed for further study. These lines are gradually being raised and subjected to CO_2 stress in low concentration (20 ppm) CO_2 chamber for 72 hours (Fig. 15) and high-throughput screened for loss of C4 functions.

Investigator: SM Hisam Al Rabbi, Shahanaz Sultana, Munnujan Khanam, Sazzadur Rahman, Md Enamul Hoque

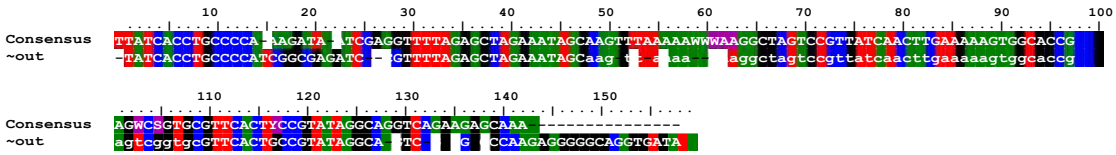

Fig. 13. Comparison of second amplicon for blast resistance with the reference sequence.

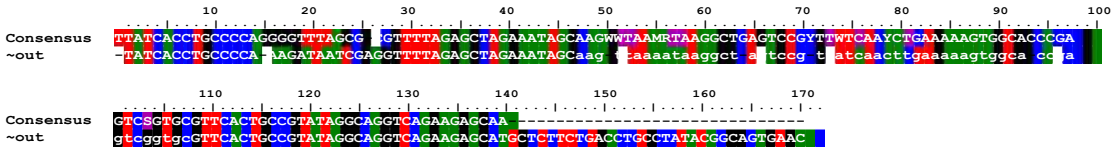

Fig. 14. Comparison of third amplicon for blast resistance with the reference sequence.

Fig.15. M_3 Kaoun plants are subjected to CO_2 stress in low concentration (20 ppm) CO_2 chamber.

Genetic Resources and Seed Division

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SUMMARY

In total, 156 rice germplasm of which eight in Aus, one *Jhum* rice from hilly areas, 88 in T. Aman, 46 in B. Aman and 13 in Boro seasons were collected from different districts of Bangladesh. Forty-eight germplasm accessions in Boro 2019-20 under PBRG-NATP-2 project, 28 germplasm in T. Aus 2020 and 50 in T. Aman 2020 and 30 in Boro 2020-21 were morphologically characterized using „Rice Germplasm Descriptors and Evaluation Form‟ of GRSD. Molecular characterization of 48 Aus germplasm using 60 SSR markers and 72 T. Aman germplasm using 61 SSR markers were performed under PBRG-NATP-2 project. The highest PIC values were found in RM 334 (0.78) in Aus and RM114 (0.77) in T. Aman germplasm and confirmed them as the best markers respectively. Dinajpur Kataribhog (Acc. no. 4791) and Bangladesh Kalijira (Acc. no 247) were ranked as GI products of Bangladesh.

Rejuvenation of 2,679 accessions was completed of which 632 in T. Aus 2020, 1,465 in T. Aman 2020 and 582 in Boro 2020-21. A total of 2,015 accessions of which 632 in Aus 2020 and 1,383 in T. Aman 2020 were processed and stored in short-term storage. Similarly, 310 accessions of which 65 in Aus and 245 in T. Aman were processed and stored in medium and 590 accessions of which 153 in Aus and 437 in T. Aman seasons were processed and stored in long-term storages respectively. Apart from this, 26 new germplasm were registered as new accessions (from accession number 8,605 to 8,630) in BRRI Genebank. Besides, 1,545 samples of rice germplasm and BRRI developed varieties were supplied to 33 different users.

One hundred and eleven BRRI developed and recommended rice varieties were maintained along with nucleus seed. Besides, nucleus seed stocks of 51 varieties were produced for the source of breeder seed. In total, 193.03 tons of breeder seed with tags of which 139.39 tons of 17 Boro varieties, 9.64 tons of eight Aus varieties and 44 tons of 28 T. Aman varieties were produced. At the same time, 186.164 tons of breeder seed of which 134.391 tons of 17 Boro varieties, 8.851 tons of eight Aus varieties and 42.922 tons of 28 T. Aman varieties were distributed among 996 partners (GO, NGO and PS) of „BRRI Rice Seed Network‟. Breeder and foundation seed producing plots and farms were also visited to observe the varietal purity and performance of respective seed.

RICE GERMPLASM CONSERVATION AND MANAGEMENT

Dinajpur Kataribhog and Bangladesh Kalijira ranked as GI Products. Two rice varieties of Bangladesh namely Dinajpur Kataribhog (Acc. no. 4791) and Bangladesh Kalijira (Acc. no 247) from BRRI Rice Genebank were ranked as GI products of Bangladesh in Journal no. 5 and 6 of „The Geographical Indication (GI) Journal‟ of Bangladesh on November 2020 by the Department of Patents, Designs and Trade Marks, Ministry of Industry, Bangladesh.

Germplasm collection and acquisition. Four collection missions including one under PBRG-NATP-2 project were made during the reporting year and 156 rice germplasm of which eight in Aus, one *Jhum* rice, 88 in T. Aman, 46 in B. Aman and 13 in Boro seasons were collected from different districts of Bangladesh including hilly areas (Fig. 1). PI: Mohammad Khalequzzaman.

Germplasm rejuvenation for storage. Rice germplasm were rejuvenated to increase the seed for safe storage in the Genebank. The experiment was carried out under transplanted conditions using double row of 5.4 m long per accession with 20 × 20 cm spacing between rows and plants respectively. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aus and T. Aman and @ 80:20:40 kg NPK/ha in Boro seasons.

A total of 2,679 germplasm of which 632 accessions (between Acc. 2501 to 5000) in T. Aus 2020, 1,465 accessions (between Acc. 2001 to 4000) in T. Aman 2020 and 582 accessions (between Acc. 01 to 4600) in Boro 2020-21 were rejuvenated in field for getting fresh seed and on average 500 g of seeds per accession were produced. PI: Tonmoy Chakrabarty (T. Aman), Md Humayun Kabir Baktiar (Boro) and Armin Bhuiya (T. Aus).

Fig. 1. Pictorial views of collecting rice germplasm from different areas of Bangladesh.

Morphological characterization of germplasm. Four experiments were conducted to characterize 156 rice germplasm (accessions as well as new collections) of which 48 in Boro 2019-20 under PBRG_NATP-2 project, 28 in T. Aus 2020 and 50 in T. Aman 2020 through 52 agro-morphological traits (both 21 quantitative and 31 qualitative characters) using the Rice Germplasm Descriptors and Evaluation Form (2018), GRSD, BRRI at GRSD, BRRI, Gazipur.

But in Boro 2020-21, 30 germplasm were characterized on the basis of 10 quantitative characters. The experiments were conducted using a single row of 5.4 m long for each entry/accession with 25 × 20 cm spacing during T. Aman and 20 × 20 cm spacing during Boro between rows and plants respectively. Fertilizers were applied @ 60:20:40 kg NPK/ha in T. Aus and T. Aman and @ 80:20:40 kg NPK/ha in Boro seasons. Appropriate control measures were taken for insect, pests, diseases and weeds when necessary.

In Boro 2019-21 under PBRG NATP-2 project, 48 germplasm accessions were characterized. The range of seedling height was found 17.2 cm (Boro 120 and Boro 259) to 22.8 cm (Boro 40/2) and average number of effective tiller was 13. On average, days to 50% flowering were 119 days and range was found 113 days (Boro 734) to 128 days (Boro 120 and Boro 259). The average plant height and panicle length were found 124.57 cm and 23.7 cm, respectively. The maximum filled grains per panicle were found 145 (Boro 65/2). The range of decorticated grain length- breadth ratio was observed 1.78 (Boro 134/1) to 2.47 (Boro 10/3). The highest grain length and breadth was found 7.94 mm (Dhali Boro 104/1) and 3.2 mm (Boro 734), respectively. The highest yield per hill was found 26.88 (Boro 40/2) and average yield per hill was 18.51 g. PI: Mohammad Khalequzzaman.

In T. Aus 2020, 28 new collection (NC) germplasm were characterized. Among them nine had medium (120-150 days) and 19 had long (>150 days) growth duration (Table 1). Nine germplasm were found with short (<90 cm), 17 moderate (90-120 cm) and the rest two with long (>120 cm) plant height. Two germplasm were found with short (~15 cm), 21 with long (~25 cm) and five had very long (>35 cm) panicle length. Twenty germplasm possessed intermediate (5-9), One had high (>9) and the rest seven had the lowest (<5) number of effective tiller. Considering decorticated grain length-breadth ratio, 17 germplasm were medium slender (2.1-3.0), two were bold (1.1-2.0) and nine were slender (>3.0) types grain. For 1000-grain weight (TGW), 11 germplasm had low (15-19 g), 12 had medium (20-23 g) and five had high (24-27 g) TGW. Two germplasm possessed low (<5 g/hill), 11 had moderate (5-10 g/hill) and 15 had higher (>10 g/hill) yield. PI: Nasirum Monir.

In T. Aman 2020-21, all 50 NC germplasm were characterized. Among them, 17 had short (≤128 days), 12 had medium (129-135), 12 had moderate (136-142) and nine had long (≥143) growth duration (Table 2). In case of height, out of 50, 11 germplasm were found with short (≤110

cm) and three with long (≥150 cm) plant height. In case of grain weight, three germplasm had very low (≤18 g) and 14 had high (≥28 g) TGW at 14% moisture. Twenty-two germplasm had low (≤10 g/hill) and 25 possessed medium (10-20 g) yield per hill. The shortest growth duration (122 days) was observed in Narikel Badhi, Sadadepa, Bashiraj. The shortest plant height (90.60 cm) was observed in 09 (Noy) and the longest (160.60 cm) in Jota Bhaula and AjolDigha. JolDigha, Narikel Badhi had the highest (31.15 g) and Ajol Digha had the lowest (13.53 g) TGW. The highest yield per hill (30.25 g) was observed in Bhaowaley. PI: Tonmoy Chakrabarty.

In Boro 2020-21, among the 30 germplasm accessions, seven germplasm had short (<135 days), 22 had medium (135-150 days) and one had long >150 days) growth duration (Table 3). Similarly out of 30, ten germplasm were found with short (<110 cm) and one with long (>130 cm) plant height. In case of panicle length, six had long (26-30 cm) panicle. For TGW, four germplasm had very low (≤15), five had high (24-27g) and three had very high (>25) TGW. For yield, 25 germplasm had higher (>10 g) yield per hill. The shortest growth duration (130 days) was observed in Tepiboro (Kalo) (Acc. 8058). The shortest plant height (67 cm) was observed in Jalda IRRI (Acc. 4206) and the longest (132 cm) in Lenga Boro (Acc. 4205). Shrestho aromatic dhan (Acc. 8228) had the lowest (11.0 g) and Ferilal (Acc. 4200) had the highest (29.5 g) TGW. The highest yield per hill (31.47 g) was observed in Black rice (Acc. 8096). PI: Armin Bhuiya.

Molecular characterization of rice germplasm. Forty-eight Aus and 72 T. Aman rice germplasm were studied in the Molecular Laboratory of GRSD, BRRI for developing DNA profiles under PBRG-NATP-2 project. Total genomic DNA was extracted from young leaves of three-week-old plants following the quick DNA extraction protocol of Ferdous *et al.* (2012). PCR analysis was performed in 10µl reaction sample containing 3µl of DNA template, 4.5µl of GoTaq G2 Green Master Mix (Promega), 1.5 µl of Nuclease-Free Water, 0.5µl each of 10 µM forward and reverse primers using a GeneAtlas G (Astec, Japan) 96-well thermal cycler. The mixture was overlaid with 10 µl of mineral oil to prevent evaporation. After initial denaturation for five minutes at 94°C, each cycle comprised 30 sec denaturation at 95°C, 30 sec annealing at 55°C, and 25 sec extension with a final extension for 5 min at 72°C at the end of 32 cycles. The PCR products were mixed with bromophenol blue gel loading dye and were analyzed by electrophoresis on 8% polyacrylamide gel with a 1 Kb/50 bp DNA ladder (Thermo Scientific, USA) using mini vertical polyacrylamide gels for high throughput manual genotyping (CBS Scientific Co. Inc., CA, USA). Then 2.5 µl of amplification products were resolved by running gel in 0.5X TBE buffer for 1.5-2.5 hrs depending upon the allele size at around 100 volts and 500 mA current. The gels were stained in 5 µl SYBR Safe DNA gel stain (10,000X concentration in DMSO, USA) with 200 ml 0.5X TBE buffer for 15 min and exposed to UV light using a molecular imager gel documentation unit (XR System, Uvitec Cambridge, France) for visualization. Microsatellite or simple sequence repeat (SSR) markers were used for molecular analysis (Temnykh *et al*., 2001; McCouch *et al.*, 2002). Sixty SSRs for Aus and 61 SSRs for T. Aman, both SSRs of well distributed over all 12 chromosomes of rice, were used for diversity analysis. Most of these markers were obtained from a panel of 50 standard SSR markers proposed by CGIAR for rice diversity analysis.

Aus rice germplasm: A total of 219 alleles were detected. The number of alleles per locus ranged from two alleles to eight alleles, with an average of 3.65 alleles across the 60 loci. The PIC values ranged from 0.08 (RM201, RM162) to 0.78 (RM334) with an average of 0.38. Primer RM334 had the highest PIC value (0.78) and was the best marker for characterizing the studied genotypes. Figure 2 shows the DNA profile of 48 Aus rice germplasm with SSR marker RM447. The unrooted neighbour-joining tree revealed that the germplasm were grouped into three major clusters using MEGA software (Fig. 3).

Table 1. Some important features of characterized germplasm in T. Aus 2020.

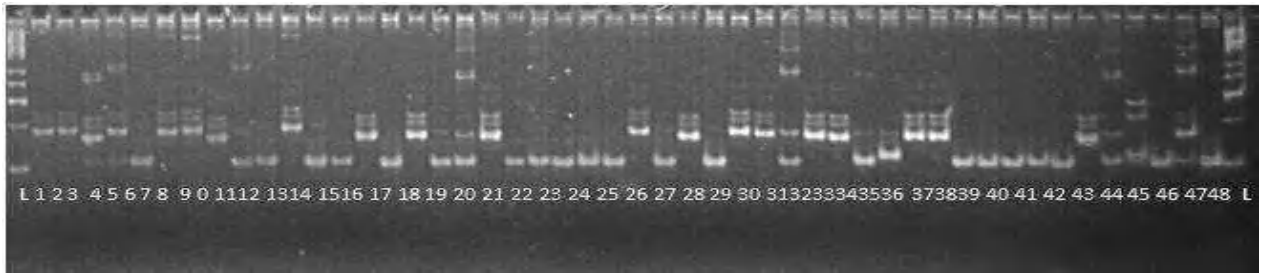
Growth duration (day)		Plant height (cm)		Panicle length (cm)		No. of tiller		No. of effective tiller		Grain LB ratio		1000-grain weight (g)		Yield/hill (g)	
Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries
<120	0	<90	9	<11	1	<5	1	<5	7	<1.1	0	<15	0	<5	2
120-150	9	90-120	17	~15	1	5-10	25	5-9	20	1.1-2.0	2	15-19	11	5-10	11
>150	19	>120	2	~25	21	>10	2	>9	1	2.1-3.0	17	20-23	12	>10	15
				~35	5					>3.0	9	24-27	5		
				>40	0							>27	0		
Shortest (131)	NC (D (A) 32)	Shortest (44.6)	NC (Pg 84)	Shortest (10.8)	NC (Pg 84)	Lowest (4)	NC (Pg 84)	Lowest (3)	NC (Pg 84)	Lowest (1.77)	NC (Turki Dhan)	Lowest (15.00)	NC (Bojha Dhan)	Lowest (3.64)	NC (Pg 84)
Longest (158)	NC (Kala Binni)	Longest (128.0)	NC (Galon)	Longest (27.8)	NC (Hamarong Dhan)	Highest (11)	NC (Kamarang, 20 Nombor Dhan)	Highest (10)	NC (20 Nombor Dhan)	Highest (4.49)	NC (D (A) 32)	Highest (26.70)	NC (Bish Nombor)	Highest (25.44)	NC (20 Nombor Dhan)
Mean	145.43		95.92		21.27		8.00		6.75		2.94		20.44		11.97
Std. Dev.	7.49		18.93		4.18		2.33		2.10		0.56		3.15		6.33
CV	5.15		19.74		19.65		29.07		31.13		19.09		15.41		52.90
LSD	2.77		7.01		1.55		0.86		0.78		0.21		1.17		2.35

Table 2. Some important features of characterized germplasm in T Aman 2020-21.

Growth duration (day)		Day to 50% flowering		Plant height (cm)		Panicle length (cm)		No. of tiller		Filled grain/panicle		1000-grain weight (g)		Yield/hill (g)	
Range	No. of entries	Range	No. of Entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries
≤128	17	≤98	14	≤110	11	≤15	3	≤6	5	≤50	14	≤18	3	≤10	22
129-135	12	99-105	10	110-130	14	15-19	5	6-9	30	50-100	26	18-23	11	10-20	25
136-142	12	106-112	18	130-150	22	19-23	24	9-12	14	≥100	10	23-28	22	20-30	2
≥143	9	≥113	8	≥150	3	≥23	8	≥12	1			≥28	14	≥30	1
Shortest (122)	NarikelBadhi, Sadadepa, Bashiraj, AjolDigha	Shortest (92)	NarikelBadhi, Sadadepa	Shortest (90.60)	09 (Noy)	Shortest (12.00)	Ajoldigha	Lowest (4.40)	Bhogdhan	Lowest (17.20)	Digha Dhan	Lowest (13.53)	AjolDigha	Lowest (3.70)	Laldepa
Longest (149)	Ganga	Longest (119)	Ganga	Longest (160.60)	Jota Bhaula, AjolDigha	Longest (27.40)	Jota Bhaula	Highest (13.00)	NashtaShaingla	Highest (125.20)	Jota Bhaula	Highest (31.15)	JolDigha, NarikelBadhi	Highest (30.25)	Bhaowaley
Mean	133.62		104.14		126.32		21.62		8.43		68.44		25.15		11.25
S. Dev.	7.50		7.20		18.06		3.23		2.10		27.24		3.78		6.01
CV	5.6		6.9		14.3		14.9		24.9		39.8		15.0		53.4
LSD	2.08		2.00		5.01		0.90		0.58		7.55		1.05		1.67

Table 3. Some important features of characterized germplasm in Boro 2020-21.

Growth duration (day)		Plant height (cm)		Panicle length (cm)		No. of tiller		No. of effective tiller		Grain LB ratio		1000-grain weight (g)		Yield/hill (g)	
Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries	Range	No. of entries
<135	7	<110	10	≤20	2	<10	24	<6	0	<1.1	0	≤15	4	<5	0
135-150	22	110-130	19	21-25	22	10-15	6	6-10	30	1.1-2.0	8	16-19	13	5-10	5
>150	1	>130	1	26-30	6	>15	0	>10	0	2.1-3.0	22	20-23	5	>10	25
				>30						>3.0		24-27	5		
												>27	3		
Shortest	Tepiboro (Kalo)	Shortest	Jalda IRRI	Shortest	Bogoya	Lowest	Ferilal, Lenga Boro	Lowest	Ferilal, Lenga Boro	Lowest	Chinikuri	Lowest	Shrestho aromatic dhan	Lowest	Chinikuri
130	(Acc. 8058)	67	(Acc. 4206)	18	(Acc. 8209)	6	(Acc. 4200, 4205)	5	(Acc. 4200, 4205)	1.59	(Acc. 8097)	11	(Acc. 8228)	4.96	(Acc. 8097)
Longest	Asharalo	Longest 132	Lenga Boro	Longest 28	Gachi Boro	Highest	Tepiboro (Kalo), Khaira Boro, Lawa Tepi	Highest	Tepiboro (Kalo), Khaira Boro, Lawa Tepi	Highest	Jalda IRRI	Highest	Ferilal	Highest	Black rice
152	(Acc. 8224)		(Acc. 4205)		(Acc. 4204)	11	(Acc. 8058, 4207, 4209)	10	(Acc. 8058, 4207, 4209)	3.44	(Acc. 4206)	29.5	(Acc. 4200)	31.47	(Acc. 8096)
Mean	142.67		103.21		23.57		8.31		7.37		2.30		19.96		16.14
S. Dev.	6.62		15.58		2.61		1.58		1.37		0.39		5.07		6.40
CV	4.64		15.10		11.08		19.04		18.61		16.93		25.40		39.64
LSD	2.37		5.57		0.93		0.57		0.49		0.14		1.81		2.29

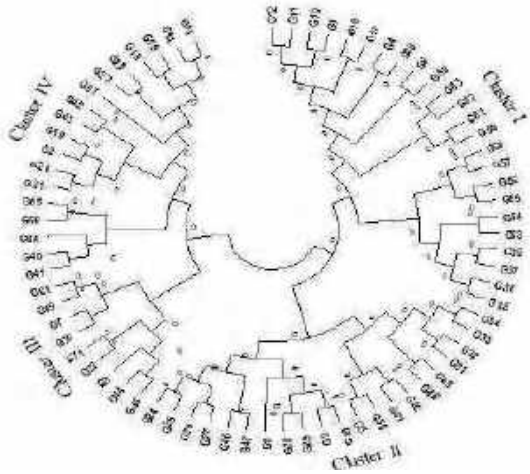


Legend: L=Ladder, 1=Atlal, 2=Charnak, 3=Dhala Saita, 4=Dhala Saita, 5=Harinmuda, 6=Kali Atia,7=Kataktara, 8=Patuakhali, 9=Parang, 10=Mi-Timbra, 11=Kachilon-1, 12=Kachilon- 2, 13=Bowalia, 14=Bowalia, 15=Juma, 16=Kasia Panja, 17=Bokri Joli, 18=Balam, 19=Rawnok, 20=Gojal Goria, 21=Joli, 22=Rangouri (Sada), 23=Shoni, 24=Kumri, 25=Dal Kaisha, 26=Boumail, 27=Achar Bhog, 28=Bari Bhog, 29=Jaba Hulu, 30=Garia, 31=Gungur Bali, 32=Hijolee, 33=Shoni, 34=Jabar Sail, 35=Laxmi Dia, 36=Madida, 37=Ashini, 38=Mi-Cochu, 39=Dharial, 40=Lema, 41=Porang, 42=Kali Haitya, 43=Hirgal, 44=Ingra, 45=Mati Char, 46=Boilam, 47=Boteswar (2), 48=Laxmi Bini.

Fig 2. DNA profile of 48 Aus rice with SSR marker RM447.

Fig. 3. An unrooted neighbour-joining tree showing the genetic relationships among the 48 Aus rice germplasm.

T. Aman rice germplasm: A total of 190 alleles were detected across 72 T. Aman rice germplasm. The number of alleles per locus ranged from 2 to 9 alleles, with an average of 3.92 alleles across the 61 loci. The PIC values ranged from 0.05 (RM134) to 0.77 (RM144) with an average of 0.39. Primer RM 144 had the highest PIC value (0.77). Therefore, RM144 was the best marker for characterizing the studied germplasm. The genetic distance-based results seen in the unrooted neighbour-joining tree revealed that the 72 T. Aman rice germplasm were grouped into four major clusters (Fig. 4). Mohammad Khalequzzaman.



Legend: G1=Abchaya, G2=Manikdigha, G3=Luta, G4=Gabura, G5=Bhawalia Diga, G6=Diga (2), G7=Diga, G8=Raj Bhawalia, G9=Molla Diga, G10=Molla Digha, G11=Bhawalia, G12=Bhawalia, G13=Bhawalia, G14=Bhawla, G15=Netpasha, G16=Netpasha, G17=Ijol Diga (1), G18=Ijol Diga (2), G19=Ijol Diga (3), G20=Bawoi Jhak (3), G21=Bawoi Jhak (4), G22=Bawoi Jhak (5), G23=Bawoi Jhak (6), G24=Bawoijhak (2), G25=Lema, G26=Chini Sagar, G27=Bansha Pur, G28=Roshon Bok, G29=Loiatag, G30=Subulkua, G31=Khorma, G32=Fulgainda, G33=Baish Binni, G34=Fulkadi, G35=Kumri, G36=Kaisha Binni, G37=Kaisha Binni, G38=Kaisha Binni, G39=Lal Binni, G40=Laksmi Bilash, G41=Bashi Raj, G42=Pahari Sail, G43=Indra Sail, G44=Lal Kumara, G45=Purabinni (3), G46=Kashiabinni (2), G47=Kashia Binni (2), G48=Gurdoi (2), G49=Kalijira (3), G50=Telot, G51=Bazail, G52=Joli Amon, G53=Bazail, G54=Bazail, G55=Kancha Noni, G56=Naria Bochi, G57=Khirsha Bhog, G58=Sham Rush, G59=Dudh Kalam, G60=Dudh Kalam, G61=Bora Dudh Kalam, G62=Lal Soru, G63=Gojol Goria, G64=Sojoni, G65=Ganjia, G66=Bindi Pakri, G67=Jhoshua, G68=Akand Sail, G69=Lal Dupa, G70=Jiga Sail, G71=Cheng Sail, G72=Shul Kumor.

Fig. 4. An unrooted neighbour-joining tree showing the genetic relationships among the 72 T. Aman rice germplasm.

Germplasm processing, registration and storage. In total 2,915 germplasm were processed and conserved with respective accession number in different storages of Genebank during the reporting year. The germplasm were cleaned and dried with a seed moisture content of less than 9% for short-term storage.

In details, 2,015 accessions of which 632 in Aus 2020 and 1,383 in T. Aman 2020 were processed and stored in short-term storage. Similarly, 310 accessions of which 65 in Aus 2020 and 245 in T. Aman 2020 were processed and stored in medium and 590 accessions of which 153 in Aus 2020 and 437 in T. Aman 2020 seasons were processed and stored in long-term storages respectively. Therefore, 850 accessions in Aus 2020 and 2,065 in T. Aman 2020 seasons were processed and stored. Apart from this, 26 new germplasm were registered as new accessions (from accession number 8605 to 8630) in BRRI Genebank.

Viability testing, periodic evaluation and routine monitoring of stored germplasm. The seed viability of the stored germplasm in short-term storage of BRRI Genebank was monitored from randomly selected germplasm in three seasons. Ninety accessions in Aus, 115 in T. Aman and 100 in Boro seasons were checked and monitored randomly for viability (germination %) test in short-term storage. Among the randomly selected 305 stored germplasm, 114 had viability between 80-90% and 147 had above 90%. Viability was also monitored in mid and long-terms storage using

five tester varieties namely Dharial (Acc. no. 649), Hashikalmi (Acc. 3575), Purbachi (Acc. 6207), Nizersail (Acc.1229) and Patnai-23 (Acc. 52.) to predict the viability of germplasm in respective storages. The viability was measured on six month interval usually on October and March of each year. The germination percentages of the five test samples/testers in the medium-term storages were found ranging from 79 to 92% in October 2020 and 81 to 95% in March 2021. Similarly, the germination percentages of the test samples/testers in the long-term storages were found ranging from 79 to 93% in October 2020 and 77 to 93% in March 2021. The germination percentages of the five test samples/testers indicating the probable viability condition of stored germplasm in respective storages.

The seed viability of the germplasm just before storage in the Genebank was also monitored. The germination tests of 300 germplasm just before storage in short-term were carried out of which 100 were for Aus, 150 were T. Aman and 50 were Boro seasons. Among them, 176 had germination between 80-90% and 92 had above 90%. The germplasm that possessed less than 80% germination will be grown again in the following season for safe keeping.

Germplasm distribution and exchange. A total of 1,545 samples were supplied to 33 different users in the reporting year. Among the samples, 1,123 germplasm accessions were supplied for research purpose and 422 samples of BRRI developed rice varieties were supplied to the researchers, Department of Agricultural Extension (DAE) personnel and university students for research, demonstration as well as other purposes. PI: Mohammad Khalequzzaman.

SEED PRODUCTION AND VARIETY MAINTENANCE

Variety maintenance and nucleus seed production. One hundred and eleven BRRI developed and recommended rice varieties including 14 locally improved varieties (LIVs) were maintained using panicle to row method, implementing time isolation and performing thorough roguing (Table 4). After harvest, both intact panicles and nucleus seed of each variety were stored (20°C with 40% RH) for variety maintenance and distribution to researchers, DAE personnel and students respectively. PI: Ebna Syod Md. Harunur Rashid (T. Aman) and Mir Sharf Uddin Ahmed (Boro) for BRRI varieties and Tonmoy Chakrabarty (T. Aman) and Mohammad Khalequzzaman (Boro) for LIVs.

Table 4. List of BRRI developed and recommended rice varieties maintained during 2020-21.

Season	Type	Number	Variety
T. Aman	MV	53	BR4, BR5, BR10, BR11, BR21, BR22, BR23, BR24, BR25, BRRI dhan27, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan33, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan40, BRRI dhan41, BRRI dhan42, BRRI dhan43, BRRI dhan44, BRRI dhan46, BRRI dhan48, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan66, BRRI dhan70, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76, BRRI dhan77, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan82, BRRI dhan83, BRRI dhan85, BRRI dhan87, BRRI dhan90, BRRI dhan91, BRRI dhan93, BRRI dhan94, BRRI dhan95
	LIV	8	Nizersail, Latisail, Rajasail, Kalijira, Kataribhog, Basmati-D, Patnai23, Tilockkachari
Boro	MV	44	BR1, BR2, BR3, BR6, BR7, BR8, BR9, BR12, BR14, BR15, BR16, BR17, BR18, BR19, BR26, BRRI dhan28, BRRI dhan29, BRRI dhan35, BRRI dhan36, BRRI dhan45, BRRI dhan47, BRRI dhan50, BRRI dhan55, BRRI dhan58, BRRI dhan59, BRRI dhan60, BRRI dhan61, BRRI dhan63, BRRI dhan64, BRRI dhan65, BRRI dhan67, BRRI dhan68, BRRI dhan69, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan96, BRRI dhan97, BRRI dhan98, BRRI dhan99
	LIV	6	Hbj Boro II, Hbj Boro IV, Hbj Boro VI, Hbj Boro VIII, Purbachi, IR8
Total		111	

Nucleus seed stock production. Fifty-one BRRI developed rice varieties of which 33 in T. Aman and 18 in Boro were grown following panicle to row method to produce nucleus seed stocks for breeder seed production. The objective for nucleus seed production was to maintain genetic purity and homogeneity of morphological characteristics of a variety and subsequently breeder seed production.

„Panicle to row‟ method was used to maintain nucleus stocks, where intact panicles were sown instead of threshed seeds. If off-type plants were identified in a row then whole row was discarded or rogued out for variety maintenance. At maturity, panicles from „true to type‟ plants of all the varieties were harvested and both intact panicles for BRRI HQ, Gazipur and nucleus seed stocks for BRRI regional stations were stored in controlled temperature (20°C with 40% RH).

Breeder seed production and distribution. GRS Division, Farm Management Division and nine regional stations of BRRI were engaged in breeder seed (BS) production as per national demand. The BS plots were visited to monitor the varietal purity and performances. Off-type plants were identified and rogued out in every growth stage. After harvesting of a variety, the seeds were separately threshed, dried, cleaned and stored in controlled temperature (20°C with about 40% RH) at BRRI HQ, Gazipur. The harvested seeds then offered as seed lot for getting „tag‟ from Seed Certification Agency (SCA) which is required for distribution.

A total of 193.03 tons of breeder seed with tags of which 139.39 tons of 17 Boro varieties, 9.64 tons of eight Aus varieties and 44.00 tons of 28 T. Aman varieties were produced during 2019-20 (Tables 5, 6 and 7). At the same time, 186.164 tons of breeder seed of which 134.391 tons of 17 Boro varieties, 8.851 tons of eight Aus varieties and 42.922 tons of 28 T. Aman varieties were distributed among 996 partners (GO, NGO and PS) of „BRRI Rice Seed Network‟. Breeder and foundation seed producing plots and farms were also visited to observe the varietal purity and performance of respective seed. PI: Armin Bhuiya (T. Aman) and Ebna Syod Md Harunur Rashid (Boro).

Sending SMS to SeedNet partners for breeder seed distribution. Text message (SMS) with variety name and allotted quantity of breeder seed were sent through mobile apps to 8 and 175 partners before Aus 2021 and T. Aman 2021 seasons, respectively for distributing breeder seed through BRRI „Rice Seed Network‟. PI: Armin Bhuiya.

Table 5. Production and distribution of rice breeder seed on Boro 2020-21.

Variety	Production (with tag)		Distribution	
	Favourable variety (kg)	Stress tolerant variety (kg)	Favourable variety (kg)	Stress tolerant variety (kg)
BR14	460		300	
BR16	760		650	
BR26	6970		2620	
BRRI dhan28	39320		39092	
BRRI dhan29	25500		26282	
BRRI dhan36		260		248
BRRI dhan47		3150		3100
BRRI dhan50	4520		4403	
BRRI dhan58	15100		13960	
BRRI dhan63	4120		4132	
BRRI dhan67		8270		7852
BRRI dhan74	8220		8342	
BRRI dhan81	1550		1645	
BRRI dhan84	4320		4697	
BRRI dhan88	2840		2996	
BRRI dhan89	13480		13520	
BRRI dhan92	550		552	
Total	1,27,710	11,680	1,23,191	11,200
Grand Total	1,39,390		1,34,391	

Table 6. Production and distribution of rice breeder seed on Aus 2020-21.

Variety	Production (with tag) (kg)	Distribution (kg)
BR16	510	10
BR26	1210	1210
BRRI dhan42	50	10
BRRI dhan 43	40	10
BRRI dhan 48	6300	6301
BRRI dhan 65	190	190
BRRI dhan 82	1280	1060
BRRI dhan 83	60	60
Total	9,640	8,851

Table 7. Production and distribution of rice breeder seed on T. Aman 2020-21.

Variety	Production (with tag)		Distribution	
	Favourable variety (kg)	Stress tolerant variety (kg)	Favourable variety (kg)	Stress tolerant variety (kg)
BR11	2540		2540	
BR22	1550		1530	
BR23	2890		2826	
BRRI dhan30	320		320	
BRRI dhan32	100		90	
BRRI dhan34	3430		3215	
BRRI dhan39	160		160	
BRRI dhan41		10		10
BRRI dhan44	20		25	
BRRI dhan46	40		40	
BRRI dhan49	9170		9208	
BRRI dhan51		1750		1770
BRRI dhan52		2780		2780
BRRI dhan56		650		120
BRRI dhan57		70		60
BRRI dhan62	460		440	
BRRI dhan66		90		10
BRRI dhan71		40		35
BRRI dhan72	770		685	
BRRI dhan73		120		125
BRRI dhan75	5080		5122	
BRRI dhan76	1780		1645	
BRRI dhan77	590		510	
BRRI dhan80	140		140	
BRRI dhan87	9230		9286	
BRRI dhan93	40		45	
BRRI dhan95	110		115	
Nizersail	70		70	
Total	38,490	5,510	38,012	4,910
Grand Total	44,000		42,922	

Monitoring seed production plots and farms. Breeder seed production plots of BRRI regional stations (RSs) at Rangpur and Cumilla along with foundation seed production farm of BADC at Kashimpur, Mymensingh were visited. During the visit, no major insect-pest damage, varietal impurity (<1%) and no obnoxious weeds were observed. Isolation distances and crop conditions were satisfactory. The seed producers were advised for thorough roguing by themselves for one more time before harvesting. PI: Mir Sharf Uddin Ahmed.

EXPLORATORY AND GENETIC STUDIES

Secondary yield trial (SYT) of Balam rice germplasm. Balam (Acc. 516) and Jesso-Balam

TAPL (Acc. 2473, 2472) along with BR7 and BRRI dhan80 as standard checks were grown in T. Aman 2020. The highest panicle length and plant height were found as 25.3 cm and 130 cm respectively in Balam (Acc. 516). The highest grain yield per pot (6 sq. m) as yield per hectare was observed in Jesso-Balam (Acc. 2472) (4.93 kg as 4.57 t ha^{-1}), followed by 4.29 kg as 3.98 t ha^{-1} in Balam (Acc. 516), 3.35 kg as 3.10 t ha^{-1} in Jesso-Balam (Acc. 2473), which were significantly different from the checks. Therefore, acc. 516, 2472 and 2473 along with BRRI dhan80 will be evaluated at BRRI HQ, Gazipur and BRRI RS, Barishal in T. Aman 2021 as regional yield trial (RYT). PI: Mir Sharf Uddin Ahmed.

Secondary Yield Trial (SYT) of Sada Mota and Lal Mota rice germplasm. Sada Mota (Acc. 7888) and Lal Mota (Acc. 7889) along with BRRI dhan76 and BRRI dhan77 as standard checks were grown in T. Aman 2020. The highest panicle length was found as 26.7 cm in Lal Mota (Acc. 7889), followed by 26.3 in BRRI dhan76 and 26 cm in Sada Mota (Acc. 7888). The highest grain yield per pot (6 sq. m) as yield per hectare was observed in Lal Mota (Acc. 7889) (4 kg as 3.68 t ha^{-1}), followed by 3.8 kg as 3.47 t ha^{-1} in Sada Mota (Acc. 7888), which were significantly different from the checks. Therefore, acc. 7888 and 7889 along with BRRI dhan77 as standard check will be evaluated at BRRI, Gazipur and BRRI RS, Barishal in T. Aman 2021 as RYT. PI: Mir Sharf Uddin Ahmed.

Performance study of nine aromatic rice germplasm. Nine aromatic rice germplasm accessions *viz.* Chinigura, Jirakatari, Chinisail, Chiniatop, Dhonia, Khatobabu, SubalLata, Katari-1 (Sada), Katari-2 (Lal) and BRRI dhan34 as standard checks were evaluated as PYT during T. Aman 2020. Table 8 presents the detailed yield performance of the germplasm for the studied parameter. The highest grain yield (5.04 t ha^{-1}) was observed in Chiniatop, followed by 4.53 t ha^{-1} in Chinigura, 4.51 t ha^{-1} in Katari-1 (Sada) and 4.49 t ha^{-1} in Chinishailalong with 3.51t ha^{-1} for BRRI dhan34. PI: Armin Bhuiya.

DNA finger printing of Kalijira rice germplasm. Forty-two Kalijira accessions in T. Aman season were studied using 50 SSR markers during T. Aman 2020. DNA extracted, PCR products, temperature profiles, gel documentation and data analysis were performed as same as described earlier in molecular characterization of rice germplasm experiment under Germplasm Conservation and Management section. Figure 5 presents the DNA profiles of 42 Kalijira accessions with SSR marker RM209.-PI: Armin Bhuiya.

Evaluation of photosensitive rice germplasm collected from northern districts of Bangladesh. A total of 10 photosensitive germplasm along with three checks were grown late (transplanting 15 September) in T. Aman season to identify germplasm suitable for late transplanting after flood in northern region of Bangladesh (Bogura, Kurigram, Lalmonirhat, Gaibandha, Rangpur and Jamalpur). One germplasm from Mal Shira group (Acc. no. 299), one from Ganjia group (Acc. no. 520) and one Bindi Pakri (Acc. no. 4810)

Table 8. Performance of nine aromatic rice germplasm for various yield contributing traits.

Germplasm	Acc. no.	PH	GD	FG/P	UFG/P	TGW (g)	Yield (t ha^{-1})
Chinigura	4867	131.8	112	141	17	10.17	4.53
Jirakatari	5975	143.6	110	117	15	11.18	3.49
Chinisail	7343	131.6	110	126	21	10.68	4.49
Chiniatop	5093	125.8	120	175	22	10.15	5.04
Dhonia	NC	117.6	100	101	16	16.94	3.24
KhatoBabu	8675	79.6	110	114	14	17.16	4.43
SubalLata	7680	71.2	100	77	20	18.60	2.35
Katari-1 (Sada)	NC*	118.6	120	135	16	13.64	4.51
Katari-2 (Lal)	NC	103.6	112	128	24	13.61	3.52
BRRI dhan34	7093	129.8	112	146	23	8.64	3.51
CV(%)		20.504	6.091	21.043	18.733	26.581	20.875
LSD(0.05)		14.666	4.178	16.422	2.190	2.156	0.506

*NC=New collection.

Legend: L=Ladder, 1=Kalijira (3)(Acc.247), 2=Kalajira(305), 3=Kaliajira (607), 4=Kalijira(2)(856), 5=Kalijira(3)(857), 6=Kalijira(858), 7=Kalajira(971), 8=Kalojira(2)(1129), 9=Kalojira(1130), 10=Kalojira(1303), 11=Kali Zira(1589), 12=Kaliajira(1937), 13=Kalijira Tapl-64(2492),14=Kalijira Tapl-65(2493),15=Kalijira Tapl-66(2494), 16=Kalijira Tapl-67(2495), 17=Kalijira Tapl-68(2496), 18=Kalijira Tapl-70(2497),19=Kalijira Tapl-71(2498), 20=Kalijira Tapl-72(2499), 21=Kalijira Tapl-73(2500), 22=Kalijira Tapl-74(2501), 23=Kalijira(3200), 24=Kalijira(3429), 25=Kalijira (Short Gracn)(4357), 26=Kalikira (Hong Grain)(4358), 27=Kalijira (Short Gracn)(4359), 28=Kaliajira(4540), 29=Kalijira(4755), 30=Kalijira(4814), 31=Kalijira (Finer)(4815), 32=Kalijira(4820), 33=Kalijira(4832), 34=Kalijira(4862), 35=Kalijira(4872), 36=Kali Jira(7066), 37=Kali Jira(7073), 38=Kalojira(7290), 39=Kalijira(7505), 40=Kalijira(Lal)(7551), 41=Kalojira(7879), 42=Kali Jira(7945).

Fig. 5. DNA profile of 42 Kalijira accessions with SSR marker RM209.

were selected on the basis of their morpho-agronomic traits (Table 9). Grain weights for five hills of the selected germplasm were 13.02 g, 11.36 g and 17.0 g, respectively. Higher number of effective tiller (12 to 14), longer panicle length (24.8 to 29.0 cm) and medium growth duration (132 to 138 days) were observed in selected three local germplasm and will be tested further in Rangpur region. PI: Ebna Syod Md Harunur Rashid.

Performance evaluation of local aromatic rice germplasm from BRRI genebank. A total of 65 T. Aman aromatic rice germplasm were evaluated for different traits to select the suitable/ desired/ superior germplasm comparing with BRRI dhan34 for releasing as a new variety.

Thirteen germplasm *viz.* Sai bail, Khaskani, Tulsimala, Chini Atop, Jira Dhan, Deshi Katari, Katari Bhog, Chini Sail, Chini Kanai, Parbat Jira, Modhu Madab, Mee Dhan and Khasa Mukhpura were selected on the basis of their morpho-agronomic traits (Table 10). One of the selected germplasm, "Jira Dhan" showed the highest panicle length (29 cm) with minimum TGW (9.0 g). Grain weight for five hill of the selected germplasm

Table 9. Performance of ten photosensitive T. Aman rice germplasm from BRRI genebank.

Name	Acc. no.	Effective tiller per hill	Culm length (cm)	Panicle length (cm)	Day to maturity	TGW (g)	Filled grain/ panicle	Unfilled grain/ panicle	Grain weight (5 hill)	Decort grain length (mm)	Decort grain breadth (mm)	L/B ratio
Mal Shira	545	10.6	81.8	24.4	133	20.1	65.4	13.4	12.02	5.66	2.43	2.33
Mal Shira	299	14	90	25.2	132	19.5	80.2	7.8	13.02	6.08	2.11	2.88
Mal Shira	360	12.2	83.2	24.4	132	19	78	14.2	12.4	5.98	2.15	2.78
Ganjia	287	10.8	82	28.2	136	16	75.2	26.8	12.44	5.62	1.96	2.87
Ganjia	520	12.4	85.8	29	135	16.1	82.2	13.4	11.36	5.92	1.89	3.13
Ganjia	531	12.6	84.6	25.6	135	18.4	102	9.4	10.02	5.36	1.93	2.78
Bindi Pakri	285	13.4	72.4	28.2	132	18.8	60.4	12.4	11.49	5.97	1.92	3.11
Bindi Pakri	4810	14	83	24.8	138	18.2	64	8	17.0	5.82	2.14	2.72
Indur Sail	3661	13.8	82	28.2	126	20.1	43	27.2	8.5	5.61	2.12	2.65
Joy Shail	5969	13.2	84.8	26	136	18	63.4	7.2	13.52	4.65	2.07	2.25
BR22 (check)	--	12.4	71	26.8	147	20	91.8	13.6	12.48	5.47	2.21	2.48
BR23 (check)	--	14.4	70	28.2	146	22.1	83.8	18	17.64	6.87	2.43	2.83
Nizersail(check)	--	13.4	84.8	29.4	127	17.4	96.8	12.6	12.34	5.88	2.04	2.88
Mean		12.86	81.18	26.8	135.0	18.75	75.86	14.15	12.63	5.76	2.11	2.74
Std. Dev.		1.18	6.13	1.81	6.13	1.69	16.39	6.46	2.45	0.49	0.17	0.26
CV		9.21	7.56	6.78	4.55	9.04	21.62	45.65	19.46	8.68	8.25	9.69
LSD (0.05)		0.84	4.32	1.28	4.33	0.92	11.57	4.55	1.33			

showed the difference from the local germplasm and it was 15.38 g for Sai Bail. Six germplasm possess TGW lower than 10.0 g indicates very small grain and suitable for special dishes preparation. Mee Dhan and Khasa Mukhpura are the Jhum rice, collected from hilly region and selected for better agronomic traits. Finally, the utmost important is the filled grain number per panicle (93.66% in Deshi Katari), which is higher in all selected germplasm along with higher L/B ratio (3.15) as long slender grain (>3.0). PI: Ebna Syod Md Harunur Rashid.

Performance study of Jirasail genotype: Different Jirasail accessions collected from Bogura, Jashore, Rajshahi. Naogaon and Tangail along with BRRI dhan81 as standard check was evaluated as Secondary Yield Trial (SYT) during Boro 2020-21 at BRRI Gazipur. Forty-five-day-old seedling was transplanted on 24 January 2021 in RCBD with three replications. The unit plot size of crop cut area was 6.4 m^2. Results revealed that, Rajshahi Jirasail produced the highest grain yield (5.10 t ha^{-1}) followed by Bogura Jirasail (5.01 t ha^{-1}) which is about 0.6 t ha^{-1} higher than check variety BRRI dhan81 (Table 11).

PI: Mohammad Khalequzzaman.

Table 10. Performance of 13 selected T. Aman aromatic rice accessions from BRRI genebank.

Name	Acc. no.	Effective tiller/hill	Culm length (cm)	Panicle length (cm)	Day to maturity	TGW (g)	Filled grain/ panicle	Unfilled grain/ panicle	Grain weight (5 hill)	Decort grain length (mm)	Decort grain breadth (mm)	L/B ratio
Sai Bail	873	12.8	106	26.8	133	12.0	75.6	18.6	15.38	6.32	1.86	3.40
Khaskani	4341	11.8	90	28.4	138	10.0	97	11	10.76	4.25	1.71	2.49
Tulsimala	4870	14.6	102	26	141	9.4	114	16	13.28	4.19	1.89	2.22
Chini Atop	5093	12.4	73.2	24.2	143	9.0	81.6	48	11.26	4.73	1.54	3.07
Jira Dhan	5313	12.8	114.4	29	140	9.0	112	15.6	11.3	4.24	1.93	2.20
Deshi Katari	5978	13	90.8	26.4	141	11.9	177.4	12	10.72	5.38	1.71	3.15
Katari Bhog	7082	12.8	84.8	27.8	141	16.0	115.8	12	11.42	5.44	1.89	2.88
Chini Sail	7343	9.8	84	28.2	138	11.1	74.6	10	12.3	3.31	2.05	1.61
Chini Kanai	7350	10	104	28	140	13.1	91.4	14.6	12.92	4.27	2.14	2.00
Parbat Jira	7351	13.8	93.4	26.4	139	9.0	106.6	22.6	11.78	4.37	1.84	2.38
Modhu Madab	7352	12.6	84	28.2	137	12.6	84.2	16.6	13.72	4.3	2.09	2.06
Mee Dhan	7537	14.6	84.4	27	138	12.4	93	25.2	13.18	4.39	1.92	2.29
Khasa Mukhpura	7586	12.2	87	25.6	138	9.7	84.8	12.6	13.16	4.25	1.88	2.26
Mean		12.30	96.03	27.51	139.13	11.82	84.23	26.93	8.79	4.68	1.93	2.45
Std. Dev.		1.66	11.18	1.50	2.81	3.45	31.57	14.73	2.93	0.69	0.22	0.43
CV		13.53	11.64	5.47	2.02	29.21	37.48	54.68	33.37	14.66	11.30	17.44
LSD (0.05)		0.53	3.55	0.48	0.89	1.10	10.02	4.68	0.93	0.22		0.14

Table 11. Yield and other characters of five Jirasail rice germplasm during Boro 2020-21, Gazipur.

Genotype	Plant height (cm)	Effective tiller/hill	Grain /panicle	Un-filled spikelet /panicle	Thousand grain weight (g)	Growth duration (day)	Yield (t ha^{-1})
Jirasail (Bogura)	109.3	10	171	16	17	130	5.01
Jirasail (Jashore)	126.2	9	164	36	10	135	1.33*
Jirasail (Rajshahi)	99.5	10	130	19	19	131	5.10
Jirasail (Tangail)	91.8	9	140	15	19	135	4.23
Jirasail (Naogaon)	85.0	9	171	18	20	135	4.02
BRRI dhan81 (ck)	86.3	10	172	19	20	135	4.52
CV	4.56	4.41	16.11	17.99	21.50	3.00	31.11
LSD	2.91	0.33	14.12	2.21	2.96	2.79	1.09

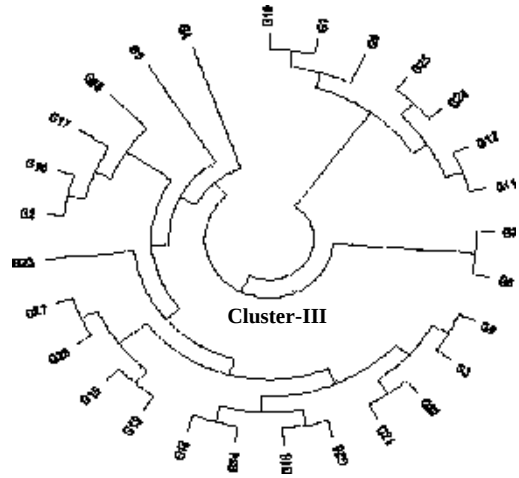
*infected by neck blast

Characterization of similar named Tepi Boro group of rice germplasm. Twenty-five similar named Tepi Boro group of rice germplasm were characterized through 33 qualitative agro-morphological traits, sensory test and three SSR markers at GRSD, BRRI, Gazipur. For field experiment, a single row of 5.4 m long for each entry with 20 × 20 cm spacing between rows and plants respectively, was used in T. Aman 2020. For sensory test, 1.7% KOH solution (Sood and Siddiq 1978) was used. For molecular study, all germplasm along with Kalizira (Acc. 1589), Bangladesh Kalijira (Acc. 247) and BRRI dhan34 were characterized using aroma link RM282, RM273 and RM223 markers. Methodology and data analysis were same as described earlier in molecular characterization of rice germplasm experiment.

The frequency distributions of 33 main characters revealed that nine main characters had no variation, 14 main characters were most diversified and further divided into more than three sub characters, 12 sub characters were most dominated (more than 72% frequency) and 19 sub characters had the rare genotypes (less than 8% frequency). The combined result of the five sensory tests revealed that all of evaluators of the sensor test found aroma from the leaf of the genotypes G7 (Acc. 4526), G16 (Acc. 7931) and G19 (Acc. 4373), followed by two persons from G15 (Acc. 6213) and G25 (Acc. 2257) etc. Finally, ten alleles were identified. The average number of alleles per locus was 3.33, ranging from 3 (RM273 and RM282) to 4 (RM223). The Gene diversity ranged from 0.31 to 0.56. The PIC ranged from 0.29 (RM282) to 0.47 (RM223). The unrooted neighbour-joining tree revealed that the germplasm were grouped into three major clusters (Fig. 6).

PI: Mir Sharf Uddin Ahmed.

Identification and selection of sticky rice from *Jhum* rice germplasm. Fifty-six *Jhum* rice germplasm were characterized to study the selection criteria during Aus 2020. The highest grain yield/hill (20.08 g) was observed in Rengkhoea dhan followed by 19.42 g in Chhuri dhan, 18.96 g in Sray, 18.92 g in company, 18.54 g in Kamra and the lowest (2.91 g) in Horina Binni followed by 3.26 g in Lankapuri. PI: Armin Bhuiya.



Legend: 1=Tape Boro (Acc. no. 7297), 2=Tepa IRRI (7855), 3=Tepakain (1532), 4=Tepi Boro (258), 5=Tepi Boro (930), 6=Tepi Boro (3998), 7=Tepi Boro (4526), 8=Tepi Boro (4959), 9=Tepi Khorch (931), 10=Tepi Sail (1712), 11=Tepi Sail (1724), 12=Tepi Boro Dhan (Kalo) (8058), 13=Tepu (7382), 14=Tepu (7473), 15=Tepu IRRI (6213), 16=Tepu Dhan (7931), 17=Tepu Dhan (7986), 18=Topa (2256), 19=Topa Boro (4373), 20=Topa Boro (4981), 21=Topa Boro (4983), 22=Topa Boro (5041), 23=Topa Boro (62), 24=Tupa (1811), 25=Tupa (2257), 26=Kalizira (1589), 27=Bangladesh Kalijira (247), 28=BRRI dhan34.

Fig. 6. Unrooted neighbour-joining tree showing distribution 25 Tepi Boro rice germplasm along with Kalizira, Bangladesh Kalijira and BRRI dhan34.

Dormancy and storage ability of newly released BRRI rice varieties. Freshly harvested 13 new BRRI released rice varieties (Fig 7) of Boro season were tested for germination to check the dormancy and storage ability. After sun-drying and grading, the seeds (<12% moisture) of all the varieties were stored at 20˚C in 50% RH. One hundred healthy seeds were set in each Petri dish in three replications. Germination data were collected starting from 6 June 2021 and continued with maintaining a seven days interval from the initial date of storage.

No dormancy period was observed in any of the studied varieties (Fig. 7). Over all, the germination percent decreased over time. For example, the germination percent continuously decreased over intervals for BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan89, BRRI dhan96, BRRI dhan98 and BRRI

dhan99, except BRRI dhan74, BRRI dhan81, BRRI dhan84 and BRRI dhan98, where the germination once increased shortly. But in cases of BRRI dhan67, BRRI dhan97 and BRRI dhan100, surprisingly the germination in last interval started increasing. Therefore, the experiment needs to continue for six months with maintaining a 15 days interval for getting consistent result. PI: Tonmoy Chakrabarty.

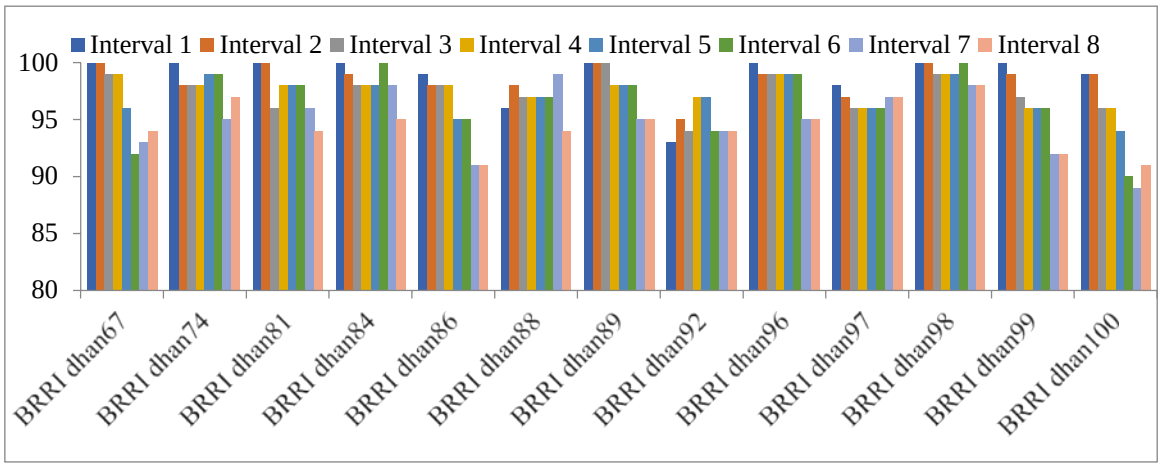


Fig. 7. Bar diagram of germination fluctuations of stored BRRI developed varieties.

Grain Quality and Nutrition Division

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SUMMARY

A total of 663 breeding lines were analyzed, among them 75 had more than 70% milling outturn, 92 had more than 60% head rice recovery, 22 have shown translucent (Tr) grain, 257 had long grain, 172 had more than 3.0 L/B ratio, 371 had more than 25.0% amylose content, 55 had more than 9.0% protein content, 27 had more than 1.5 elongation ratio and 190 had between the range of (4.0-5.0) volume expansion ratio. Some of the promising lines were identified for higher milling and head rice recovery, size and shape, amylose content, protein content, elongation ratio and acceptable other physicochemical properties.

A total of four thousand four hundred five 4,405 transforming breeding lines were evaluated for physicochemical and cooking properties for superior quality. Based on the performance on grain quality, we recommended 21 preliminary yield trial and nine advanced yield trial of favourable Boro and cold tolerant rice lines for further advancement.

Physicochemical properties and micronutrient contents of same variety have shown variation at different locations due to climatic factor such as drought, flood, salinity, high temperature and soil conditions. The range of milling outturn is 69 to 72%, head rice recovery is 57 to 67%, milled rice length is 6.5 to 6.9 mm, L/B ratio is 3.1 to 3.7, 1000 grain wt. is 23.3 to 25.5 g, amylose content is 20.0 to 23.1%, protein content is 8.6 to 9.8, cooking time is 16:30 to 18:30 min., imbibition ratio is 3.9 to 4.3, iron content is 6.5 to13.2 ppm and zinc content is 15.9 to 20.1 ppm of BRRI dhan62. Similarly, the range of milling outturn is 69 to 72%, head rice recovery is 53 to 61%, milled rice length is 6.5 to 6.7 mm, L/B ratio is 2.6 to 2.8, 1000 grain wt. is 27.8 to 28.9 g, amylose content is 22.3 to 26%, protein content is 6.9 to 9.2%, imbibition ratio is 3.7 to 4.5, iron content is 4.5 to15.0 ppm and zinc content is 10.7 to 17.4 ppm of BRRI dhan72.

Black pericarp rice has been reported for the presence of anti-cancerous component such as anthocyanidin specially Cyanidin-3-Glocoside (C3G). A total of 15 germplasms including 11 black pericarp rice such as BK1, BK2, BK3, BK4, BK5, BK6, BK7, BK8, BK9, BK10, BK11, two red pericarp rice such as laxmidegga, BRRI dhan84 and two white pericarp rice such as BRRI dhan80, Gabura were grown in BRRI westbyed farm and collected from GQN (Grain Quality and Nutrition) Division of BRRI, Gazipur to evaluate the presence of Cyanidin-3-Glocoside (C3G). Our data reveal that all black rice possess Cyanidin-3-Glocoside (C3G), an active anti-cancerous compound with a ride range of 2.58 to 806.17 ppm except red and white pericarp rice in Bangladesh. C3G content has a thermal sensitive property as it reduces 48% of C3G content just after cooking. So, regarding developing black rice breeding materials, we should consider the higher C3G content germplasm for parental selection. In this regard BK11, BK10, BK8 and BK9 (aromatic) can potentially be used in black rice breeding programme at BRRI.

Puffed, popped and flattened rice were produced from BRRI varieties to evaluate the quality products. Comparing few parameters (fully puffed rice, length and breadth increased percentage) with BR16 (Std), it is ascertained from the results that BRRI dhan92 and BRRI hybrid dhan6 are better in producing whole puffed rice followed by BRRI dhan90 and BRRI dhan95. Considering physical parameters, BRRI dhan87 and BRRI dhan89 show excellent performance for whole, partial broken, broken and unpopped rice. Among the tested varieties, in terms of weight of whole, partial broken and broken flattened rice as well as percentage of length increased, BRRI Dhan93 showed the best performance comparing with BR16.

GRAIN QUALITY CHARACTER

Determination of physicochemical and cooking properties of breeding lines

PI: MAS; **CI:** MAH, SSD, NF, TKS and HBS

After yield, grain quality of rice is important parameters for researchers and consumers. Consumer acceptance of rice depends on its physicochemical quality of rice. Physical parameters were measured by milling outrun, head rice yield as well as size and shape. Cooking quality was determined by cooking time, elongation

ratio and volume expansion ratio. Chemical parameters were determined by amylose content, protein content and alkali spreading value. New HYR varieties that have better benefits than the existing ones will be more accepted if their characteristics are in accordance with consumers' preferences (Zen 2007). High quality rice, uniform shape, whiteness and translucency are major factors defining market value of rice (Fitzgerald et al. 2008). Rice is a very rich source of carbohydrate followed by protein. A total of 128 samples were provided from different divisions of BRRI and outside of BRRI to find out the desirable characteristics. In Bangladesh, consumers prefer long slender type translucent grains as premium quality rice with higher price. But medium bold type grains are most suitable for milling. Out of 248 samples, 75 had more than 70% milling outturn and 92 had more than 60% head rice recovery. Out of 248 samples, 22 have shown translucent (Tr) grain that means 0% chalkiness, 118 have shown less than 10% chalkiness, 53 have shown between the range of (10.0-20.0)% chalkiness and 55 have shown more than 20% chalkiness. Out of 439 samples, 257 had long grain, 178 had medium grain and four had short grain. Among these samples 172 had more than 3.0 L/B ratio, whereas 265 had between the range of (2.0-3.0) L/B ratio. Out of 235 samples, 180 samples had more than 30.0 g 1000-grain wt TGW, Two had between the ranges of (20.0-30.0) g TGW and 53 had less than 20 g TGW. (Table-1).

Amylose is the most important trait for eating quality, which indicates the texture of cooked rice and also volume expansion. Out of 663 samples, 371 had more than 25.0% amylose, 223 had between the range of (20.0-25.0)% amylose and 69 had less than 20% amylose. Nutritional quality is measured by protein content. Out of 264 samples, 55 had more than 9.0% protein, 172 had between the range of (7.0-9.0)% protein and 37 had less than 7.0% protein. Less than 7% protein content in brown rice, which is not normally recommended for variety release. Grain with high gelatinization temperature is not desirable. Out of 286 samples, 23 had more than 20 min. cooking time, 238 had between the range of 15-20 min. cooking time and only 25 had less than 15 min. cooking time. The samples, having more than 20 min. cooking time may give comparatively hard cooked rice. Among 286 samples, 27 had more than 1.5 elongation ratio, 164 had between the range of 1.4-1.5 elongation ratio and 95 had less than 1.4 elongation ratio. More than 1.5 elongation ratio, which were desirable. High volume expansion of cooking is still considered to be a good quality for the working-class people who do not care whether the expansion is lengthwise or crosswise. Among these samples, no one had more than 5.0 volume expansion ratio, 190 had between the range of 4.0-5.0 volume expansion ratio and 96 had less than 4.0 volume expansion ratio (Table-2).

Some of the promising samples were identified for higher milling and head rice recovery, amylose content, protein content, elongation ratio and acceptable other physicochemical properties (Table-3).

Determination of physicochemical and cooking properties of transforming rice breeding lines.

PI: SSD **CI:** MAS

Grain quality is an important component for consumer's preference and profitability. For the transforming rice breeding project on rice grain quality screening, 4405 (LST- line stage trial 2,749, OYT-observational yield trial 591 and PYT-preliminary yield trial 1,065) were received, processed and evaluated.

A total of 3,340 LST and OYT materials were analyzed for size, shape and amylose content. Grain length and length to breadth ratio determines the grain size and shape. Out of 2,749 LST (Salinity tolerant Boro 970, Salinity tolerant Transplanted Aman 778, Transplanted Aus 538, Favourable and Cold tolerant Boro 326, and Cold tolerant Boro 137) brown rice lines, forty four were extra long slender, followed by one were extra long medium, 703 were long slender, 1,445 were long medium, 27 were medium slender, 501 were medium, one were medium bold, three were short medium, three were short bold and 12 were short bold. Out of 591 OYT (Insect resistant (BPH), Transplanted Aman 454 and cold tolerant Boro 137) milled rice two were extra long slender followed by 175 were long

Table 1. Physical properties of rice samples.

Range	Sample
	Milling outturn (%) (Total sample 248)
>70.0	75
68.0-70.0	135
<68.0	38
	Head rice recovery (%) (Total sample 248)
>60.0	92
50.0-60.0	85
<50.0	71
	Chalkiness (%) (Total sample 248)
0 (Tr)	22
<10.0	118
10.0-20.0	53
>20.0	55
	Length (mm) (Total sample 439)
Long	257
Medium	178
Short	4
	L/B ratio (Total sample 439)
3.0>	172
2.0-3.0	265
<2.0	2
	1000-grain wt. (g) (Total sample 235)
>30.0	180
20.0-30.0	2
<20.0	53

Table 2. Chemical and cooking properties of rice samples.

Range	Sample
	Alkali spreading Value (Total sample 286)
6-7	68
4-5	112
<4	106
	Amylose content (%) (Total sample 663)
>25.0	371
20.0-25.0	223
<20.0	69
	Protein content (%) (Total sample 264)
>9.0	55
7.0-9.0	172
<7.0	37
	Cooking time (mim.) (Total sample 286)
>20	23
15.0-20	238
<15.0	25
	Elongation ratio (Total sample 286)
>1.5	27
1.4-1.5	164
<1.4	95
	Volume expansion ratio (Total sample 286)
>5.0	-
4.0-5.0	190
<4.0	96

Table 3. Physicochemical properties of promising samples.

Variety/Line	Milling outturn (%)	Head rice recovery (%)	Size & Shape	1000 grain wt. (g)	Amylose (%)	Protein (%)	ER	IR
BRH10-3-9-17-B	72	61	MS	17.0	28.2	8.9	1.5	4.5
BRH15-2-4-6-4B	63	64	LS	17.0	27.2	8.8	1.5	4.5
PL-22	70	66	LS	20.9	27.5	9.8	1.4	4.3
PL-26	70	64	LB	21.5	26.7	9.3	1.5	4.5
BZM-89	70	64	LS	20.8	28.8	8.9	1.6	3.9
HRB-15	71	64	MB	25.0	29.3	7.8	1.5	4.1
HRB-27	71	63	LS	23.7	26.8	9.0	1.5	3.7
Local Nonperboiled (Khato and Mota)	70	66	SB	12.5	28.8	7.6	1.4	4.2
Local Nonperboiled (Khato and Chikon)	72	64	SB	11.5	28.5	8.0	1.4	4.3
BRRI dhan48-SC27-1-1	71	64	MB	21.9	26.6	9.6	1.4	3.7
BR9930-2-3-2-2	70	51	LS	22.5	27.6	7.4	1.4	4.3
BR9005-53-1-1	70	65	MB	19.4	25.5	9.0	1.5	4.1

slender, 252 were long bold, 29 were medium slender, 131 medium bold, and two short bold. In Bangladesh, medium slender and medium bold grains are suitable for milling. But long slender rice is sold at high price in the market. Rice contains two types of starch namely amylose and amylopectin. Amylose content of rice grain determines the hardness and stickiness of cooked rice. More than 25% amylose content gives nonsticky cooked rice; 20-25% amylose containing rice provides soft and comparatively sticky cooked rice. Out of 2,926 LST and OYT lines, 2000 had more than 25.0% amylose, 682 lines were amylose content between the range of (20.0-25.0)% and 244 lines had less than 20.0% amylose (Table-4).

Milling is one of the parameters determining milled rice yield per unit paddy weight. Among 1065 advanced lines 684 had high (>70%) and 317 lines had intermediate (68.0-70.0%) milling yield. On the contrary, 448 lines had more than 60% head rice yield. Chalkiness in grain is not a positive quality factor for the unparboiled rice consumers. Around 181 lines had translucent grains. Six hundred thirty six lines had long (>6.0mm), 405 had medium (5.0-6.0 mm) and only 24 had short (< 5.0 mm) grains. Two hundred twenty seven lines had slender grain (Table-5).

Amylose content determines the quality of cooked rice. Out of 1,065 lines, 862 had high (>25%), 159 had intermediate (20-25%) and 44 had low (<20%) amylose content. Low amylose rice is not acceptable to our people. Protein content measures the nutritional value of rice. Out of 1,065 lines 574 had high (9.0%) protein content, 462 had intermediate protein content (7.0-9.0%). Generally a variety of having less than 7% protein content in brown rice is not recommended for release. Alkali spreading value has inverse relationship with gelatinization temperature. Among the lines, 880 had intermediate and 69 had high gelatinization temperature (Table-6).

High volume expansion of rice is a positive quality factor for low-income group of people. Among 1,065 lines 32 had high (>4), 674 had intermediate (3.5-4.0) and 359 had low (<3.5) volume expansion ratio. Elongation ratio is the important quality indicator. The grain that elongates more in length looks finer. On the contrary, the grain that expands more in girth looks coarse. Among 1,065 lines 46 had high (1.5) and 1,007 had intermediate (1.3-1.5) elongation ratio (Table-6).

Table 4. Physicochemical properties of Transforming Rice Breeding (LST and OYT) rice lines.

Parameter and total number of sample	Classification	Number of sample
Size and Shape (Brown rice) (Total sample no. 2,749)	Extra long slender	44
	Extra long medium	1
	Long slender	703
	Long medium	1445
	Medium slender	27
	Medium medium	501
	Medium bold	1
	Short medium	3
	Short bold	3
	Short round	21
Size and Shape (Milled rice) (Total sample no. 591)	Extra long slender	2
	Long slender	175
	Long bold	252
	Medium slender	29
	Medium bold	131
	Short bold	2
Amylose content (%) (Total sample no. 2,926)	High	2000
	Intermediate	682
	Low	244

Table 5. Physical properties of transforming rice breeding (PYT) rice sample.

Range	Properties and Sample number
	Milling Outturn (%) (Total sample 1065)
>70.0	684
68.0-70.0	317
<68.0	64
	Head rice recovery (%) (Total sample 1065)
>60.0	448
50.0-60.0	370
<50.0	247
	Length (mm) (Total sample 1065)
>6.0	636
5.0-6.0	405
<5.0	24
	L/B ratio (Total sample 1065)
3.0>	227
2.0-3.0	805
<2.0	33
	Chalkiness (%) (Total sample 1065)
(0) Tr	181
<10	68
10.0-20.0	122
>20.0	692
Opaque	2

Table 6. Chemical and cooking properties of transforming rice breeding (PYT) rice samples.

Range	Properties and sample no.
	Amylose content (%) (Total sample 1065)
>25.0	862
20.0-25.0	159
<20.0	44
	Protein content (%) (Total sample 1065)
>9.0	574
7.0-9.0	462
<7.0	29
	Alkali spreading value (Total sample 1065)
1.0-3,0	69
3.1- 5.9	880
>6.0	116
	Cooking time (min.) (Total sample 1065)
>20	14
15-20	846
<15	205
	Elongation ratio (Total sample 1065)
>1.5	46
1.3-1.5	1007
<1.3	12
	Volume expansion ratio (Total sample 1065)
>4.0	32
3.4-4.0	674
<3.5	359

This study identified 21 of the promising preliminary yield trial lines for high milling and acceptable other physicochemical properties (Table 7).

Table 7. Physicochemical properties of promising (PYT) genotypes for favourable Boro (FBR) and cold tolerant (CTR) on transforming breeding lines.

Genotype	Head rice recovery (%)	Size and shape	Amylose content (%)
BR10296-36-4-1-1	63.5	LS	29.3
BR9945-39-4-3-1	68.2	LS	27.8
TP 30596	67.3	LS	26.1
TP 30597	58.1	LS	25.7
TP 30598	68.6	LS	25.2
TP 30606	57.4	LS	26.0
TP 30610	57.4	LS	28.0
IR 106452-B-B-B-PRN B-PRN B-PRN 114	60.0	LS	25.4
IR15A3768	60.1	LS	25.0
IR16A2287	65.3	LS	26.1
IR 107995-B-B RGA-B RGA-54-1	68.5	LS	26.5
BR10707-5R-46	70.8	LS	28.4
BR10707-5R-66	66.5	LS	28.6
BR10707-5R-83	63.6	LS	29.4
BR10707-5R-89	69.1	LS	25.8
BR10707-5R-179	69.0	LS	25.3
BR10715-5R-9	64.7	LS	27.2
IR100723-B-B-B-B-61	67.3	LS	25.5
IR99107-B-B-B-B-28	61.5	LS	28.6
IR99090-B-B-61-1	61.1	LS	26.1
BR9989-23-CS1-1-CS2-16-1-7	66.9	LS	28.5

Table 8. Physicochemical properties of promising (AYT) genotypes for favourable Boro (FBR) and cold tolerant (CTR) on transforming breeding lines.

Genotype	Head rice recovery(%)	Size and shape	Amylose content (%)
BR10296-55-4	63.6	LS	25.5
BR9950-12-2-1	61.0	LS	28.6
IR99982-B-B-B-B-1	60.3	LS	27.2
IR100722-B-B-B-B-16	63.7	LS	26.6
BR9945-28-7-3	66.6	LS	25.0
BR9945-40-1-3	61.4	LS	27.5
BR8905-17-2-3-3-1-4	67.9	LS	26.2
BR8910-B-6-3-CS1-5-CS2-P3-1-5	65.3	LS	27.5
BR8938-30-2-4-2-1	61.2	LS	26.8

NUTRITIONAL QUALITY ASSESSMENT OF RICE

Effect of Fe and Zn activities on Zn enriched rice varieties at different locations in T. Aman season

PI: NF; **CI:** HBS, TKS, MAH and MAS

Due to climate change, agriculture is facing different adverse conditions, such as drought, flood, salinity, extreme temperature stress and low soil fertility. Moreover, complex socio-environmental factors such as decreasing cultivated land, increasing population growth and limited resources contribute negative impact to ongoing food and nutritional security in Bangladesh. Rice varieties grown in different locations vary significantly in composition (Abbas et al., 2011), milling and cooking quality as well as in starch characteristics (Singh et al., 2005). This might be due to the variation in genetic, climatic factor, cultivation method and soil conditions (Burešová et al., 2010; Mapiemfu et al., 2017; Singh et al., 2005).

Determinations of the relative magnitude of effects of physicochemical properties and micronutrient content of Zn enriched rice varieties grown at different locations of Bangladesh are limited. Therefore, the main objective of this research was to analyze the cumulative effect of the growing environment, different locations and Zn enriched varietal differences on milled rice. Two BRRI released HYVs of T. Aman season such as BRRI dhan62 and BRRI dhan72 the collected at different locations of Bangladesh. The stability analysis experiment was conducted by Statistics Division of BRRI at different regional stations. All agronomic practices were done following the BRRI recommendation. All types of physicochemical properties were analyzed as per GQN manual as well as micronutrients content were analyzed by Atomic Absorption Spectrometer (AAS).

Minerals consist of macro and micronutrient. Some traces of micronutrient like iron, zinc etc. are present along with macronutrient like calcium, magnesium, phosphorus etc. Minerals present in rice like iron and zinc play an important role in body regulatory functions. Mineral contents are greatly influenced by cultivation conditions including fertilization and soil conditions. Iron deficiency (anemia) is the most dominant micronutrient deficiency as well as zinc is known to be essential for the normal growth and development of the fetus worldwide. So, both iron and zinc deficiency are major public health problems.

BRRI dhan62. The result of physicochemical properties and micronutrient contents of BRRI dhan62 at different locations (Barishal, Bhanga, Cumilla, Gazipur, Kushtia, Rajshahi, Rangpur and Shatkhira) has been described. The range of milling outturn of BRRI dhan62 varies from 69 to 72%. The highest milling outturn (72%) of BRRI dhan62 was shown in Gazipur and Shatkhira but the lowest milling outturn (69%) of BRRI dhan62 was shown in Barishal and Cumilla region. The range of head rice recovery of BRRI dhan62 varies from 57 to 67%. The highest head rice recovery (67%) of BRRI dhan62 was shown in Rajshahi but the lowest head rice recovery (57%) of BRRI dhan62 was shown in Barishal region. The range of milled rice length of BRRI dhan62 varies from 6.5 to 6.9 mm. The highest milled rice length (6.9 mm) of BRRI

dhan62 was shown in Kushtia but its lowest milled rice length (6.5 mm) was shown in Rangpur region. The range of milled rice breadth of BRRI dhan62 varies from 1.8 to 2.1 mm. The highest milled rice breadth (2.1 mm) of BRRI dhan62 was shown in Bhanga but its lowest milled rice breadth (1.8 mm) was shown in Cumilla region. The range of L/B ratio of BRRI dhan62 varies from 3.1 to 3.7. The highest L/B ratio (3.7) of BRRI dhan62 was shown in Cumilla but its lowest L/B ratio (3.1) was shown in Barishal region. The range of TGW of BRRI dhan62 varies from 23.3 to 25.5g. The highest TGW (25.5g) of BRRI dhan62 was shown in Gazipur but its lowest TGW (23.3g) was shown in Rangpur region (Table-9). The range of alkali spreading value of BRRI dhan62 varies from 3.0 to 6.0. The highest alkali spreading value (6.0) of BRRI dhan62 was shown in Rajshahi but its lowest alkali spreading value (3.0) was shown in Bhanga region. The range of amylose content of BRRI dhan62 varies from 20.0 to 23.1%. The highest amylose content (23.1%) of BRRI dhan62 was shown in Gazipur but the lowest amylose content (20.0%) was shown in Barishal region. The range of protein content of BRRI dhan62 varies from 8.6 to 9.8%. The highest protein content (9.8%) of BRRI dhan62 was shown in Gazipur but its lowest protein content (8.6%) was shown in Kushtia region. The range of moisture content of BRRI dhan62 varies from 11.8 to 13.1%. The highest moisture content (13.1%) of BRRI dhan62 was shown in Gazipur but its lowest moisture content (11.8%) was shown in Bhanga region. The range of cooking time of BRRI dhan62 varies from 16:30 to 18:30 min. The highest cooking time (18:30 min.) of BRRI dhan62 was shown in Barishal but its lowest cooking time (16:30 min.) was shown in Cumilla region. Similar elongation ratio (ER) 1.3 of BRRI dhan62 was shown in all the regions. The range of imbibition ratio (IR) of BRRI dhan62 varies from 3.9 to 4.3. The highest IR (4.3) of BRRI dhan62 was shown in Barishal, Rangpur and Shatkhira but its lowest IR (3.9) was shown in Gazipur. The range of iron content of BRRI dhan62 varies from 6.5 to13.2 ppm. The highest iron content (13.2 ppm) of BRRI dhan62 was shown in Kushtia but its lowest iron content (6.5 ppm) was shown in Rajshahi region. The range of zinc content of BRRI dhan62 varies from 15.9 to 20.1 ppm. The highest zinc content (20.1 ppm) of BRRI dhan62 was shown in Barishal but its lowest zinc content (15.9 ppm) was shown in Gazipur region (Table-10).

BRRI dhan72. The result of physicochemical properties and micronutrient contents of BRRI dhan72 at different locations (Barishal, Bhanga, Cumilla, Gazipur, Kushtia, Rajshahi, Rangpur and Shatkhira) has been described. The range of milling outturn of BRRI dhan72 varies from 69 to 72%. The highest milling outturn (72%) of BRRI dhan72 was shown in Gazipur and Kushtia but its lowest milling outturn (69%) was shown in Cumilla region. The range of head rice recovery of BRRI dhan72 varies from 53 to 61%. The highest head rice recovery (61%) of BRRI dhan72 was shown in Gazipur, Kushtia, Rangpur and Shatkhira but its lowest head rice recovery (53%) was shown in Barishal region. The range of milled rice length of BRRI dhan72 varies from 6.5 to 6.7 mm. The highest milled rice length (6.7 mm) of BRRI dhan72 was shown in Rajshahi but its lowest milled rice length (6.5 mm) was shown in Gazipur region. The range of milled rice breadth of BRRI dhan72 varies from 2.4 to 2.5 mm. The highest milled rice breadth (2.5 mm) of BRRI dhan72 was shown in Shatkhira but its lowest milled rice breadth (2.4 mm) was shown in Bhanga region. The range of L/B ratio of BRRI dhan72 varies from 2.6 to 2.8. The highest L/B ratio (2.8) of BRRI dhan72 was shown in Rajshahi but its lowest L/B ratio (2.6) was shown in Barishal region. The range of TGW of BRRI dhan72 varies from 27.8 to 28.9g. The highest TGW (28.9g) of BRRI dhan72 was shown in Barishal but the lowest TGW (27.8g) of BRRI dhan72 was shown in Bhanga region (Table-9). The range of alkali spreading value of BRRI dhan72 varies from 3.7 to 6.0. The highest alkali spreading value (6.0) of BRRI dhan72 was shown in Rangpur but its lowest alkali spreading value (3.7) was shown in Barishal region. The range of amylose content of BRRI dhan72 varies from 22.3 to 26%. The highest amylose content (26%) of BRRI dhan72 was shown in Bhanga and Shatkhira but the lowest amylose content (22.3%) of BRRI dhan72

Table 9. Physical properties of rice samples with regional variation in T. Aman season.

Variety	Region	Milling outturn (%)	Head rice recovery (%)	Appearance	Chalkiness	Milled rice length (mm)	Milled rice breadth (mm)	L/B ratio	Size and Shape	1000 grain wt. (g)
BRRI dhan62	Barishal	69	57	Good	Tr	6.6	2.1	3.1	LS	25.2
BRRI dhan62	Bhanga	70	64	Good	Tr	6.6	2.1	3.1	LS	25.1
BRRI dhan62	Cumilla	69	65	Good	Tr	6.7	1.8	3.7	LS	23.7
BRRI dhan62	Gazipur	72	62	V.good	Tr	6.7	2.0	3.4	LS	25.5
BRRI dhan62	Kushtia	70	60	Good	Tr	6.9	1.9	3.6	LS	24.3
BRRI dhan62	Rajshahi	71	67	Good	Tr/ Wc9(few)	6.6	2.0	3.3	LS	23.6
BRRI dhan62	Rangpur	71	66	Good	Tr	6.5	2.0	3.3	LS	23.3
BRRI dhan62	Shatkhira	72	64	V.good	Tr	6.7	2.0	3.4	LS	24.0
BRRI dhan72	Barishal	70	53	Good	Wb1	6.6	2.5	2.6	LB	28.9
BRRI dhan72	Bhanga	71	58	Good	Tr	6.6	2.4	2.8	LB	27.8
BRRI dhan72	Cumilla	69	57	Good	Tr =Wc5	6.6	2.5	2.6	LB	28.3
BRRI dhan72	Gazipur	72	61	Good	Tr/ Wc9(few)	6.5	2.4	2.7	LB	28.8
BRRI dhan72	Kushtia	72	61	Good	Tr	6.6	2.4	2.8	LB	28.1
BRRI dhan72	Rajshahi	71	57	Good	Tr	6.7	2.4	2.8	LB	28.5
BRRI dhan72	Rangpur	71	61	Good	Tr/ Wc5(few)	6.5	2.4	2.7	LB	28.1
BRRI dhan72	Shatkhira	71	61	Good	Tr/ Wc5(few)	6.6	2.5	2.6	LB	28.6

was shown in Kushtia region. The range of protein content of BRRI dhan72 varies from 6.9 to 9.2%. The highest protein content (9.2%) of BRRI dhan72 was shown in Gazipur but its lowest protein content (6.9%) was shown in Shatkhira region. The range of moisture content of BRRI dhan72 varies from 11.4 to 14.2%. The highest moisture content (14.2%) of BRRI dhan72 was shown in Gazipur but its lowest moisture content (11.4%) of BRRI dhan72 was shown in Bhanga region. The range of cooking time of BRRI dhan72 varies from 17:30 to 18:00 min.. The highest cooking time (18:00 min.) of BRRI dhan72 was shown in Bhanga, Comilla, Rangpur and Shatkhira but its lowest cooking time (17:30 min.) was shown in Barishal, Gazipur, Kushtia and Rajshahi region. The range of

elongation ratio (ER) of BRRI dhan72 varies from 1.3 to 1.4. The highest ER (1.4) of BRRI dhan72 was shown in all the regions except two but its lowest ER (1.3) was shown in Barishal and Rajshahi. The range of imbibition ratio (IR) of BRRI dhan72 varies from 3.7 to 4.5. The highest IR (4.5) of BRRI dhan72 was shown in Gazipur and Kushtia but its lowest IR (3.7) was shown in Barishal, Cumilla and Rajshahi. The range of iron content of BRRI dhan72 varies from 4.5 to15 ppm. The highest iron content (15 ppm) of BRRI dhan72 was shown in Gazipur but its lowest iron content (4.5 ppm) was shown in Rangpur region. The range of zinc content of BRRI dhan72 varies from 10.7 to 17.4 ppm. The highest zinc content (17.4 ppm) of BRRI dhan72 was shown in Barishal but its lowest zinc content (10.7 ppm) was shown in Bhanga region (Table-10).

Study on anti-cancer properties of pigmented (black, red, purple) rice varieties in Bangladesh.
PI: HBS; **CI:** SH and MAS.

A total of 15 germplasms including 11 black pericarp rice such as BK1, BK2, BK3, BK4, BK5, BK6, BK7, BK8, BK9, BK10, BK11, two red pericarp rice such as laxmidegga, BRRI dhan84 and two white pericarp rice such as BRRI dhan80, Gabura were grown in BRRI west byed farm and collected from GQN Division of BRRI Gazipur. GQN Division, BRRI has collected black rice

Table 10. Chemical, cooking properties and micronutrient content of rice samples with regional variation in T. Aman season.

Variety	Region	Alkali spreading value	Amylose (%)	Protein (%)	Moisture (%)	Cooking time (min.)	ER	IR	Iron (ppm)	Zinc (ppm)
BRRI dhan62	Barishal	3.7	20.0	8.7	12.4	18:30	1.3	4.3	8.2	20.7
BRRI dhan62	Bhanga	3.0	21.9	8.9	11.8	17:00	1.3	4.2	8.7	18.1
BRRI dhan62	Cumilla	4.3	20.6	8.7	12.6	16:30	1.3	4.0	10.9	18.1
BRRI dhan62	Gazipur	4.3	23.1	9.8	13.1	16:30	1.3	3.9	6.7	15.9
BRRI dhan62	Kushtia	4.3	20.8	8.6	12.6	17:00	1.3	4.2	13.2	20.1
BRRI dhan62	Rajshahi	6.0	20.5	9.0	12.4	17:00	1.3	4.0	6.5	16.2
BRRI dhan62	Rangpur	3.2	21.0	8.7	12.3	18:00	1.3	4.3	7.9	16.7
BRRI dhan62	Shatkhira	3.9	22.7	8.7	12.0	17:30	1.3	4.3	11	16.1
BRRI dhan72	Barishal	3.7	23.0	7.6	12.1	17:30	1.3	3.7	6	17.4
BRRI dhan72	Bhanga	6.0	26.0	8.7	11.4	18:00	1.4	3.9	5.1	10.7
BRRI dhan72	Cumilla	6.0	22.8	7.1	12.3	18:00	1.4	3.7	6.7	16.4
BRRI dhan72	Gazipur	5.6	24.3	9.2	14.2	17:30	1.4	4.5	15	15.7
BRRI dhan72	Kushtia	6.0	22.3	8.0	11.9	17:30	1.4	4.5	12.9	12.2
BRRI dhan72	Rajshahi	5.5	25.6	7.0	12.2	17:30	1.3	3.7	7.1	12.5
BRRI dhan72	Rangpur	6.0	25.1	8.2	12.0	18:00	1.4	3.9	4.5	14.3
BRRI dhan72	Shatkhira	5.8	26.0	6.9	12.1	18:00	1.4	4.5	7.8	12

cultivars from different parts of Bangladesh including hilly regions such as Sylhet, Bandarban, and Khagrachori to evaluate anthocyanins especially active component such as Cyanidin-3-glucoside (C3G) which has anti-cancerous effect.

Black rice powder was extracted three times with buffer solutions (prepared by 0.2M disodium hydrogen phosphate and 0.1M citric acid, pH 3.2) at a solid-liquid ratio of 1:12 for 120 min. The solutions were first filtered with a 3 kDa membrane at room temperature under an operating pressure of 0.5 MPa, and the filtrate was then loaded on a glass column (20 mm × 1000 mm) of AB-8 resin, and 80% (v:v) ethanol was subsequently used as the eluent at a flow rate of 1.0 mL/min. The eluate was collected and stored at -20ºC refrigerator for further experiments.

The identification of anthocyanins especially active component such as Cyanidin-3-glucoside (C3G) in black rice extraction was performed by a Shimadzu UFLC system (Japan). The diode array detector (SPD-M20A) was set at 520 nm. The anthocyanins were separated by a Prevail C18 (4.6 mm × 250 mm) with an average particle size of 5.0 µm at 0.2 mL/min at room temperature. The mobile phase consisted of A (water: formic acid = 99:1, v: v) and B (acetonitrile: formic acid = 99:1, v:v), with the following binary gradient elutions:0 ±10 min, 95% A; 10 ±15 min, 95 ± 5% A; 15±17 min, 5% A; 17±17.1 min, 5±95% A; and 17.1±22 min, 95% A. Oven temperature was set at 25ºC and the sample injection volume was 10µL. The data were processed with LabSolutions software (Shimadzu, Japan). UFLC peak of C3G (Retention time; 12.99±0.05 mins) in raw rice (BK11) and cooked rice was monitored at 520 nm and 280 nm respectively. C3G concentration of tested samples was calculated by using standard calibration curve ($y = 20784x + 286223$, $R^2 = 0.9992$) which is applied to this present study, and units of C3G were expressed in ppm (µgg-1).

Before LCMS analysis, the individual anthocyanin C3G from raw black rice and a fraction collected from cooked rice were isolated using a Prevail C18 (4.6 mm × 250 mm). The composition of the mobile phase was the same as that described above. The flow rate was 3.0 mL, and the gradient was programmed 0 ±10 min, 95% A; 10 ±15 min, 95 ± 5% A; 15±17 min, 5% A; 17±17.1 min, 5±95% A; and 17.1±22 min, 95% A. Fractions collected were applied to a preconditioned PrepSep C18 SPE cartridge (Fisher Scientific, Darmstadt, Germany). After flushing buffer salts from the C18 SPE cartridge with water, the phenolic compounds were eluted with 85% methanol. Confirmation of the identity of the components isolated by preparative HPLC was carried out using a prominence-I (LC-2030C 3D Plus) and LCMS-2020 (Shimadzu, Japan). Samples (20+µL) were analyzed for scanning mode. The mobile phase was 50% methanol in water, and the flow rate was 0.1 mL/min. MS interface was operated in positive ion mode using a cone voltage of 20 V, capillary voltage of 3.0 kV, and collision energy of 12 eV. The ion source temperature was maintained at 140°C and the dissolution gas temperature at 340 °C. The flow rates of nitrogen (Peak Scientific) and cone gases were 460 L/h and 67 L/h respectively.

Among the tested black rice, we found BK11 as the highest C3G (806.17 ppm) enriched black rice in Bangladesh which is popularly grown in the hilly part of Bangladesh namely Khagrachori followed by BK10 (608.81 ppm) and BK8 (337.89 ppm) (Table 11). Red and white pericarp rice does not contain any C3G. Cooking has a significant effect on C3G content. While cooking, C3G reduces significantly from raw rice to cooked rice and our data also validate similarly. At raw rice, we have found the highest content of C3G in BK11 (806.17 ppm) and in same cooked BK11 rice we have found C3G 387.40 ppm (Data not shown) and it was reduced by 48.05% after cooking. BRRI dhan84 and BRRI dhan80 do not have any C3G content in raw rice (Table 11). We examined C3G at 520 nm for raw rice in UFLC (Fig 1), and m/z (499.0) of C3G has validated in LCMS accordingly (data not shown).

Our data reveals that C3G has wide range of 2.58 to 806.17 ppm in black rice cultivars in Bangladesh and C3G is seems thermal sensitive as it reduces 48% after cooking. So, when we will consider black rice breeding materials then we should consider the higher C3G content germplasm in parental selection.

Table 11. Estimation of C3G in local germplasms and HYVs.

Germplasm	Pericarp	R1(ppm)	R2 (ppm)	R3(ppm)	Average(ppm)	STDEV
BK1	Black & White	2.55	2.75	2.45	2.58[j]	0.15
BK2	Black	82.78	77.17	87.10	82.35[g]	4.98
BK3	Black	44.77	40.99	43.19	42.98[h]	1.90
BK4	Black	50.53	57.40	50.56	52.83[i]	3.95
BK5	Black	156.54	148.24	147.65	150.81[e]	4.97
BK6	Black	146.74	146.95	144.65	146.11[e]	1.27
BK7	Black	92.91	90.21	91.22	91.45[f]	1.36
BK8	Black	343.09	337.89	340.34	340.44[c]	2.60
BK9	Black	247.57	243.86	245.32	245.59[d]	1.87
BK10	Black	608.81	616.44	609.21	611.48[b]	4.29
BK11	Black	806.15	807.23	805.12	806.17[a]	1.06
Laxmiidigga	Black & Red	ND	ND	ND	NA	NA
BRRI dhan84	Red	ND	ND	ND	NA	NA
BRRI dhan80	White	ND	ND	ND	NA	NA
Gabura	White	ND	ND	ND	NA	NA

ND: Not detected, Any two-means having a common letter (s) are not statistically different at a P<0.05, as measured by the Duncan Multiple Range Test (DMRT).

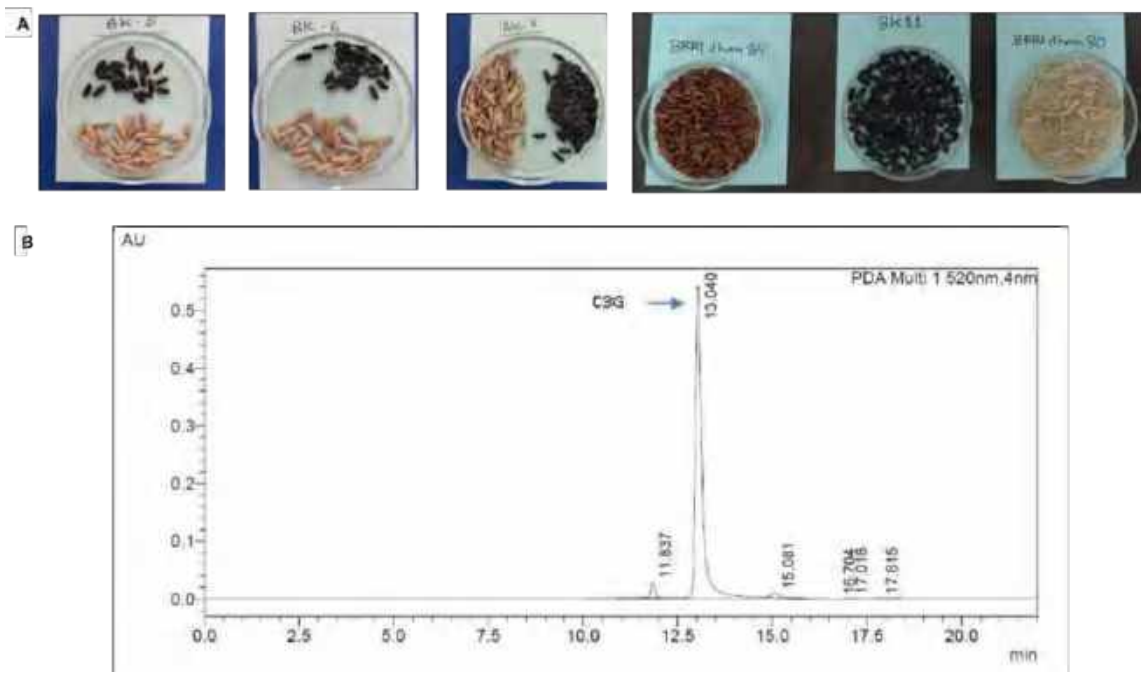

Fig. 1. (A). some pictorial view of tested local germplams such as BK5, BK6, BK7, BRRI dhan84, BK11 and BRRI dhan80. (B). UFLC peak of Cyanidin-3-glucoside (RT;13.04 mins) in raw rice (BK11) was monitored at 520 nm.

COMMERCIAL RICE BASED PRODUCTS

Determination of physicochemical properties and quality of puffed, popped and flattened rice from newly released BRRI varieties

PI: MAH; **CI:** NF, TKS, HBS and MAS

Physical properties viz. length, breadth, thickness, increased length and breadth, volume of rice products such as puffed, popped and flattened rice were determined. This study aims to screen out the BRRI released varieties that are suitable for popular snack food products: puffed, popped and flattened rice for instances. BR16 is used as standard for all the products of puffed, popped and flattened rice. Comparing with the standard variety, it is ascertained from the results that BRRI dhan92 and BRRI hybrid dhan6 are better in producing whole puffed rice 57.81% and 58.06% respectively followed by BRRI dhan90 (48.21%) and BRRI dhan95 (28.75%) in terms of weight of fully puffed rice. Considering overall parameters, BRRI dhan92 and BRRI hybrid dhan6 yielded better results: puffed rice length =12.04 mm and 14.10 mm; increased percentage of puffed rice length= 96.35% and 98.35%; and 50 g puffed rice volume = 500 ml and 575 ml followed BRRI dhan90, (puffed rice length =7.24 mm, increased percentage of length =91.06%, volume =443 ml) and BRRI dhan95 (puffed rice length =10.88 mm, increased percentage of length =100.19%, volume =518 ml) respectively (Table 12). Results of correlation matrix for relationships revealed that puffed rice length is highly significant and positively correlated with milled rice length ($r=0.876$, $p<0.01$). Increased percent of puffed rice length is significant and positively correlated with percent of fully puffed rice wt. ($r=0.616$, $p<0.05$). Puffed rice breadth is significant and positively correlated with increased percent of puffed rice length ($r=0.687$, $p<0.05$). Increased percent of puffed rice breadth is significant and positively correlated with increased percent of puffed rice length ($r=0.692$, $p<0.05$). 1000 puffed rice wt. is highly significant and positively correlated with milled rice length, milled rice breadth and puffed rice length ($r=0.931$, 0.659 and 0.881, $p<0.01$). Volume of 50 g puffed rice is significant and positively correlated with puffed rice length ($r=0.699$, $p<0.05$) and increased percentage of puffed rice length ($r=0.704$, $p<0.05$) (Table 13).

In the case of popped rice, BRRI dhan87 and BRRI dhan89 show excellent performance followed by BRRI dhan80, BRRI dhan86 BRRI dhan88 considering total popped rice percent, fully popped rice percent, partial and broken popped rice percent. On the other hand, in terms of increased popped rice length and volume of 50 g popped rice, BRRI dhan89 (110.99% and 916.67 ml) performed better than BRRI dhan87 (101.44% and 880.33 ml). However, BRRI dhan80 (128.86%) and BRRI dhan86 (93.03%) showed the highest potential in increasing breadth percent and fully popped percent respectively after being popped (Table 14). Results of correlation matrix for relationships ascertained that length of popped rice is significant and positively correlated with percent of broken weight ($r=0.728$, $p<0.05$). Moreover, popped rice length is significant and positively correlated with increased percentage of popped rice length ($r=0.607$, $p<0.05$). Breadth of popped rice is significant and positively correlated with increased percentage of popped rice breadth ($r=0.636$, $p<0.05$). Percent of total popped rice is highly significant and positively correlated with volume of 50g popped rice ($r=0.753$, $p<0.01$). (Table 15).

Similarly, physical properties such as whole, partial and broken flattened rice were considered. Comparing with the standard variety (BR16), it revealed from the results that in terms of weight of whole, partial and broken flattened rice as well as percentage of length increased, BRRI dhan93 showed the best performance followed by BRRI dhan94 and BRRI dhan95. Moreover, the results demonstrated that BRRI dhan93 showed possessed potential in producing flattened rice considering thickness of flattened rice and volume of 50 g sample (t=0.68 mm, vol=141 ml) which is better than the standard as of BR16 (t=0.82 mm, vol=110 ml) and other varieties considered for this study (Table 16). It is ascertained from the study that, brown rice length and breadth are not or insignificantly correlated with the flattened rice length and breadth. Results of correlation matrix for relationships among parameters displayed that flattened rice length is positively correlated with

volume (r=0.902, p<0.01) and there is highly significant correlation between length and volume. Similarly, there is a positive and highly significant correlation between flattened rice breadth and volume (r=0.969, p<0.01). However, the increased percentage of flattened rice length is highly significant and positively correlated with increased percentage flattened rice breadth and volume of 50 g flattened rice (r=0.881, p<0.01). The results also showed that there is highly significant correlation between flattened rice length and increased percent of length (r=0.739, p<0.01) and increased percent of breadth(r=0.805, p<0.01). Moreover, it is also revealed that, there is highly significant correlation between flattened rice breadth and increased percent of length (r=0.845, p<0.01) and increased percent of breadth (r=0.894, p<0.01) (Table 17).

Table 12. Physical properties of puffed rice of BRRI developed modern varieties.

Variety name	Fully puffed rice wt. (%)	Partial puffed rice wt. (%)	Puffed rice length (mm)	Puffed rice length increased (%)	Puffed rice breadth (mm)	Puffed rice breadth increased (%)	1000 puffed rice wt. (g)	50 gm puffed rice volume (ml)
BR16	65.66A	34.13E	11.54C	73.013D	3.66DE	66.36EF	16.82C	456.00D
BRRI dhan83	24.00CD	75.81BC	11.40C	85.97C	4.03B	75.21DE	17.83B	410.00E
BRRI dhan85	1.65E	98.26A	10.00E	65.50E	3.45F	67.47EF	15.00D	375.00F
BRRI dhan90	48.21B	51.85D	7.24G	91.06BC	3.55EF	105.19A	7.02J	443.33D
BRRI dhan91	19.49D	80.35B	9.70E	76.30D	3.97BC	78.67CD	13.84G	412.67E
BRRI dhan92	57.81A	42.06E	12.04B	96.35AB	3.80CD	93.06B	14.62E	500.00C
BRRI dhan93	19.12D	80.76B	9.38F	66.25E	3.50EF	61.13F	12.73I	368.67F
BRRI dhan94	20.80CD	79.00BC	9.20F	64.64E	3.52EF	64.03F	13.18H	375.00F
BRRI dhan95	28.75C	71.13C	10.88D	100.19A	4.30A	90.96B	14.33F	518.33B
BRRI hybrid dhan4	3.47E	96.43A	11.68C	65.34E	3.64DE	84.15BC	16.69C	500.00C
BRRI hybrid dhan6	58.06A	41.86E	14.10A	98.35A	3.88BC	77.98CD	18.22A	575.00A
Mean±SD	31.5±21.994	68.3±21.992	10.6±1.756	80.3±14.256	3.8±0.273	78.6±14.055	14.6±3.012	448.6±66.406
SE	3.8449	3.8655	0.145	2.7972	0.0905	4.3083	0.0769	8.6702
CV%	14.93	6.93	1.67	4.27	2.95	6.72	0.65	2.37

Table 13. Correlation among the physical properties of puffed rice of BRRI developed modern varieties.

Parameter	Correlation								
	Fully puffed rice wt. (%)	Partial puffed rice wt. (%)	Mill rice length (mm)	Mill rice breadth (mm)	Puffed rice length (mm)	Puffed rice length increased (%)	Puffed rice breadth (mm)	Puffed rice breadth increased (%)	1000 puffed rice wt. (g)
Partial puffed rice wt. (%)	-1.000**								
Mill rice length (mm)	.011	-.013							
Mill rice breadth (mm)	-.116	.114	.449						
Puffed rice length (mm)	.317	-.318	.876**	.422					
Puffed rice length increased (%)	.616*	-.615*	-.154	-.046	.339				
Puffed rice breadth (mm)	.162	-.163	.087	.523	.408	.687*			
Puffed rice breadth increased (%)	.302	-.299	-.440	-.617*	-.108	.692*	.346		
1000 puffed rice wt. (g)	-.001	-.001	.931**	.659*	.881**	-.011	.340	-.430	
50 gm puffed rice volume (ml)	.522	-.522	.390	-.071	.699*	.704*	.508	.533	.346

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Table 14. Physical properties of popped rice of BRRI developed modern varieties.

Variety name	Total popped rice (%)	Total waste (%)	Fully popped rice wt. (%)	Partial wt. (%)	Broken wt. (%)	Popped rice length (mm)	Popped rice length increased (%)	Popped rice breadth (mm)	Popped rice breadth increased (%)	1000 popped rice wt. (gm)	50 gm popped rice volume (ml)
BR16	40.97 DE	41.29BC	86.78BC D	12.52BC D	0.60C	13.83BC	95.89D	5.01A	117.68AB C	20.48A	711.67E
BRRI dhan80	45.4B C	38.06E	86.43BC D	11.31CD E	2.03A	13.83BC	95.62D	4.94AB	128.86A	20.33A	775.00C
BRRI dhan81	42.96C D	41.96B	81.79CD E	16.64BC	1.50B	14.68A	98.33CD	3.53F	84.03E	17.53CD	765.00CD
BRRI dhan82	39.53E	47.51A	81.32DE	18.29AB	0.30CD	11.88F	100.73B C	4.37D	73.41E	17.77C	638.67G
BRRI dhan83	46.92B	38.4DE	85.68BC D	15.37BC D	0.46CD	13.14D	99.00CD	4.77AB	101.41D	20.37A	646.67G
BRRI dhan84	34.92F	42.83B	76.69E	22.95A	0.25CD	12.53E	86.41E	4.50CD	108.57CD	17.23D	598.00H
BRRI dhan85	46.1B C	38.73DE	87.58AB C	12.31CD	0D	12.36E	86.66E	4.44D	115.70BC	15.83E	678.33F
BRRI dhan86	45.41B C	39.43CD E	93.03A	5.607E	1.30B	14.42A	104.83B	4.03E	110.07CD	17.35D	863.33B
BRRI dhan87	50.34 A	30.34F	84.16BC D	15.12BC D	0.61C	13.96B	101.44B C	4.70BC	124.27AB	18.25B	880.33B
BRRI dhan88	44.4B C	40.64BC D	89.90AB	9.55DE	0.37CD	11.72F	76.99F	4.25DE	107.32CD	16.04E	746.67D
BRRI dhan89	50.68 A	30.11F	86.73BC D	12.41BC D	0.73C	13.50C	110.99A	4.88 AB	122.98AB	17.55CD	916.67A
Mean±SD	44.33± 4.6	39.027± 5.09	85.462±4 .41	13.825±4 .62	0.7406±0 .61	13.258±1 .01	96.081±9 .53	4.4942±0 .44	108.57±17 .00	18.067±1 .65	747.3±105 .43
SE	1.5402	1.1502	2.8083	2.864	0.2536	0.1618	2.3219	0.1206	5.6122	0.1537	13.617
CV%	4.26	3.61	4.02	25.37	41.93	1.49	2.96	3.29	6.33	1.04	2.23

Table 15. Correlation among the physical properties of popped rice of BRRI modern varieties.

Parameter	Correlation									
	Total popped rice (%)	Total waste (%)	Fully popped rice wt. (%)	Partial wt. (%)	Broken wt. (%)	Popped rice length (mm)	Popped rice length increased (%)	Popped rice breadth (mm)	Popped rice breadth increased (%)	1000 popped rice wt. (gm)
Total waste (%)	-.849**									
Fully popped rice wt. (%)	.574	-.301								
Partial wt. (%)	-.555	.302	-.983**							
Broken wt. (%)	.184	-.118	.203	-.346						
Popped rice length (mm)	.326	-.379	.171	-.262	.728*					
Popped rice length increased (%)	.435	-.405	.073	-.103	.360	.607*				
Popped rice breadth (mm)	.215	-.404	.035	.004	-.153	-.126	.134			
Popped rice breadth increased (%)	.477	-.731*	.379	-.405	.168	.250	.011	.636*		
1000 popped rice wt. (g)	.043	-.063	-.050	.041	.399	.417	.365	.579	.199	
50 gm popped rice volume (ml)	.753**	-.760**	.520	-.593	.463	.585	.556	.010	.477	-.056

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Table 16. Physical properties of Flattened rice of BRRI modern varieties (Sample size: 250 gm).

Variety	Fully flattened rice wt. (g)	Partial flattened rice wt. (g)	Broken flattened rice wt. (g)	Brown rice length (mm)	Brown rice Breadth (mm)	Flattened rice Length (mm)	Flattened rice Breadth (mm)	Increased flattened rice L (%)	Increased flattened rice B (%)	Flattened rice thickness (mm)	1000 flattened rice wt. (g)	50 gm flattened rice volume (ml)
BR16	138.93C	3.50FG	107.27F	6.97	2.17	11.56A	3.97C	66.56D	83.25D	0.82B	19.24C	110.00D
BRRI dhan83	39.26G	35.78B	166.61D	6.48	2.33	8.75E	3.35E	35.13G	43.91G	1.13A	20.22A	83.00G
BRRI dhan85	112.03 D	16.23D	116.09F	6.39	2.12	9.89C	3.58D	54.87E	68.86E	0.82B	16.52E	93.33F
BRRI dhan90	44.49 FG	19.96C	178.47C	4.21	1.69	6.91F	3.27E	64.20D	93.68C	0.75C	9.80J	103.33E
BRRI dhan91	103.39E	4.54EF	140.10E	5.91	2.25	11.40A	4.56A	85.61BC	102.66B	0.72CD	15.51F	128.33B
BRRI dhan92	0H	48.63A	198.81A	6.61	1.94	0G	0F	0I	0H	0F	0K	0H
BRRI dhan93	179.43 A	6.82EF	63.27H	5.82	2.05	10.80B	4.52A	93.00A	120.65A	0.68DE	15.20G	141.67A
BRRI dhan94	166.85B	7.69E	75.20G	5.74	2.14	10.52B	4.25B	83.38C	98.74BC	0.68DE	14.36H	131.67B
BRRI dhan95	170.93B	0G	78.58G	5.66	2.21	10.84B	4.55A	91.57AB	105.88B	0.65DE	12.74I	121.67C
BRRI Hyb dhan4	114.97 D	12.84D	114.59F	7.30	1.92	10.64B	3.93C	45.79F	104.68B	0.75C	19.89B	96.00F
BRRI Hyb dhan6	47.58F	6.13EF	188.95B	7.49	2.15	9.45D	3.44DE	26.25H	60.30F	0.82B	16.84D	95.33F
Mean±SD	101.63±60.985	14.742±15.029	129.81±48.007	6.2345±0.91805	2.0882±0.1799	9.1645±3.3191	3.5861±1.2846	58.763±29.8634	80.239±34.9388	0.6842±0.26972	14.576±5.7507	100.39±38.0685
SE	3.8231	1.7601	4.6954			0.2105	0.0857	3.5263	4.1008	0.0297	0.0956	2.4288
CV%	4.61	14.62	4.43	0	0	2.81	2.93	7.35	6.26	5.32	0.8	2.96

Table 17. Correlation among the physical properties of flattened rice of BRRI modern varieties.

Correlations											
Parameter	Fully flattened rice wt. (g)	Partial flattened rice wt. (g)	Broken flattened rice wt. (g)	Brown rice length (mm)	Brown rice breadth (mm)	Flattened rice length (mm)	Flattened rice breadth (mm)	Increased flattened rice L (%)	Increased flattened rice B (%)	Flattened rice thickness (mm)	1000 flattened rice wt. (g)
Partial flattened rice wt. (g)	-.778**										
Broken flattened rice wt. (g)	-.982**	.649*									
Brown rice length (mm)	-.120	.036	.128								
Brown rice breadth (mm)	.270	-.244	-.250	.388							
Flattened rice length (mm)	.752**	-.867**	-.673*	.059	.455						
Flattened rice breadth (mm)	.777**	-.871**	-.700*	-.159	.363	.969**					
Increased flattened rice L (%)	.824**	-.773**	-.765**	-.517	.210	.739**	.845**				
Increased flattened rice B (%)	.808**	-.837**	-.743**	-.351	-.024	.805**	.894**	.881**			
Flattened rice thickness (mm)	.214	.132	-.290	-.283	.041	.057	.037	.278	.057		
1000 flattened rice wt. (g)	.415	-.538	-.375	.349	.484	.853**	.749**	.330	.484	.047	
50 gm flattened rice volume (ml)	.785**	-.892**	-.696*	-.315	.304	.902**	.969**	.906**	.899**	.025	.596

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

Abbreviation: MAS: Muhammad Ali Siddiquee; MAH: Md Anwarul Haque; SSD: Sharifa Sultana Dipti; NF: Nilufa Ferdous; TKS: Tapash Kumar Sarkar; HBS: Habibul Bari Shozib; SH: Shakir Hosen

Hybrid Rice Division

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SUMMARY

In T. Aman season 2020, a total of 256 test crosses and 299 (A × R) crosses were made from source nursery. One hundred sixty-nine test crosses (F_1s) were evaluated for their pollen fertility status of which 12 entries have been found heterotic over check varieties. Pollen parents of those combinations were regarded as suspected restorers and selected for fertility restoration ability with other (cytoplasmic male sterile) lines in the next season. Fourteen entries were found completely sterile and their corresponding male parents were regarded as suspected maintainer lines. Six backcross entries were advanced as new CMS lines. Other backcross generations were advanced to next generations except three BC_1 generations which were found unstable in terms of pollen sterility and hence discarded. Seventy CMS lines along with their respective maintainer lines were maintained by hand crossing.

A total of 134 test crosses and 427 (A × R) crosses were made using 13 CMS lines in Boro season 2020-21. One hundred ten test crosses (F_1s) were evaluated for their pollen fertility status. Among them eight entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, eleven entries have been selected for their high yielding ability compared with check varieties. Four BC_6 entries were advanced as new CMS lines and advanced to CMS maintenance and evaluation nursery. Other entries were advanced for next generations except for three BC_1 generations. One hundred fourteen CMS lines along with their respective maintainer lines were maintained by hand crossing in CMS maintenance and evaluation nursery for their genetic purity.

In T. Aman, out of 336 test hybrids under observational trials five hybrid combinations were selected based on yield, duration and grain type and produced more than 16-22% yield advantage over check variety BRRI hybrid dhan6, 20-26% over AZ7006 and 14-20 % over Dhanny Gold but growth duration 5 to 7 days earlier than the check variety AZ7006 and Dhanny Gold. The heritability obtained from plant height, growth duration and grain yield were 61%, 72% and 82% respectively, indicating high level of precision in this experiment. In Boro, out of 173 test hybrids 18 hybrid combinations were selected based on yield, duration and grain type. The selected hybrid combinations expressed 5-28% yield advantage over BRRI hybrid dhan5, 11-35% over Dhanny Gold, 9-32% over Teea and 26-53% over SL8H. The heritability obtained from growth duration, thousand grain weight, spikelet fertility and grain yield were 84%, 80%, 57% and 59% respectively, indicating high level of precision in this experiment.

In T. Aman preliminary yield trials, one hybrid was selected out of 10 that showed yield advantage 12 % over BRRI hybrid dhan6, 26 % over AZ7006 and 28 % over Dhanny Gold. In T. Aman under multi-location trials three hybrids out of twelve produced 7-13% yield advantage over BRRI hybrid dhan6, 11-16% over AZ7006 and 15-21% over Dhanny Gold. In Boro, 14 hybrids were evaluated along with four hybrids as check variety. Three hybrids were selected based on yield, grain quality and amylose content. All the selected hybrids showed yield advantage ranging from 6 to 12 % over BRRI hybrid dhan5, 10 to 16 % over Tej Gold, 15 to 22 % over Teea and 11 to 17 % over SL8H. Heritability of yield was 75 % indicating high level of precision of this experiment. In T. Aman, under multi-location yield trials twelve hybrids were evaluated with three check variety in Gazipur, Ishwardi and Barishal. Three hybrids were selected and produced yield advantage 7-13% over BRRI hybrid dhan6, 11-16% over AZ 7006 and 15-21% over Dhanny Gold. On the other hand, in Boro, 17 hybrids were evaluated with four checks in Gazipur, Ishwardi and Barishal. Three hybrids were selected based on stable yield performance and advantage over check across location. All the selected hybrids showed yield advantage ranged 3-4 % over BRRI hybrid dhan5, 10-12 % over Tej Gold, 14-16 % over Teea and 9-10 % over SL8H. Adaptability under saline condition of BRRI released and popular company hybrids along with popular saline tolerant inbred check BRRI dhan67 and BINA dhan10 along with locally adapted inbred IT was done at two coastal location of Satkhira and one coastal location Koyra, Khulna. None of the tested entries survived at Kaliganj, Satkhira and Koyra, Khulna due to very

high-water salinity (30.23 ds/m and 25.8 dS/m, respectively). We found that the top three highest yielding genotypes were BRRI hybrid dhan5 (8.23 t ha^{-1}), BRRI hybrid dhan4 (8.20 t ha^{-1}) and BRRI hybrid dhan3 (7.90 t ha^{-1}) followed by BRRI hybrid dhan6 (7.75 t ha^{-1}), IT (7.20 t ha^{-1}), BRRI hybrid dhan7 (6.51 t ha^{-1}) . Therefore, we can conclude that BRRI hybrid dhan5, BRRI hybrid dhan4, BRRI hybrid dhan3 and BRRI hybrid dhan6 can be cultivated profitably in areas where water salinity level of the paddy field remains 3 ds/m to 7 ds/m. National hybrid rice yield trials were conducted through SCA in T. Aman 2020 and Boro 2020-21, which included 19 and 51 hybrids along with one hybrid check variety. Results were compiled by SCA. Seed yield of 48.5 kg/plot (0.09 t/ha), 101 kg/plot (1.01 t/ha), 145 kg/plot (0.9 t/ha) and 710 kg/plot (1.3 t/ha) were obtained from BRRI7A, BRRI10A, BRRI97A and IR79156A respectively in T. Aman season 2020. Seed yield was very poor due the heavy rainfall during flowering time. In Boro 2020-21, CMS seed yield of 350 kg (1.40 t/ha), 624 kg (1.84 t/ha), 251kg (2.04 t/ha), 289 (1.4 t/ha) and 1938 kg (2.85 t/ha) were obtained from BRRI10A, BRRI11A, IR58025A, BRRI7A and IR79156A, respectively. Experimental F_1 seed production was made using eight CMS with eight different restorer lines and seed yield was ranged 0.19 - 14.5 kg/plot from selected promising hybrid combinations during T. Aman 2020 which was equivalent to 0.06 to 2.90 t/ha. Experimental F_1 seed production ranged 1.1 - 58.2 kg/plot from selected promising hybrid combinations during Boro 2020-21 which was equivalent to 0.07 to 3.90 t/ha. In Boro 2020-21, a total of 860 kg seeds (2.15 t/ha) from BRRI hybrid dhan5 and 1330 kg (2.2 t/ha) from BRRI hybrid dhan6 were obtained. Seed yield of 1.0 kg/plot (0.2 t/ha), 1.3 kg/plot (0.26 t/ha) and 3.0 kg/plot (0.4 t/ha) were obtained from IR58025A, IR102758A and IR78369A respectively in T. Aman season 2020. Seed yield was very poor due to pollen was washed out for continuous heavy rain during supplementary pollination period.

Seed amount obtained from selected promising CMS lines ranging from 0.81 to 2.08 t/ha during Boro 2020-21. We had also F_1 seed production programme in Ishwardi during Boro 2020-21 through contract growers. We got 5,000 kg (2.5 t/ha) of BRRI hybrid dhan3, 4420 kg (2.46 t/ha) of BRRI hybrid dhan4, 6790 kg (2.61 t/ha) of BRRI hybrid dhan5, 4550 kg (2.47 t/ha) of BRRI hybrid dhan6 and 4,000 kg (2.08 t/ha) seeds of BRRI hybrid dhan7 from Ishwardi, Pabna. In T Aman 2020, Hybrid Rice Division supplied 2,483 kg of parental lines and F_1 seeds to 85 farmers, 13 seed companies, scientists, extension people, projects and staffs of BRRI. In Boro 2020-21, this division supplied 11740 kg of parental lines and F_1 seeds to 120 farmers, 24 seed companies, scientists, extension people, projects and staffs of BRRI. Twenty-six stake holders produced more than 200 MT F_1 seeds using BRRI developed hybrid rice parental lines during Boro 2020-21.

DEVELOPMENT OF PARENTAL MATERIALS

Source Nursery

Two hundred and fifty-six test crosses and 299 (A x R) crosses were made during T. Aman season 2020. A total of 134 test crosses and 427 (A × R) crosses were made using 13 CMS lines during Boro season 2020-21.

Test cross nursery

In. Aman 2020, 169 test crosses (F_1s) were evaluated for their pollen fertility status of which 12 entries have been found heterotic over the check varieties. Pollen parents of those combinations were regarded as suspected restorers and selected for fertility restoration ability with other CMS lines in the next season. Fourteen entries were found completely sterile and their corresponding male parents were regarded as suspected maintainer lines.

In Boro 2020-21, one hundred ten test crosses (F_1s) were evaluated for their pollen fertility status. Among them eight entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, 11 entries have been selected for their high yielding ability compared with the check varieties.

Back cross nursery

In T. Aman 2020, six backcross entries were advanced as new CMS lines. Other backcross generations were

advanced to next generations except three BC_1 generations which were found unstable in terms of pollen sterility and hence discarded.

In Boro 2020-21, Four BC_6 entries were advanced as new CMS lines and advanced to CMS maintenance and evaluation nursery. Other entries were advanced for next generations except for three BC_1 generations.

CMS maintenance and evaluation nursery

Seventy CMS lines were maintained by hand crossing for seed increase and genetic purity in T. Aman 2020 and in Boro 2020-21, whereas 114 CMS lines were maintained through hand crossing for seed increase and genetic purity.

EVALUATION OF PARENTAL LINES AND HYBRIDS

In T Aman 2020, out of 336 test hybrids under observational trials five hybrid combinations were selected based on yield, duration and grain type and produced more than 16-22% yield advantage over check variety BRRI hybrid dhan6, 20-26% over AZ7006 and 14-20 % over Dhanny Gold but with five to seven days earlier than the check varieties AZ7006 and Dhanny Gold. The heritability obtained from plant height, growth duration and grain yield were 61%, 72% and 82% respectively, indicating high level of precision in this experiment (Table 1).

Table 1. List of experimental hybrids found heterotic over check variety during T Aman 2020.

Sl.	Designation	PHT (cm)	GD (day)	Plot yield (kg/plot)	Yield (t/h)	Heterosis (%)		
						Ck-1	Ck-2	Ck-3
	BRRI7A/BAU521R	105	125	1.45	7.25	12	16	10
	BRRI7A/Win2R	107	122	1.46	7.30	12	17	11
	BRRI7A/S-1203R	110	124	1.54	7.69	18	23	17
	BRRI35A /Win2R	109	126	1.58	7.9	22	26	20
	BRRI97A/S-1203R	114	123	1.40	6.98	7.0	12	6.0
	BRRI97A/FengleR	110	122	1.56	7.8	20	25	18
	BRRI99A/EL253R	105	112	1.39	6.96	7.0	11	5.0
	BRRI99A/EL254R	107	113	1.46	7.31	12	17	11
	BRRI99A/EL260R	110	115	1.49	7.46	15	19	13
	BRRI99A/EL262R	110	114	1.46	7.31	12	17	11
	BRRI99A/CHH35R	112	111	1.36	6.79	4.0	9.0	3.0
	BRRI99A /LPH47R	112	113	1.52	6.48	-	4.0	-
	BRRI99A /CDE15R	115	124	1.27	7.62	17	22	15
	BRRI99A /R line7	120	110	1.51	6.33	-	1.0	-
	BRRI99A /EL220R	109	124	1.48	7.22	11	16	9.0
	BRRI99A/EL224R	115	123	1.43	7.53	16	20	14
	BRRI99A/S-1203R	114	120	1.41	7.42	14	19	12
	BRRI99A/FengleR	113	118	1.45	7.13	10	14	8.0
	BRRI99A/IR86625-8-1-1-1-3-1-1-1R-1-1	110	111	1.42	7.03	8.0	12	7.0
	BRRI99A/IR86522-29-4-2-1-1-1-1-1-1-1R	107	124	1.40	7.23	11	16	10
	IR79156A /LPH47R	109	121	1.37	7.08	9.0	13	7.0
	IR79156A /MetalR New	107	114	1.30	6.98	7.0	12	6.0
	IR79156A /IR86404-7-2-1-1-1-1-1-1R	105	128	1.27	6.83	5.0	9.0	3.0
	IR79156A/Win2R	110	126	1.20	6.48	-	4.0	-
	BRRI hybrid dhan6	109	120	1.30	6.50			
	AZ 7006	110	129	1.25	6.25			
	Dhanny Gold	112	131	1.32	6.60			
	LSD (0.05)	8.14	5.29		1.6			
	Heritability (%)	0.61	0.72		0.82			

Yield data counted from 30 hills per entry, spacing were 20 cm×15 cm (R × P)
DS: 12 Jul 2020; DT: 8 Aug 2020
Legend: PHT (cm) = Plant height in centimeter; GD =Growth duration

Upon commercial seed production feasibility of these selected hybrid combinations and grain quality assessment it will be tested under preliminary yield trial (PYT) and multi-location yield trials (MLT). Upon satisfactory yield advantage over check variety it is subjected to registration under national hybrid rice yield trial (NHRYT) for releasing as new hybrid rice of BRRI. In Boro, out of 173 test hybrids 18 hybrid combinations were selected based on yield, duration and grain type. The selected hybrid combinations expressed 5-28% yield advantage over BRRI hybrid dhan5, 11-35% over Dhanny Gold, 9-32% over Teea and 26-53% over SL8H. The heritability obtained from growth duration, thousand grain weight, spikelet fertility and grain yield were 84%, 80%, 57% and 59% respectively, indicating high level of precision in this experiment (Table 2).

Preliminary yield trials of promising hybrids

Under preliminary yield trials one hybrid was selected out of 10 and showed yield advantage 12 % over BRRI hybrid dhan6, 26 % over AZ7006 and 28 % over Dhanny Gold in T. Aman 2020 (Table 3). In Boro, 14 hybrids were evaluated along with four hybrids as check variety. Three hybrids were selected based on yield, grain quality and amylose content. All the selected hybrids showed yield advantage ranging from 6-12 % over BRRI hybrid dhan5, 10-16 % over Tej Gold, 15-22 % over Teea and 11-17 % over SL8H. Heritability of yield was 75 % indicating high level of precision of this experiment (Table 4).

Table 2. List of the hybrid combinations found heterotic from observational nursery during Boro season 2020-21.

Sl.	Designation	DTM	TGW	SF (%)	PY 2m^2	Yield (t/h)	Ck-1	Ck-2	Ck-3	Ck-4
	BRRI97A /CHA15R	145	26.7	91.9	2.3	11.6	25	32	29	49
	BRRI99A /CHH67R	144	24.2	94	2	10.2	10	16	13	31
	BRRI7A/IR86403-5-5-2-1-1-1-1-1R	140	30.8	93.5	2.3	11.4	23	30	27	46
	BRRI48A/IR86526-3-5-1-1-1-1-1R	141	22.1	92.2	2	10.1	9	15	12	29
	BRRI11A/CTR-3	142	24.5	83.2	2.1	10.4	12	18	16	33
	IR102758A /IR86522-29-10-1-1-1-1-1-1R	143	25.3	93	2.1	10.6	14	20	18	36
	IR105687A /EL260R	133	21	86	2.1	10.7	15	22	19	37
	BRRI97A/R line7	141	24	89.8	2	9.8	5	11	9	26
	BRRI99A /IR86522-29-10-1-1-1-1-1-1R	144	24.1	94.2	2.4	11.9	28	35	32	53
	BRRI97A/BRRI26R	145	29.7	94.1	2.4	11.8	27	34	31	51
	BRRI97A/IspahaniR	145	29.4	90	2.1	10.4	12	18	16	33
	BRRI99A/BRRI29R	148	25.1	86.5	2.3	11.5	24	31	28	47
	IR105688A/ IR86404-8-1-1-1-1R	135	24.4	92.2	2.3	11.5	24	31	28	47
	IR79125A /CHA-15R	149	25.7	88.7	2.2	11.1	19	26	23	42
	IR79125A /Win3R	150	29.2	82.4	2.4	11.9	28	35	32	53
	IR79156A /IR86526-3-5-1-1-1-1-1R	147	24	92.1	2.2	11.0	18	25	22	41
	BRRI11A/CTR-2	148	24.2	73.1	2.2	11.1	19	26	23	42
	IR105687A /CHH67R	133	24.6	86.1	2.3	11.6	25	32	29	49
Ck-1	BRRI hybrid dhan5	146	30.7	89.2	1.8	9.3				
Ck-2	Tej Gold	144	23.8	70.1	1.9	8.8				
Ck-3	Teea	140	28.2	82.4	1.8	9				
Ck-4	SL8H	149	26.3	71.3	1.6	7.8				
	Heritability	0.84	0.8	0.57	0.59	0.59				
	$LSD_{(0.05)}$	5.1	3.3	17.3	2.9	0.6				

DS: 7 Dec 2020; DT: 11 Jan 20201; Plot size: 2 m^2

Table 3. Results of preliminary yield trials in T. Aman 2020.

Sl.	Designation	PHT (cm)	GD (day)	GT	SF (%)	Amy (%)	Yield (t/h)	Heterosis (%)		
								Ck-1	Ck-2	Ck-3
	BRRI13A/EL254R	108	108	MS	81.3	23.3	6.90	4.23	18.0	19.4
	IR79156A/EL255R	112	107	MS	76.2	24.0	5.79	-	-	-
	BRRI13A/EL260R	103	110	MS	80.5	23.4	6.80	2.72	16.2	17.7
	BRRI48A/EL260R	107	118	S	79.6	24.1	6.43	-	9.91	11.3
	IR79156A/EL262R	111	120	S	81.5	23.7	6.82	3.02	16.6	18.0
	BRRI13A/CHA15R	104	124	S	83.3	23.7	6.64	0.3	13.5	14.9
	BRRI48A/CHA15R	105	121	S	85.8	23.5	7.39	11.6	26.3	27.9
	IR79156A/CHA15R	116	121	S	83.7	22.8	7.06	6.6	20.7	22.1
	BRRI48A/Win1R	108	114	S	83.0	23.6	7.13	7.7	21.9	23.4
	IR79156A/109R	113	126	S	76.1	23.3	5.75	-	-	-
Ck-1	BRRI hybrid dhan6	109	113	S	81.7	24.0	6.62			
Ck-2	AZ7006	112	130	S	80.2	-	5.85			
Ck-3	Dhanny Gold	108	133	MS	79.8	-	5.78			
Mean		108.9	118.85	-	80.98	-	6.54			
CV (%)		3.46	6.90	-	3.42	-	8.71			
LSD (0.05%)		2.70	5.87	-	1.98	-	0.41			

DS: 14 Jul 2020; DT: 4Aug 2020; Plot size=10 m^2; PHT (cm) = Plant height (cm); GD = Growth duration; GT= Grain type; S=Slender, M=Medium, MS=Medium slender; SF (%) = Spikelet fertility; Amy (%) = Amylose.

Table 4. Result of preliminary yield trials in Boro 2020-21.

Sl.	Designation	PH	GD	AC (%)	GT	Yield(t/h)	Heterosis (%)			
							Ck-1	Ck-2	Ck-3	Ck-4
	BRRI50A/CTR-1	105	140	20.4	MS	8.68	-	-	-	-
	BRRI97A/CTR-1	97	138	19.3	MS	9.65	2	6	11	7
	IR79125A/CTR-1	108	145	23.4	LS	10.37	10	14	19	15
	BRRI50A/FengleR	105	138	21.7	MS	9.45	-	4	9	5
	BRRI97A/FengleR	103	138	18.9	MS	8.95	-	-	3	-
	BRRI99A/FengleR	107	139	18.7	MS	9.3	-	2	7	3
	IR105688A/Win 1R	111	140	22.4	SS	9.03	-	-	4	-
	IR105688A/Win 2R	106	140	23.6	SS	10.01	6	10	15	11
	BRRI50A/CHA15R	108	142	23.0	MS	9.45	-	4	9	5
	BRRI97A/EL255R	109	144	24.2	LS	10.58	12	16	22	17
	BRRI99A/EL255R	110	143	20.0	MS	9.9	5	9	14	10
	IR79125A/EL255R	80	137	21.3	MS	8.57	-	-	-	-
	BRRI99A/EL260R	104	142	23.1	MB	9.57	1	5	10	6
	IR79125A/EL260R	107	140	24.0	LS	9.36	-	3	8	4
Ck-1	BRRI hybrid dhan5	108	145	19.0	LB	9.46				
Ck-2	Tej Gold	103	146	18.0	LS	9.1				
Ck-3	Teea	105	142	18.7	MS	8.7				
Ck-4	SL8H	112	143	17.3	MB	9.04				
	Heritability	0.96	0.71			0.75				
	$LSD_{(0.05)}$	3.83	4.15			1.12				

DS: 8 Dec 2020; DT: 15 Jan 2021; Plot size: 30 m^2

PH=Plant height (cm), GD= Growth duration (day), AC (%) = Amylose content, GT= Grain type, MS= Medium slender, LS = Long slender, SS= Short slender, MB = Medium bold, LB= Long bold

Multi-location yield trials of promising hybrids

In T Aman 2020, under multi-location trials three hybrids out of 12 produced 7-13% yield advantage over BRRI hybrid dhan6, 11-16% over AZ7006 and 15-21% over Dhanny Gold (Table 5). In Boro 2020-21, seventeen hybrids were evaluated along with three company and one BRRI developed hybrid as check variety. Three hybrids were selected based on stable yield performance and advantage over check across location. All the selected hybrids showed yield advantage ranging 3-4 % over BRRI hybrid dhan5, 10-12 % over Tej Gold, 14-16 % over Teea and 9-10 % over SL8H. Yield fluctuation in Barishal happened due to disease and bird attack during flowering and maturity stage. Heritability of mean yield was 76 % indicating high level of precision of this experiment (Table 6).

Development of maintainer and restorer lines through (B×B) and (R×R) crosses

Ten new R×R and seventeen B×B crosses were made for new recombinant line development with broad genetic base and high amylose. These twenty seven cross combinations will be confirmed as true F_1 under ongoing T Aman season 2021. Ten R×R and five B×B crosses were confirmed as true F_1 compared with respective corresponding parents and sufficient seeds collected for raising F_2 population. In Boro, 15 B×B and six R×R crosses were confirmed as true F_1 compared with corresponding parents and sufficient F_2 seeds were collected for generation advancement. 8832 progenies from 18 crosses (10 R × R, 3 A × R and 5 B × B) were advanced to F_3 generation using field rapid generation advance (FRGA) technique (Table 7).

Evaluation of Fatema dhan

Ten lines of Fatema dhan were evaluated in T. Aman 2020 and made some crosses with available best CMS lines. All the tested lines were low tillering ability, panicle exertion rate was very low and flower blooms inside the leaf sheath with long awn. Some of the lines still segregating, highly infected by sheath rot diseases and some had large panicle with more spikelets and strong stem. At maturity out of ten segregating lines, selected nineteen plants as new lines based on red stigma, white stigma, awn less and with awn. In Boro 2020-21, twenty one lines were selected out of 19 based on red stigma, white stigma, awn less, awn present, plant type panicle size and also other agronomic performance.

Table 5. Results of multi-location yield trials during T. Aman 2020.

Sl.	Hybrid	PH (cm)	DTM (day)	Yield (t/ha) Gaz	Ish	Bari	Av	SF (%)	Grain type	Amy (%)	Aver yield Advantage over Ck (%) Ck-1	Ck-2	Ck-3	Remarks
	BRRI99A/EL254R	108.0	111	6.4	6.7	4.67*	5.92	77.3	MS	24.2	-	-	-	Bird damage was the main reason for obtaining the lower yield in Barishal
	BRRI99A/EL255R	110.3	110	5.8	6.2	5.32*	5.77	74.6	MS	23.4	-	-	-	
	BRRI35A/EL260R	105.5	113	5.9	6.0	5.79	5.90	75.0	M	23.2	-	-	-	
	BRRI99A/EL260R	103.2	110	6.1	6.5	5.56	6.05	81.2	S	23.5	-	-	-	
	BRRI35A/EL262R	118.2	114	6.3	6.7	6.09	6.36	84.6	M	23.6	8.9	12.4	16.7	
	BRRI99A/EL262R	118.1	115	6.6	7.2	4.13*	5.84	73.2	MS	24.2	-	-	-	
	BRRI35A/Win1R	111.1	110	6.0	7.3	4.17*	5.82	74.7	M	23.4	-	-	-	
	BRRI99A/Win1R	109.0	114	6.5	7.1	6.12	6.57	83.2	MS	23.4	12.5	16.0	20.5	
	IR79156A/BRRI31R	111.8	110	6.1	6.3	5.87	6.09	82.6	S	24.0				
	BRRI99A/BRRI31R	110.6	114	6.4	7.3	5.08*	6.26	81.3	S	23.7	7.2	10.6	14.7	
	BRRI35A/BRRI31R	108.9	113	5.7	5.9	6.20	5.93	78.7	MS	23.6				
	BRRI50A/BRRI31R	112.3	110	5.8	6.1	5.76	5.89	77.3	M	23.5				
Ck-1	BRRI hybrid dhan6	116.7	115	5.6	6.2	5.72	5.84	73.8	S	24.0				
Ck-2	AZ-7006	118.3	127	5.8	5.8	5.39	5.66	71.7	S					
Ck-3	Dhanny Gold	110.7	127	5.6	5.5	5.25	5.45	72.6	MS					
Mean		111.5	114.2	6.04	6.45	5.41	5.96	77.5						
CV (%)		4.12	4.86	5.52	8.94	12.16	4.69	5.47						
LSD (0.05%)		2.75	3.23	3.68	5.95	8.10	3.12	3.64						

DS: 7 Jul 2020; DT: 26 Jul 2020; Unit plot size: 30 m^2

Table 6. Results of multi-location yield trials during Boro 2020-21.

En	Hybrid	PH	DTM	Yield (t/h)				Yield advantage over check (%)			
				Gazi	Ishw	Bar	Mean	Ck-1	Ck-2	Ck-3	Ck-4
	BRRI48A/CTR1	104	147	9.1	9.3	7.5	8.6	-	-	4	-
	BRRI99A/CTR1	107	150	9.5	9.8	7.5	8.9	-	3	7	2
	IR105688A/CTR1	104	147	9.1	9.5	8.0	8.9	-	3	7	2
	IR105688A/FengleR	103	147	8.2	8.3	7.1	7.8	-	-	-	-
	IR79156A/FengleR	115	152	8.2	8.7	7.9	8.3	-	-	-	-
	BRRI99A/Win1R	112	149	9.3	9.5	7.9	8.9	-	3	7	2
	BRRI11A/CHA15R	112	152	9.5	8.8	7.5	8.6	-	-	4	-
	BRRI99A/CHA15R	114	151	9.9	9.6	9.2	9.6	4	12	16	10
	IR105688A/CHA15R	110	149	8.6	9.7	8.4	8.9	-	3	7	2
	BRRI11A/EL255R	111	146	9.2	8.7	7.8	8.6	-	0	4	-
	IR105688A/EL255R	103	143	8.0	8.3	8.5	8.3	-	-	0	-
	BRRI11A/EL260R	108	148	9.2	9.6	9.2	9.4	2	9	13	8
	IR105688A/EL260R	108	146	9.0	9.0	8.7	8.9	-	3	7	2
	BRRI11A/BRRI31R	113	152	10.6	9.3	7.4	9.1	-	6	10	5
	IR105688A/BRRI31R	107	151	9.5	8.8	8.9	9.0	-	5	8	3
	BRRI99A/BRRI31R	111	152	9.7	9.9	9.1	9.6	4	12	16	10
	BRRI99A/EL254R	115	149	9.5	9.8	9.1	9.5	3	10	14	9
Ck-1	BRRI hybrid dhan5	111	145	9.2	9.2	9.2	9.2				
Ck-2	Tej Gold	111	145	8.9	8.3	8.7	8.6				
Ck-3	Teea	111	143	8.7	8.2	8.2	8.3				
Ck-4	SL-8H	107	146	8.9	8.3	9.0	8.7				
	Heritability	0.74	0.92				0.76				
	$LSD_{(0.05)}$	7.7	2.2				0.88				

Gazipur: DS: 4 Dec 2020; DT: 13 Jan 2021; Barishal: DS: 15 Dec 2020; DT: 20 Jan 2021
Ishwardi: DS: 10 Dec 2020; DT: 15 Jan 2021; PH (cm) = Plant height; DTM = Days to maturity
Unit plot =20 m^2

Table 7. Progenies selected through Field RGA, during Boro 2020-21.

Genotype	Cross type	Progeny advanced as F_3 generation
BRRI10R/IR76902-C2-11-1-2	R × R	805
3028R/IR06N126	R × R	667
EL260R/IR85553-18-2-1-14-1-1-1	R × R	736
CHA15R/IR05N162	R × R	230
LPH47R/IR86515-19-1-2-1-1-1-1R	R × R	207
CHH67R/IR86555-16-1-1-1-1-1-1-1-1-1-1	R × R	621
107R/IR05N181	R × R	805
LPH47R/IR90928-15-4-1-1-1	R × R	828
CHH67R/IR86522-29-10-1-1-1-1-1-1	R × R	736
3028R/IR85503-8-11-1-1-1-2-1-1-1	R × R	713
US-88 F_2	A × R	230
Dhanny Gold F_2	A × R	253
AZ-7008 F_2	A × R	322
BRRI7B/IR105687B	B × B	276
BRRI13B/IR102758B	B × B	414
BRRI48B/IR102571B	B × B	345
BRRI110B/IR75596B	B × B	644
BRRI115B/IR79125B	B × B	506
Total		8832

Generation Advancement of Parental Lines having multi stress genes (HRDC materials) at Restorer (R) and Maintainer (M) background

In T Aman 2020, thirty four F_6 progenies from 10 crosses were evaluated and 36 progenies were selected from pedigree generations based on the better performance with phenotypic acceptability, insect and disease reaction, grain type and growth duration. In Boro 2020-21, a total of 43 progenies were selected from F_7 generation, among them 15 progenies were harvested as a single plant basis and 28 progenies bulked through pedigree method.

Blast tolerant parental line development

Five blast tolerant materials were collected from Plant Pathology Division of BRRI and seed multiplication was done and at the same time six test crosses were performed to confirm the presence and absence of fertility restorer (*Rf)* gene in the blast tolerant lines.

Assessment of specific and general adaptability for selection of suitable rice hybrids under saline prone areas for Boro season

Adaptability under saline condition of BRRI developed and popular company hybrids along with popular saline tolerant inbred checks BRRI dhan67, Bina dhan-10 and locally cultivated rice IT was done at two coastal locations of Satkhira and one location at Koyra, Khulna. None of the tested entries survived at Kaliganj, Satkhira and Koyra, Khulna due to very high-water salinity (30.23 ds/m and 25.8 ds/m, respectively). We found that the top three highest yielding genotypes were BRRI hybrid dhan5 (8.23 t ha^{-1}), BRRI hybrid dhan4 (8.20 t ha^{-1}) and BRRI hybrid dhan3 (7.90 t ha^{-1}) followed by BRRI hybrid dhan6 (7.75 t ha^{-1}), IT (7.20 t ha^{-1}), BRRI hybrid dhan7 (6.51 t ha^{-1}). Therefore, we can conclude that BRRI hybrid dhan5, BRRI hybrid dhan4, BRRI hybrid dhan3 and BRRI hybrid dhan6 can be cultivated profitably in areas where water salinity level of the paddy field remains 3 ds/m to 7 ds/m (Table 8 and Fig. 1).

Table 8. Yield and agronomic performance of sixteen genotypes from adaptive trial in Boro 2020-21.

Genotype	GD	PH	Yield (t/ha)			Predicted Yield	PM	SF	PAcp	
			Assasuni	Kaliganj	Koyra				Veg	Mat
Binadhan-10	138	89	5.83	*	**	5.83	290	87	3	3
BRRI dhan67	137	88	5.35	*	**	5.36	302	96	3	3
BRRI hybrid dhan2	138	108	5.31	*	**	5.32	288	88	3	3
BRRI hybrid dhan3	138	99	7.90	*	**	7.88	286	85	3	3
BRRI hybrid dhan4	139	106	8.20	*	**	8.18	289	85	5	5
BRRI hybrid dhan5	138	103	8.23	*	**	8.21	290	86	5	5
BRRI hybrid dhan6	137	103	7.75	*	**	7.73	280	86	5	5
BRRI hybrid dhan7	140	101	6.51	*	**	6.51	288	85	3	3
BRRI99A/BRRI31R	137	101	5.95	*	**	5.95	288	83	5	5
BRRI99A/EL254R	138	103	6.45	*	**	6.45	284	84	5	5
Gold (Lal teer)	140	95	5.32	*	**	5.33	288	81	3	3
Heera (Supreme)	137	112	5.26	*	**	5.27	285	83	3	3
IT	140	121	7.20	*	**	7.19	298	81	3	3
Janokraj	139	101	4.57	*	**	4.59	273	78	3	3
SL-8 (BADC)	141	109	4.05	*	**	4.08	284	77	3	3
Tej gold (Bayer)	139	99	6.24	*	**	6.24	276	85	5	5
LSD	1.34	2.81	0.38			0.26	13.82	1.70		
CV	0.58	1.65	3.61			3.61	2.89	1.21		
Heritability	0.85	0.99				0.99	0.53	0.98		

GD=Growth duration (days), PH=Plant height (cm), PM=Panicle/m^2, SF=Spikelet fertility (%), *=All the entries died, **= All the entries survived but produced sterile spikelets.

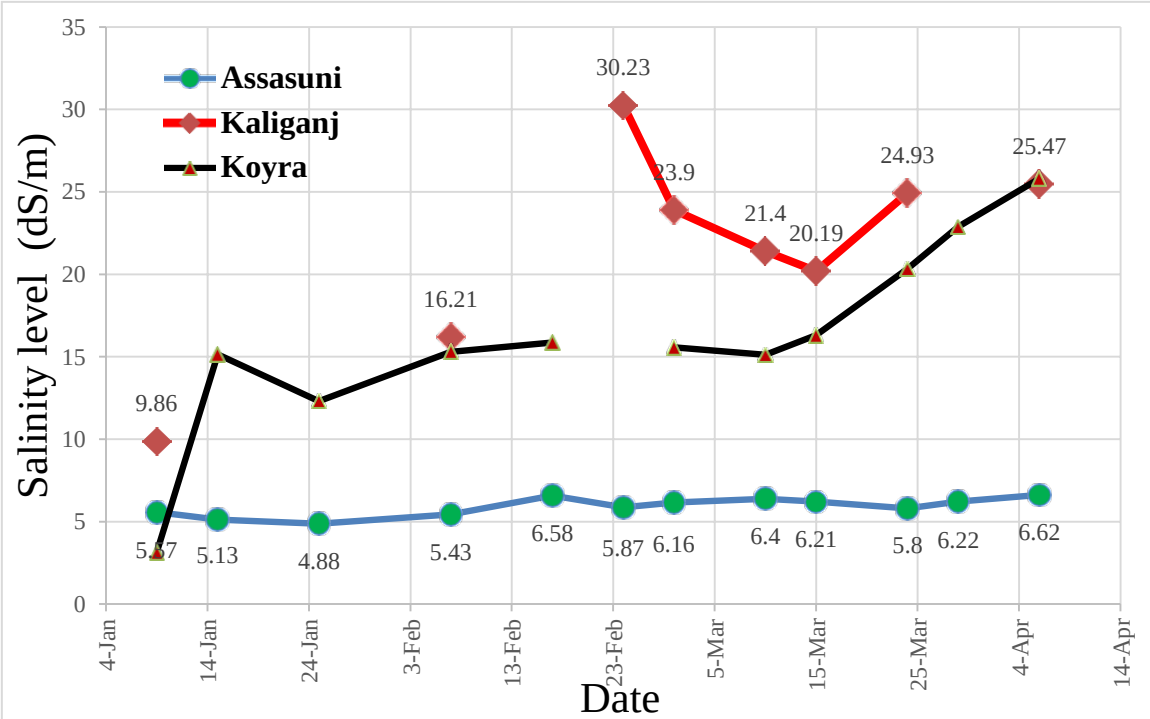

Fig. 1. Water salinity levels of different experimental plots in Boro 2020-21 at Assasuni and Kaliganj in Satkhira and Koyra, Khulna.

SEED PRODUCTION OF PARENTAL LINES AND HYBRIDS

CMS line multiplication of released hybrids

Seed yield of 48.5 kg/plot (0.09 t/ha), 101 kg/plot (1.01 t/ha), 41 kg/plot (0.41 t/ha) and 145 kg/plot (0.97 t/ha) were obtained from BRRI7A, BRRI10A, BRRI35A and BRRI97A respectively in T. Aman season 2020 (Table 9). On the other hand, in Boro 2020-21, CMS seed yield of 350 kg (1.40 t/ha), 624 kg (1.84 t/ha), 251kg (2.04 t/ha), 289 (1.4 t/ha) and 1938 kg (2.85 t/ha) were obtained from BRRI10A, BRRI11A, IR58025A, BRRI7A and IR79156A, respectively (Table 10).

Table 9. CMS lines multiplication of BRRI17A, BRRI10A, BRRI35A and BRRI97A in T. Aman 2020.

Combination	Plant height (cm)		50% flowering date		PER (%)	OCR (%)	Yield		Remarks
	A line	B line	A line	B line			Kg /plot	(t/ha)	
BRRI7A/B	83	87	75	73	77	14	48.5	0.09	Poor seed yield due to rainfall during supplementary pollination
BRRI10A/B	85	87	72	70	81	31	101	1.01	
BRRI35A/B	102	105	71	70	74	23	41.0	0.41	
BRRI97A/B	86	88	71	70	80	32	145	0.97	

DS: B_1=8 Jul 2020, A/B_2=11 Jul 2020, B_3=14 Jul 2020; DT: A/B=1 Aug 2020; DS: B_1= 03 Jul 2020, B_2/A= 6 Jul 2020, B3= 9 Jul 2020; DT: A/B=27 Jul 2020; DS: B_1=5 Jul 2020, B_2/A=08 Jul 2020, B_3=11 Jul 2020; DT: A/B=29 Jul 2020; DS: 15 Jul 2020, B_2/A=18 Jul 2020, B3=21 Jul 2020; DT: A/B=14 Aug 2020
PER=Panicle Exertion Rate, OCR= Out Crossing Rate.

Table 10. CMS multiplication of BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5 and BRRI hybrid dhan6 during Boro 2020-21.

Designation	Plant height (cm)		50% flowering (day)		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/ plot)	Seed yield (t/ha)
	A line	B line	A line	B line	A line	A line			
BRRI10A/B	86	88	125	122	78.0	38.0	2500	350	1.40
BRRI11A/B	95	99	120	118	82.34	39.9	3400	624	1.84
IR58025A/B	84	87	123	120	77.3	45.8	1230	251	2.04
BRRI7A/B	94	97	120	117	78.0	38.3	2000	289	1.40
IR79156A/B	88	91	123	121	83.0	61.0	6800	1938	2.85

DS: B_1 =2 Dec 2020; A/B_2 = 5 Dec 2020; B_3 = 8 Dec 2020; DT: A/B = 13 Jan 2021;DS: B_1 =7 Dec 2020; A/B_2 =10 Dec 2020; B_3 =13 Dec 2020; DT: A/B =11 Jan 2021; DS: B_1 =5 Dec 2020; A/B_2 =8 Dec 2020; B_3 =11Dec 2020;DT: =A/B= 08 Jan 2021; DS:B1=30 Nov 2020; A/B=08/01/2021;D/S:B_1=30/11/2020;A/B_2=03 Dec 2020;B_3=6 Dec 2020; DT:A/B=5 Jan 2021; DS: B_1=10 Dec 2020; B_2/A =13 Dec 2020; B_3=16 Dec 2020; D/T:A/B= 17 Jan 2021; PER=Panicle Exertion Rate, OCR= Out Crossing Rate.

Experimental F_1 seed production of promising hybrids during T Aman 2020 and Boro 2020-21. Eight CMS and eight restorer lines were used to produce experimental F_1 seeds of 53 hybrid combinations. Seed yield ranging from 0.19 to 14.5 kg/plot which was equivalent to 0.06 to 2.90 t/ha. Some combinations did not produce seed due to lack of flowering synchronization and frequent raining during flowering time 0.06 to 2.90 t/ha. Some combinations did not produce sufficient seeds due to lack of flowering synchronization and frequent raining during flowering time (Table 11). In Boro, 11 CMS and four restorer lines were used to produce F_1 seeds of 42 hybrid combinations. Seed yield ranging from 1.1 to 58.2 kg/plot which was equivalent to 0.07 to 3.90 t/ha. Some combinations did not produce desired seed due to lack of flowering synchronization and frequent raining during flowering time (Table 12).

Table 11. Experimental F_1 seed obtained from different hybrid combinations during T Aman 2020.

Designation	Seed amount (kg)	Yield (t/ha)	OCR (%)	Remarks
IR79156A/Win1R	5.40	1.08	27.6	
IR105688A/Win1R	2.30	0.46	17.2	
BRRI99A/Win1R	0.80	0.16	8.0	
IR79125A/Win1R	0.30	0.06	4.0	
BRRI97A/Win1R	0.70	0.14	7.0	
BRRI48A/Win1R	2.90	0.58	20.2	
BRRI35A/Win1R	3.60	0.72	23.4	
BRRI11A/Win1R	3.10	0.62	20.5	
IR79156A/Win2R	2.50	0.50	17.3	
IR105688A/Win2R	0.50	0.01	5.0	Lack of proper synchronization and continuous raining during pollination time was the main reason for poor seed yield
BRRI99A/Win2R	0.25	0.05	2.6	
IR79125A/Win2R	0.19	0.04	2.1	
BRRI97A/Win2R	0.30	0.06	4.1	
BRRI48A/Win2R	1.40	0.28	15.3	
BRRI35A/Win2R	2.20	0.44	15.6	
BRRI11A/Win2R	0.90	0.18	7.5	
BRRI48A/CTR-1	5.6	1.12	28.3	
BRRI50A/CTR-1	0.785	0.157	7.8	
BRRI97A/CTR-1	2.9	0.58	20.3	
BRRI99A/CTR-1	3.4	0.68	21.6	
IR79125A/CTR-1	1.0	0.20	7.0	
IR105688A/CTR-1	6.0	1.20	29.3	
IR79156A/CTR-1	8.7	1.74	31.4	
BRRI48A/FengleR	2.4	0.48	17.5	
BRRI50A/FengleR	0.3	0.06	4.0	
BRRI97A/FengleR	0.660	0.13	6.5	

Designation	Seed amount (kg)	Yield (t/ha)	OCR (%)	Remarks
BRRI99A/FengleR	1.5	0.30	9.0	
IR79125A/FengleR	1.175	0.24	8.6	
IR105688A/FengleR	2.6	0.52	18.3	
IR79156A/FengleR	5.56	1.11	28.0	
BRRI11A/CHA15R	4.5	0.90	26.3	
BRRI35A/CHA15R	3.5	0.70	21.1	
BRRI48A/CHA15R	2.5	0.50	17.3	
BRRI50A/CHA15R	0.6	0.12	6.0	
BRRI97A/CHA15R	0.7	0.14	7.0	
BRRI99A/CHA15R	1.5	0.30	8.7	
IR79125A/CHA15R	1.7	0.34	9.1	
IR105688A/CHA15R	5.0	1.0	28.4	
BRRI11A/EL255R	4.5	0.90	26.2	
BRRI97A/ EL255R	1.0	0.20	6.5	
BRRI99A/EL255R	0.8	0.16	7.1	
IR79125A/EL255R	0.6	0.12	5.8	
IR105688A/EL255R	5.8	1.16	30.3	
BRRI11A/EL260R	14.5	2.90	48.3	
BRRI97A/EL260R	1.8	0.36	9.5	
BRRI99A/EL260R	4.8	0.96	28.3	
IR79125A/EL260R	1.09	0.22	6.5	
IR105688A/EL260R	5.6	1.12	30.1	
BRRI11A/BRRI31R	4.7	0.94	29.1	
BRRI35A/BRRI31R	7.7	1.54	35.4	
BRRI97A/BRRI31R	3.8	0.76	23.2	
IR105688A/BRRI31R	11.2	2.24	43.5	
IR79125A/BRRI31R	3.0	0.60	18.4	

Each plot area was 50 Sqm; DS: 15 Jul 2020; DT: 4 Aug 2020

Table 12. Experimental F_1 seed obtained from different hybrid combinations during Boro 2020-21.

Designation	Seed amount (kg)	Yield (t/ha)	OCR (%)	Remarks
BRRI7A/IR77498-45-1-2-2R	5.9	0.4	15.6	
BRRI50A/IR77498-45-1-2-2R	2.4	0.2	8.2	
BRRI97A/IR77498-45-1-2-2R	12.4	0.8	27.4	
BRRI99A/IR77498-45-1-2-2R	21.0	1.4	42.8	
IR79125A/IR77498-45-1-2-2R	11.1	0.7	25.6	
IR105687A/IR77498-45-1-2-2R	2.9	0.2	7.5	
IR79156A/IR77498-45-1-2-2R	16.5	1.1	33.4	
IR102758A/IR77498-45-1-2-2R	6.9	0.5	17.5	
IR78369A/IR77498-45-1-2-2R	14.0	0.9	28.3	Lack of proper synchronization and continuous raining during pollination time was the main reason for poor seed yield
IR58025A/IR77498-45-1-2-2R	13.0	0.9	29.0	
BRRI7A/IR86526-11-6-2-1-1-1-1R	11.5	0.8	27.6	
BRRI50A/IR86526-11-6-2-1-1-1-1R	2.6	0.2	7.1	
BRRI97A/IR86526-11-6-2-1-1-1-1R	11.75	0.8	27.1	
BRRI99A/IR86526-11-6-2-1-1-1-1R	23.55	1.6	45.3	
IR79125A/IR86526-11-6-2-1-1-1-1R	2.8	0.2	6.9	
IR105687A/IR86526-11-6-2-1-1-1-1R	3.5	0.2	7.0	
IR79156A/IR86526-11-6-2-1-1-1-1R	12.0	0.8	28.3	
IR102758A/IR86526-11-6-2-1-1-1-1R	1.6	0.1	4.8	
IR78369A/IR86526-11-6-2-1-1-1-1R	1.6	0.1	4.6	
IR58025A/IR86526-11-6-2-1-1-1-1R	4.0	0.3	11.6	
BRRI11A/CTR-1	14.1	0.9	29.0	
BRRI7A/CTR-1	9.1	0.6	17.3	
BRRI50A/CTR-1	2.5	0.2	6.7	

Designation	Seed amount (kg)	Yield (t/ha)	OCR (%)	Remarks
BRRI97A/CTR-1	11.1	0.7	24.5	
BRRI99A/CTR-1	17.7	1.2	38.5	
IR79125A/CTR-1	9.2	0.6	18.5	
IR105687A/CTR-1	1.1	0.07	2.0	
IR79156A/CTR-1	19.6	1.3	40.6	
IR102758A/CTR-1	5.2	0.3	11.3	
IR78369A/CTR-1	5.3	0.4	13.0	
IR58025A/CTR-1	11.6	0.8	27.3	
BRRI11A/EL262R	27.3	1.8	47.1	
BRRI7A/EL262R	4.2	0.3	11.3	
BRRI50A/EL262R	1.4	0.09	3.0	
BRRI97A/EL262R	11.6	0.8	27.0	
BRRI99A/EL262R	42.2	2.8	56.7	
IR79125A/EL262R	37.5	2.5	53.1	
IR105687A/EL262R	1.1	0.07	2.1	
IR79156A/EL262R	58.2	3.9	76.2	
IR102758A/EL262R	11.8	0.8	26.5	
IR78369A/EL262R	38.1	2.5	53.1	
IR58025A/EL262R	27.1	1.8	46.8	
Mean	13.05	0.87	24.70	
Range	57.1	3.83	74.2	

Each plot area was 150 m^2; DS: 5 Dec 2020; DT: 4 Jan 2021

F_1 seed production of BRRI hybrid dhan5 and BRRI hybrid dhan6 in Boro 2020-21

A total of 860 kg (2.15 t/ha) from BRRI hybrid dhan5 and 1330 kg (2.2 t/ha) from BRRI hybrid dhan6 were obtained (Table 13).

CMS seed multiplication of selected promising CMS lines in Boro 2020-21

Five promising CMS lines were used for seed multiplication. Seed amount got from selected promising CMS lines ranged from 0.81 to 2.08 t/ha (Table 14).

Table 13. F_1 seed production of BRRI hybrid dhan5 and BRRI hybrid dhan6 during Boro, 2020-21.

Combination	Plant height (cm)		50% flowering date		PER	OCR	Yield	
	A line	R line	A line	R line	(%)	(%)	kg/plot	t/ha
BRRI7A/BRRI31R	88	97	124	140	82	43	860	2.15
IR79156A/BRRI20R	85	94	126	129	89	47	1330	2.22

DS: R_1 = 15 Nov 2020; R_2 = 22 Nov 2020; A = 11 Dec 2020; DT: R = 20 Dec 2020; A = 11 Jan 2021.
DS: R_1 = 1Dec 2020; R_2 = 5 Dec 2020; A = 14 Dec 2020; DT: R & A = 19 Jan 2021.
PER (%) = panicle exertion rate, OCR (%) = Out crossing rate

Table 14. Seed amount got from selected promising CMS lines during Boro, 2020-21

Designation	Plant height (cm)		D50% flowering		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/plot)	Seed yield (t/ha)
	A line	B line	A line	B line					
BRRI50A/B	98	101	121	118	70.0	51.3	350	28.2	0.81
BRRI97A/B	95.0	97.0	119	116	77.3	47.2	2000	415	2.08
BRRI109A/B	104.0	107.0	120	117	68.5	42.3	100	15.5	1.60
IR102758A/B	102.0	105.0	123	120	76.0	39.5	130	14.5	1.12
IR78369A/B	105.0	108.0	131	128	71.6	51.2	120	13.3	1.11
Average	105	108	131	128	71.6	51.2	120	13.3	1.11
Lsd $_{(0.05)}$	4.0	4.2	3.7	3.8	5.3	10.3		1336.1	45.0
CV (%)	4.36	3.93	4.46	4.45	4.68	6.79		185.38	34.79

DS: B_1=30 Nov 2020; B_2/A =03 Dec 2020; B_3=06 Dec 2020; DT: 7 Jan 2021; DS: B_1=1 Dec 2020; B_2/A =04 Dec 2020; B_3=07 Dec 2020; DT: 11 Jan 2021; DS: B_1=10 Dec 2020; B_2/A =13 Dec 2020; B_3=16 Dec 2020; DT: 18 Jan 2021; DS: B_1=30 Nov 2020; B_2/A =3 Dec 2020; B_3=6 Dec 2020; DT: 4 Jan 2021;
DS: B_1=10 Dec 2020; B_2/A =13 Dec 2020; B_3=16 Dec 2020; DT: 16 Jan 2021; PER (%) = panicle exertion rate, OCR (%) = Out crossing rate

F_1 seed production through contract growers

We had F_1 seed production programme in Ishwardi through contract growers during Boro 2020-21. Seeds obtained from Ishwardi was 5000 kg (2.5 t/ha) of BRRI hybrid dhan3, 4420 kg (2.46 t/ha) of BRRI hybrid dhan4, 6790 kg (2.61 t/ha) of BRRI hybrid dhan5, 4550 kg (2.47 t/ha) of BRRI hybrid dhan6 and 4000 kg (2.08 t/ha) seeds of BRRI hybrid dhan7 from Ishwardi, Pabna (Table 15).

Dissemination of hybrid rice technology

In the reporting year, under T. Aman season Hybrid Rice Division supplied 2483 kg of parental lines and F_1 seeds to 85 farmers, 13 seed companies, scientists, extension people, projects and BRRI staffs (Table 16) and 11740 kg of parental lines and F_1 seeds to 120 farmers, 24 seed companies, scientists, extension people, projects and BRRI staffs during, 2020-21 (Table 17). Twenty six stake holders produced more than 200 MT F_1 seeds using BRRI developed hybrid rice parental lines during Boro 2020-21 (Table 18).

Table 15. F_1 seed production of BRRI developed hybrids through contract grower during Boro 2020-21.

Variety	Contract grower	Location	Area (Acre)	Seed Yield (kg)	Seed yield (t/ha)	Remarks
BRRI hybrid dhan3	Aus Bangla Agro	Ishwardi	5.0	5000	2.50	
BRRI hybrid dhan4	Aus Bangla Agro	Ishwardi	4.5	4420	2.46	
BRRI hybrid dhan5	Aus Bangla Agro	Ishwardi	6.5	6790	2.61	
BRRI hybrid dhan6	Aus Bangla Agro	Ishwardi	4.6	4550	2.47	
BRRI hybrid dhan7	Aus Bangla Agro	Ishwardi	4.8	4000	2.08	
		Total =	25.4	24760		

Table 16. Amount of parental line and hybrid seeds supplied to different organization during T Aman 2020.

Recipient	No.	F_1 (kg)	A line (kg)	B line (kg)	R line (kg)
Seed Companies	13	400	70	-	25
Farmers	85	688	-	-	-
BRRI Scientists + staffs	20	800	-	-	-
BRRI, R/S (5)+SPIRA	6	500	-	-	-
Total	124	2388	70	0.00	25.00
Grand total				2483 Kg	

Investigator: All staff of hybrid rice division.

Table 17. Amount of parental line and hybrid seeds supplied to different organization.

Recipient	**No.**	**F_1 (kg)**	**A line (kg)**	**B line (kg)**	**R line (kg)**
Seed Companies	24	856.0	1771.00	-	593.00
Farmers	120	1000.0	350.00	-	150.00
BRRI Scientists + staffs +DAE	19	2000.0	-	-	-
BRRI, R/S (5) +SPIRA	6	5020.0	-	-	-
Total	169	8876.00	2121.00	0.00	743.00
Grand total				11740.00	

Investigator: All staff of hybrid rice division.

Table 18. Seed production activities of BRRI developed hybrids during Boro 2020-21 both at private and public sectors.

Organization/person	Location	Var	Area (acre)	Yield achieved (ton)	Remark
Jalal Akand	Babuganj Barishal	BHD3	1.0	1.2	Experienced
Abdur Rahman Agro Company	Muktaghacha, Mymensingh	BHD4	10.0	10.3	Experienced
		BHD5	5.0	4.8	
		BHD6	8.0	10.0	
Ahasan seeds & Agrotech Gaffargaon, Mymensingh	Muktaghacha, Mymensingh	BHD1	1.0	0.8	Experienced
		BHD2	3.0	3.2	
		BHD3	1.0	1.3	
		BHD4	4.0	3.2	
		BHD5	1.0	0.8	
		BHD6	12.0	14.4	
Wazuddin	Chokoria Cox's bazar	BHD3	3.0	2.8	Experienced
American advanced Agro Ltd. Proprietor Kbd Kamrul Haque	Muktaghacha, Mymensingh	BHD3	20.0	24.0	Experienced
		BHD5	5.0	4.5	
		BHD6	10.0	11.0	
Bangladesh Seed Company	Raninagar Naogaon	BHD3	1.0	1.2	Experienced
Sumaya Seed Company	Kurigram	BHD3	2.0	1.8	Experienced
Rashel Seed Store	Domer Nilphamari	BHD2	1.0	1.3	Experienced
		BHD3	1.0	1.2	
		BHD5	1.0	0.7	
Khondokar Shayed Ali Ujirpur Organic Bhahumukhi Somobai Samati Ltd.	Ujirpur	BHD5	1.0	0.6	Experimental
Asha Agro Ltd. Kamarpukur, Md. Abdur Razzak	Nilphamari	BHD5	1.0	0.7	Experienced
Raja Seed Company Md Aminul Islam Razzak	Rangpur	BHD3	1.0	1.2	Experienced
		BHD6	1.0	1.0	
Aftab Bhumukhi Farms Ltd.	Bazitpur Kishoreganj	BHD5	1.0	0.8	Experienced
		BHD6	1.0	1.1	
JF Agro Ltd	Sherpur	BHD3	30.0	36	Experienced
Mohammad Jamaluddin	Bogura	BHD6	6.0	7.5	
Nora Agro Service, Kalibari	Muktagasha	BHD5	5.0	3.75	Experienced
Aus Bangla Agro	Patirajpur, Ishwardi, Pabna	BHD1	1.0	0.8	Experienced
		BHD3	5.0	5.0	
		BHD4	4.5	4.4	
		BHD5	6.5	6.7	
		BHD6	4.6	4.5	
		BHD7	4.8	4.0	
Shajalal Seeds, Naranganj	Sonargao	BHD6	0.5	0.4	Experimental
Metal Seeds Ltd.	Sreepur, Gazipur	BHD3	0.5	0.6	Experienced
		BHD5	0.5	0.4	
		BHD6	0.5	0.7	
BRRI Regional Station	Gopalganj	BHD5	1.0	0.8	Experimental
M/S Champion Seeds	Madhapur	BHD3	0.3	0.2	Experimental
		BHD4	0.3	0.2	
Mojadadia Beej Vander	Assasuni Satkhira	BHD4	1.0	0.9	Experienced
		BHD6	1.0	1.1	
		BHD7	1.0	0.7	
Supreme Seed Company	Muktagasha	BHD6	10.0	11.0	Experienced
M/S Super Discovery Seeds	Gopalganj	BHD3	1.0	1.2	Experienced

Organization/person	Location	Var	Area (acre)	Yield achieved (ton)	Remark
BADC, Kashempur, Madhupur	Kashempur	BHD5	1.5	0.8	Experimental
Md. Jafarulla Chowdhury	Habiganj	BHD5	1.0	0.7	Experimental
Sufala Seed	Rajbari	BHD6	1.0	1.1	Experienced
Durjoy Agro Farms	Muktagasha	BHD3	0.3	0.2	Experimental
ATI	Faridpur	BHD3	1.0	0.5	Experimental
Gazipur, HQ	Gazipur HQ	BHD5	1.0	0.86	Experienced
	BSRI	BHD6	1.5	1.3	
		Total=	**188.3**	**200.2**	

Legend: BHD1= BRRI hybrid dhan1, BHD2 = BRRI hybrid dhan2, BHD3 = BRRI hybrid dhan3, BHD4 = BRRI hybrid dhan4, BHD5 = BRRI hybrid dhan5, BHD6 = BRRI hybrid dhan6, BHD7= BRRI hybrid dhan7

Agronomy Division

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SUMMARY

BR8784-4-1-2-P2 produced the highest grain yield with 114 days growth duration transplanted on 25 of May at Gazipur in T. Aus season. The best planting time for maximum grain yield of BR26, BRRI dhan48 and BRRI dhan82 is 10 May in Aus season. For T. Aman varieties from 10 July to 10 August transplanting with BRRI dhan93 and BRRI dhan94 produced higher grain yield. The highest yield was observed in BRRI dhan89 on 10 January and 1 December transplanting followed by BRRI dhan58 and BRRI dhan74 on 10 January transplanting at BRRI RS, Habiganj. Twenty-five-day-old seedling produced higher grain yield of T. Aman varieties due to lower sterility% compare to other seedling age. In Boro season, significantly higher grain yield (7.19 t ha^{-1}) was observed with 35-day-old seedling followed by 40-day-old seedling. Both BRRI dhan93 and BRRI dhan95 produced similar grain yield in STB treatment as like BRRI recommended dose using 17% less Nitrogen than the other varieties. Appling 100 ppm Nano-ZnO spray at active tillering and heading stages improved the growth of BRRI dhan67 and BRRI dhan88 in rain-out shelter. Nano-ZnO spray increased the grains $panicle^{-1}$ and grain wt. (g/plant) of BRRI dhan67 for both saline and non-saline conditions. Long duration varieties were more responsive to the different management practices than che short duration variety. Mechanically transplanted rice required more N as because of higher field duration with four equal splits and 2/3 MoP as basal and 1/3 MoP should be applied with 3rd top dress of urea. Integrated crop management approach N-P-K (80-10.4-49 kg ha^{-1} might be a good option to produce about 0.5 t ha^{-1} higher yield in T. Aus season than BRRI recommended management. Specific micronutrients (Cu, Si and Fe) did not have any effect on grain yield, rather organic matter cowdung and vermicompost had positive effect to maximize grain yield. Application of organic matter (cowdung/ vermicompost) with recommended doses of fertilizer is the best option to maximize yield. Good agriculture practices (GAP) produced higher grain yield compared to conventional practices in different varieties. T. Aman season, numbers of microorganisms in rice cultivating soil were initially reduced with the application of herbicides but their numbers could be recovered 10-30 days after the applications. But in Boro season, it requires 10-60 days (depending on temperature). The economic N rate appeared as 80, 82 and 74 kg ha^{-1} for BR26, BRRI dhan48 and BRRI dhan82, respectively where initial soil N was 0.15% and organic matter was 1.5%. Four crops system is possible and profitable in stress prone area Alimganj (drought) and Amtoli (salinity) without losing the soil health/ fertility if proper agronomic practices are maintained.

SCIENTIFIC INFORMATION
PLANTING PRACTICES

Effect of planting time on growth and grain yield of advanced lines / popular varieties

The experiment was conducted to determine suitable planting time of potential genotypes suitable for T. Aus; T. Aman and Boro season.

T. Aus season 2020

Determination of optimum planting time of BRRI developed advanced lines

The experiment was conducted at BRRI farm, Gazipur during T. Aus 2020 season to determine the appropriate planting schedule of BRRI developed advanced lines. Four advanced breeding lines (BR9005-53-1-1, BR9006-40-2-3-1, BR8784-4-1-2-P2, and BR8781-16 -1-3-P2) along with three check varieties (BRRI dhan48, BRRI dhan82, and BRRI dhan27) were used as test materials. The 20-day-old rice seedlings were transplanted in the field at three scheduled times i.e. 15th and 25th of May and 5th of June. It was a factorial experiment conducted in a Randomized Complete Block Design with three replications. The field was fertilized with urea, TSP and MoP @135, 52, and 82 kg ha^{-1}, respectively. Maturity of rice occurred at different times irrespective of planting time and test entry. Harvesting was done depending upon the maturity (80%) of the tested entries. Data were analyzed statistically for analysis of variance (ANOVA). The entries BR9005-53-1-1 and BR9006-40-2-3-1 yielded less than the check varieties (BRRI dhan48

and BRRI dhan82) at all the planting times (Table 1). The test entry BR8784-4-1-2-P2 produced higher grain yield than check variety BRRI dhan27 (Table 2). BR8784-4-1-2-P2 yielded the highest with 114 days growth duration transplanted on 25th of May.

Determination of optimum planting time of BRRI developed Aus varieties

Newly released BRRI dhan82 and popular rice varieties BR26 and BRRI dhan48 were planted from 30 April to 1 June with 10 days interval to find optimum planting time at BRRI, Gazipur.

BRRI dhan48 produced the highest grain yield (4.2-5.0 t ha^{-1}) within 111-113 days in all planting time. Higher number of panicles m^{-2}, grains $panicle^{-1}$ and heavier grain contributed to higher grain yield of BRRI dhan48 (Table 3). Ten May planting in all varieties produced higher grain yield compared to other planting dates.

Table 1. Effect of planting time on grain yield and growth duration of advanced lines in T. Aus 2020 season at BRRI, Gazipur.

Line/Variety	15th May		25th May		5th June	
	Yield (t ha^{-1})	GD (day)	Yield (t ha^{-1})	GD (day)	Yield (t ha^{-1})	GD (day)
BR9005-53-1-1	3.569	102	3.622	113	4.044	112
BR9006-40-2-3-1	3.435	101	4.002	111	3.822	114
BRRI dhan48 (ck)	4.422	100	5.618	110	5.935	114
BRRI dhan82 (ck)	3.456	100	4.210	110	4.259	102
$LSD_{(0.05)}$	ns	ns	1.364	ns	0.849	7.738

Table 2. Effect of planting time on grain yield and growth duration of advanced lines in T. Aus 2020 season at BRRI, Gazipur.

Line/Variety	15th May		25th May		5th June	
	Yield (t ha^{-1})	GD (day)	Yield (t ha^{-1})	GD (day)	Yield (t ha^{-1})	GD (day)
BR8784-4-1-2-P2	4.039	113	4.635	116	4.578	114
BR8781-16-1-3-P2	3.823	113	3.277	118	4.135	115
BRRI dhan27 (ck)	3.807	110	3.529	116	3.365	113
BRRI dhan48 (ck)	4.422	100	5.618	110	5.935	114
$LSD_{(0.05)}$	ns	6.448	1.793	7.295	0.883	ns

Table 3. Effect of planting time on grain yield, growth duration, panicle m^{-2} and grains $panicle^{-1}$of BR26, BRRI dhan48 and BRRI dhan82 in Aus 2020 at BRRI, Gazipur.

Variety	30 Apr	10 May	20 May	1st June	30 April	10 May	20 May	1st June
	Grain yield (t ha^{-1})				Duration (day)			
BR26	4.54	4.66	4.24	3.77	116	118	118	117
BRRI dhan48	5.00	5.04	4.63	4.22	111	112	113	113
BRRI dhan82	4.50	4.67	4.02	3.93	104	107	105	107
LSD (0.05)	ns	ns	ns	ns	1.99	1.98	1.48	1.33
CV (%)	15.9	14.7	11.3	16.2	1.0	1.0	1.0	1.0
	Panicle m^{-2}				Grain $panicle^{-1}$			
BR26	271	275	244	231	87	90	89	87
BRRI dhan48	296	298	252	243	90	92	92	92
BRRI dhan82	256	309	262	249	84	86	85	85
LSD (0.05)	ns	ns	ns	ns	3.45	3.32	3.82	4.26
CV (%)	13.2	14.7	10.7	24.4	2.10	2.11	2.12	2.41
	1000 grain weight (g)							
BR26	21.39	21.33	21.62	20.94				
BRRI dhan48	22.38	22.11	23.39	22.54				
BRRI dhan82	21.73	22.26	22.66	22.18				
LSD (0.05)	0.54	0.43	0.38	0.66				
CV (%)	1.3	1.0	1.0	1.50				

Enhancing rice yield by optimizing planting time of newly released T. Aman varieties

The experiment was conducted to determine the effect of variable planting time on the growth and yield of newly released transplanted T. Aman varieties at BRRI, Gazipur, during Aman 2020. The treatments were A. Time of planting, eg. T_1: 10 July, T_2: 25 July, T_3: 10 August, T_4: 25 August, T_5: 10 September; and B. Varieties: V_1: BRRI dhan93, V_2: BRRI dhan94 and V_3: BRRI dhan95. The treatments were distributed in split plot design with three replications (Time of planting in main plot and variety in sub plot).

Results indicated that from 10 July to 10 August transplanting, BRRI dhan93 and BRRIdhan94 produced similar grain yield and growth duration (Table 4). After 10 August grain yield decreasing but growth duration increases gradually. Whereas, in case of BRRI dhan95 growth duration as well as grain yield decreasing from 10 July to 10 September transplanting. BRRI dhan95 produced flowering in October at all transplanting date.

The maximum growing degree day (GDD) was found in BRRI dhan94, whereas the lowest was in BRRI dhan95 (Table 5). BRRI dhan93 showed the highest grain yield in kg ha^{-1} day^{-1} in 25 July transplanting but the lowest was found in 10 September (Table 6).

Effect of planting time on growth and yield of BRRI developed varieties for haor region in Boro season

A study was taken in Boro 2020-21 at BRRI Habiganj station to identify the suitable time of planting and variety for Haor area. The tested eight varieties were BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan84, BRRI dhan88, BRRI dhan89, BRRI dhan28 (ck) and BRRI dhan29 (ck). All the entries were transplanted on five transplanting times such as: 1 December, 10 December, 20 December, 30 December and 10 January 2020-21 in the BRRI RS, Habiganj research field. The experiment was laid down in the split plot design with three replications where five planting dates were in the main plot and eight variety were in the sub-plot. Thirty-day-old seedlings were transplanted on selected dates.

Table 4. Effect of planting time of newly released transplanted Aman varieties on yield in T. Aman 2020 at BRRI farm, Gazipur.

Variety	Grain yield (t ha^{-1})				
	TP1	TP2	TP3	TP4	TP5
BRRI dhan93	4.86 (140)	5.05 (140)	4.53 (143)	4.03 (147)	3.22 (152)
BRRI dhan94	4.94 (141)	5.01 (140)	4.86 (144)	4.24 (148)	3.46 (153)
BRRI dhan95	4.79 (140)	4.65 (135)	4.24 (129)	3.51 (122)	2.87 (116)
$LSD_{(0.05)}$			0.46		
CV%			6.4		

***Growth duration (day) (in the parenthesis)**

Table 5. Effect of planting time of newly released transplanted Aman varieties on GDD in T. Aman 2020 at BRRI farm Gazipur.

Variety	GDD				
	TP1	TP2	TP3	TP4	TP5
BRRI dhan93	4196.1	4101.5	4024.55	3888.25	3794.8
BRRI dhan94	4222.3	4101.5	4043.95	3903.7	3812.6
BRRI dhan95	4196.1	3960.1	3753.6	3519.15	3284.7

Table 6. Effect of planting time of newly released T. Aman varieties on yield (kg ha^{-1} day^{-1}) in T. Aman 2020 at BRRI farm, Gazipur.

Varieties	Yield (kg ha^{-1} day^{-1})				
	TP1	TP2	TP3	TP4	TP5
BRRI dhan93	34.7	36.0	31.7	27.4	21.2
BRRI dhan94	35.0	35.8	33.8	28.6	22.6
BRRI dhan95	34.2	34.4	32.9	28.7	24.7

The result shows that grain yield of tested varieties showed significant difference irrespective of transplanting dates (Table 7). The highest yield was observed from BRRI dhan89 at 10-January and 1 December transplanting followed by BRRI dhan58 and BRRI dhan74 on 10-January transplanting. The lowest grain yield was obtained by BRRI dhan74 on 1-December transplanting and it may be occurred due to early transplanting and cold susceptibility of this variety. In case of growth duration, longer growth duration was observed in early transplanting which was decreased in late transplanting in all varieties; it was due to increased temperature.

Effect of seedling age on tillering dynamics of BRRI varieties and its impact on yield

The experiment was conducted at BRRI HQ farm, Gazipur in T. Aman 2020. Six varieties (V_1 = BRRI dhan87, V_2 = BRRI dhan90, V_3 = BRRI dhan93, V_4 = BRRI dhan94, V_5 = BRRI dhan95 and V_6 = BRRI hybrid dhan6) and four different seedling ages (15, 25 30 and 35 days) were used. Seedlings were transplanted on 31 July 2020. The treatments were distributed in a split plot design, placing varieties in the main plot and seedling age in the sub-plot with three replications.

Results indicated that the number of days of tiller initiation was significantly different among the varieties and seedling age (Table 8). The first tiller appeared in six days with 15-day-old seedling (DOS) in BRRI dhan93, while seven days with 15 DOS in BRRI dhan90, BRRI hybrid dhan6. Tillers appeared within 8-10 days with 25 and 30-day-old seedlings in BRRI dhan87, BRRI dha90, BRRI dha93, BRRI dhan94, BRRI dhan95 and BRRI hybrid dhan6, respectively (Table 8). Interaction effect of variety and seedling age was significant in productive tiller per m^{-2} and grain yield ($P > 0.05$). Total number of productive tillers m^{-2} differed significantly among varieties whereas individual effect of seedling age was not significant (Table 9). Plant height, leaf area index, panicle number m^{-2}, grains $panicle^{-1}$, 1000 grain weight (g) significantly varies among the varieties. Among the seedling age 15-day-old seedling produced the highest tillers in all varieties and BRRI dhan93 had the highest tiller number irrespective of seedling age and was statistically similar to BRRI dhan87. BRRI dhan94 produced the higher grain yield (6.72 t ha^{-1}) followed by BRRI dhan93 (6.04 t ha^{-1}), BRRI

Table 7. Effect of time of planting on grain yield, growth duration and harvesting time of BRRI developed Boro varieties at haor area Boro 2019-20, BRRI RS, farm Habiganj.

Variety name	Grain yield (t ha^{-1})					Harvesting time				
	01-Dec	10-Dec	20-Dec	30-Dec	10-Jan	01-Dec	10-Dec	20-Dec	30-Dec	10-Jan
BRRI dhan28	6.66 (152)	7.05 (145)	7.44 (147)	7.01 (134)	7.05 (136)	4-Apr	4-Apr	13-Apr	16-Apr	25-Apr
BRRI dhan29	8.11 (168)	7.82 (159)	7.75 (159)	8.05 (148)	7.81 (146)	17-Apr	18-Apr	27-Apr	29-Apr	5-May
BRRI dhan58	7.38 (165)	7.25 (157)	7.43 (152)	7.82 (139)	8.41 (139)	14-Apr	16-Apr	18-Apr	23-Apr	28-Apr
BRRI dhan67	7.93 (155)	7.41 (148)	7.36 (145)	8.08 (137)	8.02 (136)	4-Apr	7-Apr	14-Apr	16-Apr	26-Apr
BRRI dhan74	4.70 (154)	7.60 (146)	7.36 (142)	7.19 (135)	7.38 (141)	3-Apr	5-Apr	11-Apr	14-Apr	30-Apr
BRRI dhan84	7.43 (153)	7.79 (144)	7.22 (145)	7.51 (133)	8.37 (135)	2-Apr	3-Apr	12-Apr	14-Apr	24-Apr
BRRI dhan88	6.22 (154)	6.51 (146)	7.64 (149)	7.63 (138)	8.26 (134)	3-Apr	5-Apr	18-Apr	17-Apr	23-Apr
BRRI dhan89	8.60 (168)	7.60 (158)	7.57 (156)	7.76 (148)	8.69 (146)	17-Apr	17-Apr	25-Apr	27-Apr	5-May
LSD $_{(0.05)}$ for Variety = 0.3175 LSD $_{(0.05)}$ for TP Time = 0.1691 LSD $_{(0.05)}$ for V × TP = 0.6850										
CV (%) = 5.79										

*30 days old seedling was used for transplanting, **Growth duration in parenthesis

hybrid dhan6 (5.81 t ha^{-1}), BRRI dhan87 (5.51 t ha^{-1}) and BRRI dhan90 (3.51 t ha^{-1}), respectively. Among the seedling age, 25-30-day-old seedling produced higher grain yield (6.52 t ha^{-1}) followed by 15 days (6.08 t ha^{-1}) and 35-day-old seedling (4.45 t ha^{-1}).

Effect of seedling age on tillering dynamics of BRRI varieties and its impact on yield in Boro

The study was conducted to determine the effect of seedling age on tillering behavioar, dynamics and yield potential of rice. The experiment was conducted at BRRI farm Gazipur in Boro 2020-21. Seven varieties (V_1= BRRI dhan84, V_2= BRRI dhan86, V_3= BRRI dhan88 V_4= BRRI dhan92, V_5= BRRI dhan96, V_6= BRRI hybrid dhan3 and V_7= BRRI hybrid dhan5) and 5 different seedling age (30, 35, 40, 45 and 50 days) were used. The treatments were distributed in a split-plot design, placing varieties in the main plot and seedling age in the sub-plot with three replications.

Table 8. Days required for 1st tiller initiation of tested varieties under different seedling age T. Aman 2020 BRRI Gazipur.

Variety	Days required for 1st tiller initiation			
	15	25	30	35
BRRI dhan87	8	8	9	10
BRRI dhan90	7	8	10	8
BRRI dhan93	6	8	9	8
BRRI dhan94	7	6	8	9
BRRI dhan95	6	7	9	9
BRRI hybrid dhan6	7	6	8	10
LSD $_{(0.05)}$		0.91		
CV%		6.7		

Table 9. Interaction effect of variety and seedling age on growth, yield and yield components in T. Aman 2020 BRRI Gazipur.

Variety	Seedling age (day)	Plant ht. (cm)	LAI	Productive tiller	Panicle m^{-2}	Grains panicle^{-1}	1000 GW (g)	GY (t ha^{-1})
BRRI dhan87	15	119.0	2.41	238	223	109	22	5.19
	25	118.3	4.04	210	196	120	21.1	5.51
	30	120.0	2.44	197	186	124	21.7	4.95
	35	118.0	3.82	198	187	110	21.9	4.64
BRRI dhan90	15	116.1	2.02	208	198	171	9.4	3.49
	25	116.3	2.23	206	197	191	8.4	3.33
	30	117.3	1.78	213	205	156	8.7	3.32
	35	117.0	2.12	202	194	170	8.5	3.51
BRRI dhan93	15	121.3	3.12	256	247	105	18.0	5.71
	25	123.0	3.06	248	239	82	17.0	6.04
	30	121.0	2.87	260	252	107	18.1	4.76
	35	120.6	3.00	257	249	160	18.0	4.94
BRRI dhan94	15	116.6	2.36	206	202	102	17.5	6.08
	25	120.5	4.14	194	188	147	17.0	6.52
	30	117.1	2.37	199	189	145	17.2	6.20
	35	118.0	4.26	197	192	174	18.3	5.15
BRRI dhan95	15	128.1	2.14	237	229	127	19.1	4.59
	25	124.3	2.39	231	221	105	20.8	5.29
	30	126.3	2.84	235	227	122	19.2	5.62
	35	135.0	2.65	237	227	109	20.5	5.09
BRRI hybrid dhan6	15	112.0	3.89	213	189	96	22.9	5.22
	25	118.0	2.99	201	191	76	23.8	5.81
	30	117.3	3.09	209	200	85	23.9	5.63
	35	117.0	3.56	200	196	101	22.6	5.07
$LSD_{0.05}$		NS	NS	18.6	16.3	NS	NS	0.67
CV%		6.4	41.2	5.2	4.7	25.4	6.6	8.0

Results shows that the interaction effect of variety and seedling age was not significant in grain yield and yield components (P> 0.05) but individual effect of variety and seedling age significantly varied. Irrespective of seedling age, there was significant difference among the varieties. Significantly higher tiller m^{-2}, panicle m^{-2}, grain $panicle^{-1}$ and grain yield were observed in BRRI dhan92, higher thousand grain weights (g) and HI were observed in BRRI hybrid dhan3 and BRRI hybrid dhan5. Among the varieties, BRRI dhan92 and BRRI hybrid dhan3 produced the highest yield 7.70 and 7.25 t ha^{-1}, respectively mainly attributed to higher panicle m^{-2}, grains $panicle^{-1}$ and thousand grain weight (Table 10). Statistically similar yield (5.50 and 5.48 t ha^{-1}) was observed in BRRI dhan84 and BRRI dhan88, respectively. BRRI hybrid dhan3 and BRRI dhan96 also produced statistically identical yield (7.18 and 6.85 t ha^{-1}). Irrespective of variety, there were significant difference among different seedling age on tiller m^{-2}, yield and yield components. Younger seedling (35 days) produced the highest tillers followed by 30, 40, 45 and 50-day-old seedling. Significantly higher grain yield (7.19 t ha^{-1}) was observed in 35-day-old seedling followed by 40-day-old seedling. Thirty-five-day-old seedling produced highest grain $panicle^{-1}$ and thousand grain weights (g) followed by 30-day-old seedling (Table 11).

FERTILIZER MANAGEMENT

Effect of Nitrogen management to maximize grain yield of Swarna type varieties in T. Aman season

BRRI recently released swarna type BRRI dhan93 and BRRI dhan95 varieties for Aman season which may require less nitrogen. Hence yield increasing for N management is important for these varieties. The experiment was conducted at BRRI farm, Gazipur, during T. Aman 2020 to find out optimum nitrogen management for Swarna type varieties. The treatments were; A: N rate: N_1 = STB (N-P-K-S= 77-13-47-6 kg ha^{-1}), N_2= STB + 10%, N_3 = STB - 10%, N_4= BRRI Recom. dose (N-P-K-S= 92-12.5-42-10 kg ha^{-1}) and N_5= Control (0 N); and B. Varieties: V_1: BRRI dhan93, V_2: BRRI dhan95 and V_3: BRRI dhan87. The treatments were distributed

Table 10. Tiller m^{-2}, yield components, grain yield and HI of seven rice varieties as influenced by seedling age, Boro 2020-21 BRRI Gazipur.

Variety	Tiller m^{-2}	Panicle m^{-2}	Grain $panicle^{-1}$	1000 GW (g)	GY (t ha^{-1})	Harvest Index
BRRI dhan84	242	234	108	22.0	5.50	0.48
BRRI dhan86	289	280	106	21.3	6.21	0.49
BRRI dhan88	243	235	117	20.9	5.48	0.50
BRRI dhan92	297	287	115	23.6	7.70	0.48
BRRI dhan96	284	275	131	18.4	6.85	0.49
BRRI hybrid dhan3	251	233	110	28.5	7.25	0.49
BRRI hybrid dhan5	235	223	117	27.5	7.18	0.48
$LSD_{(0.05)}$	13.3	12.4	10.57	1.42	0.49	NS
CV (%)	5.0	7.0	8.4	6.3	7.3	6.3

Table 11. Effect of seedling age on tiller m^{-2}, yield components, grain yield and HI, Boro 2020-21 BRRI Gazipur.

Seedling age (day)	Tiller m^{-2}	Panicle m^{-2}	Grain $panicle^{-1}$	1000 GW (g)	GY (t ha^{-1})	HI
30	273	263	117	23.13	7.09	0.46
35	282	255	121	23.40	7.19	0.47
40	262	253	119	23.07	6.75	0.47
45	255	250	111	22.90	6.26	0.48
50	244	243	106	22.50	5.69	0.48
$LSD_{0.05}$	8.15	10.97	5.94	0.89	0.29	NS
CV(%)	5.3	7.3	8.2	6.1	7.3	6.1

in split plot design with three replications (Nitrogen management in main plot and variety in sub plot). Urea quantity was calculated on the basis of initial soil analysis. Chemical properties of initial soil were: pH= 6.2, OM (%)= 1.34, Total N (%)= 0.13, Available P= 10.3, Exchangeable K= 0.15, S=22.3.

Result indicated that BRRI dhan93 and BRRI dhan95 produced higher grain yield on STB treatment which is similar with STB + 10% and BRRI recommended dose (Table 12) and consequently panicle m^{-2} also higher in both treatments (Table 13). Grain yield showed significantly higher value than STB and control treatment. On the other hand, BRRI dhan87 produced higher yield in BRRI recommended dose, which was also similar to the STB and STB + 10% treatment. So both BRRI dhan93 and BRRI dhan95 produced similar yield in STB treatment as like BRRI recommended dose.

Table 12. Effect of Nitrogen management of Swarna type varieties on grain yield in T. Aman 2020 at BRRI farm Gazipur.

Treatment	BRRI dhan93	BRRI dhan95	BRRI dhan87
N_1: STB	5.22	5.20	4.24
N_2: STB+10%	5.15	5.09	4.64
N_3:STB-10%	4.50	4.62	3.95
N_4: BRRI recommended dose	4.94	4.88	4.79
N_5: Control	3.19	3.02	2.63
$LSD_{(0.05)}$		0.56	
CV%		7.6	

Table 13. Effect of Nitrogen management of Swarna type varieties on panicle number m^{-2} in T. Aman 2020 at BRRI farm Gazipur.

Treatment	BRRI dhan93	BRRI dhan95	BRRI dhan87
N_1: STB	234	230	190
N_2: STB+10%	222	219	206
N_3:STB-10%	197	204	177
N_4: BRRI recommended	219	209	212
N_5: Control	154	146	127
$LSD_{(0.05)}$		20.53	
CV%		6.1	

Application of nano-zinc oxide to improve salt tolerant Aman rice

Nanotechnology has a possibility to help the plants ready to tolerate biotic and abiotic stress. ZnO is considered to be safe and secure chemicals. Zinc oxide-nanoparticles have many benefits on soil fertility, which is an important micro element for enhancing plant growth and protection. Although the effects of soil and foliar application of Zn on plant yield have evaluated, few studies are available about its effects in salt tolerance plants as nano forms of ZnO. So, the experiment was taken to investigate the effect of nano-zinc oxide on growth and yield of rice under saline condition. A pot experiment was conducted at rain-out shelter of Agronomy Division, BRRI, Gazipur in T. Aman, 2020 season. The pots were set as split-split plot design with three replications. The main plots represented two salinity levels; i. 0 mM NaCl ii. 75 mM NaCl (Approximately 8 ds m^{-1}). Sub-plots represented two concentrations of nano-zinc oxide; i. 0 ppm ii. 100 ppm. Sub-sub plots represented two variety of rice; i. BRRI dhan73 ii. BRRI dhan87. Nano-zinc oxide was prepared in Agronomy laboratory of BRRI and sprayed two times at active tillering and at heading stage.

Results showed that (Table 14) BRRI dhan87 gave higher yield compare to BRRI dhan73 for all kind of treatments. In 0 mM salinity level BRRI dhan73 produced higher grains $panicle^{-1}$ than BRRI dhan87 but in 75 mM salinity level BRRI dhan87 produced higher grains $panicle^{-1}$ than BRRI dhan73. Sterility% found higher in BRRI dhan73 than BRRI dhan87 for all the combination of treatments. In 0 mM salinity level 100 ppm Nano-Zn oxide spray produced lower grains $panicle^{-1}$ and higher sterility% than non-spray plant in both BRRI dhan73 and BRRI dhan87. That means prepared nano-zn oxide adversely affect in grain filling. Panicle $hill^{-1}$ was not significantly affected for salinity and nano-Zn spray. In 75 mM salinity level 100 ppm Nano-Zn oxide spray did not improve the growth and yield of both varieties.

BRRI dhan73 can tolerate up to 8 ds m^{-1} (Approximately 75 mM) salinity level, but from present experimental results it was found that both BRRI dhan73 and BRRI dhan87 could not tolerate that level of salinity. Prepared nano-Zn could not improve the growth and yield of those variety.

Table 14. Effect of salinity and Nano-Zn oxide spray on BRRI dhan73 and BRRI dhan87 in T. Aman 2020 BRRI Gazipur.

Salinity level	Nano-Zn oxide	Variety	Panicle hill^{-1}	1000 GW(g)	Grain panicle^{-1}	Yield (g pot^{-1})	Sterility%
0 mM	0 ppm	BRRI dhan73	18	20.9	174	59.88	17.4
		BRRI dhan87	22	23.2	148	69.09	9.7
	100 ppm	BRRI dhan73	16	20.1	162	46.01	25.7
		BRRI dhan87	21	23.6	131	59.80	18.3
75 mM	0 ppm	BRRI dhan73	19	15.1	32	7.69	70.1
		BRRI dhan87	20	16.9	35	10.89	57.4
	100 ppm	BRRI dhan73	18	15.8	40	10.19	61.3
		BRRI dhan87	21	17.2	49	14.94	49.9
LSD $_{(0.05)}$			3.97	1.44	15.86	8.44	14.53
CV%			8.36	4.82	3.56	9.51	12.64

Application of nano-Zinc oxide to improve salt solerance in Boro rice

The experiment was taken to investigate the effect of nano-zinc oxide on growth and rice yield under salinity stress. A pot experiment was conducted at rain-out shelter of Agronomy Division, BRRI, Gazipur in Boro 2020-21. The pots were set assplit-split plot design with three replications. The main plots represented two salinity levels; i. 0 mM NaCl ii. 50 mM NaCl (Approximately 5.25 ds m^{-1}). Sub-plots represented two concentrations of nano- zinc oxide; i. 0 ppm ii. 100 ppm. Sub-sub plots represented two variety of rice; i. BRRI dhan67 ii. BRRI dhan88. Nano-zinc oxide sprayed two times at active tillering and at heading stage. Forty-day-old seedlings were transplanted using two seedlings per hill on 25 January 2021.

In both the varieties 50 mM salinity level reduced panicle hill^{-1} and 1000 GW TGW and it was found that, there was no effect of Nano-ZnO spray in panicle hill^{-1} and TGW. Sterility% found much higher in BRRI dhan88 than BRRI dhan67 for all treatment combinations. Grain panicle^{-1} were not significantly influenced for different treatments in BRRI dhan88 (Table 15). Yield reduction occurred due to salinity and nano-ZnO spray could not increase the yield of BRRI dhan88. But in BRRI dhan67 grain panicle^{-1} and yield reduced in saline condition but with 100 ppm Nano-ZnO application grain panicle^{-1} and yield increased in both saline and non-saline condition. In 50 mM salinity level BRRI dhan67 produced 50.4% higher yield with 100 ppm nano-ZnO spray than without spray. But in 0 mM salinity level BRRI dhan67 produced 21% higher yield with 100 ppm nano-ZnO spray than without spray.

Nano-ZnO spray increased the grain panicle^{-1} and yield of BRRI dhan67 for both saline and non-saline condition. In BRRI dhan88 it was found that nano-Zn spray could not improve the yield.

Table 15. Effect of salinity and Nano-Zn oxide spray on BRRI dhan67 and BRRI dhan88 in Boro 2020-21 BRRI Gazipur.

Salinity level	Nano-Zn oxide	Variety	Panicle hill^{-1}	Grains panicle^{-1}	1000 GW(g)	Yield (g pot^{-1})	Sterility%
0 mM	0 ppm	BRRI daha67	12	103	21.5	22.82	2.5
		BRRI dhan88	13	59	20.9	12.41	15.3
	100 ppm	BRRI daha67	12	133	20.6	27.62	2.3
		BRRI dhan88	12	70	20.5	13.45	18.9
50 mM	0 ppm	BRRI daha67	8	77	18.9	10.09	4.0
		BRRI dhan88	8	66	19.8	7.92	12.3
	100 ppm	BRRI daha67	9	107	18.9	15.18	3.6
		BRRI dhan88	8	64	19.7	7.74	14.5
LSD$_{(0.05)}$			2.66	11.74	1.80	3.19	9.09
CV%			9.13	6.87	4.94	11.38	13.1

Growth and yield improvement of T. Aman rice in charland ecosystem through integrated nutrient management

The study was carried out to determine an economically viable fertilizer management for growth and yield of rice in Charland area. The experiment was conducted at BRRI RS, Sirajganj farm during T. Aman 2020. The experimental design was RCBD with three replications. The treatment was included inorganic and organic combinations of nutrient management and varieties. The nutrient management treatments were: T_1 = Control (No fertilizer), T_2 = Recom. dose of fertilizer (RDF) (N-P-K-S @ 69-10.4-41-10.8 kgha^{-1}) , T_3 = Vermicompost (1 t ha^{-1}) + 50% of RDF , T_4 = Cowdung (5 t ha^{-1}) + 50% of RDF , T_5 = AEZ Based Fertilizer Dose (N-P-K-S-Zn@ 76-15-42.5-8.1-1.8 kg ha^{-1}), T_6 = Tricho-compost (2 t ha^{-1}) + 50% of RDF, T_7 = Poultry Manure (3 t ha^{-1}) + 50% of RDF). Initial soil status of the experimental field was pH= 6.9, Total N (%)= 0.10, OC (%)= 1.035, OM (%)= 1.8, P= 9.15 ppm, K= 0.14 me/100g, S= 19.65 ppm and Zn= 7.3 ppm.

Result shows that higher grain yield of 6.60 and 6.27 t ha^{-1} was observed in BRRI dhan87 with recom. Dose of fertilizer (RDF) (N-P-K-S @ 69-10.4-41-10.8 kg ha^{-1}) followed by treatment T_4 (cow dung @5 t ha^{-1}) + 50% of RDF 75%). Significantly higher grain yield was found in T_2 and T_4 treatments compared to the other treatments due to higher number of panicles and more grains panicle^{-1}. Lower grain yield (4.26 tha^{-1}) was found in control (Table 16).

Effect of nitrogen and potassium fertilizer management on growth and yield of mechanically transplanted Boro rice

An experiment was conducted to adjust N and K management schedule for optimum growth and yield of mechanically transplanted rice. It was hypothesized that modified N and K management increases the rice grain yield. The experiment was conducted to determine the suitable N and K fertilizer management option for mechanically transplanted rice in BRRI farm, Gazipur during Boro 2020-21 with BRRI dhan89.

The treatments were M_1 (N-P-K-S-Zn)= 138-20-82-20-3.6 kg ha^{-1} (BRRI recommended fertilizer), M_2 (N-P-K-S-Zn)= 160-20-82-20-3.6 kg ha^{-1} (Urea four equal splits and Mop 2/3 basal and 1/3 with 3rd top dress of urea), M_3 (N-P-K-S-Zn) = 150-18-82-20-3.6 kg ha^{-1} (Urea four equal splits and Mop 2/3 basal and 1/3 with 2nd top dress urea) and M_4= Traditional transplanting with BRRI recommended fertilizer (N-P-K-S-Zn= 138-20-82-20-3.6 kg ha^{-1}). The experiment was conducted following RCB design with four replications. Twenty-three-day-old tray mat seedlings were used for mechanical transplanting. For traditional transplanting 45-day-old seedlings were transplanted. Chemical properties of initial soil was: soil pH= 6.2, OM (%)= 1.35, Total N (%)= 0.13, Available P= 9.8 and Exchangeable K= 0.15.

Table 17 shows that the treatments effects were not significant. Similarly panicle per m^2 and grains per panicle were significantly higher in M_2 treatment. The highest grain yield was observed in M_2 treatment (7.70 t ha^{-1}).

Table 16. Yield and yield components of BRRI dhan87 as influenced by integrated nutrient management at BRRI regional station, Sirajgonj farm.

Treatment	Panicles m^{-2}	Grains panicle^{-1}	1000 grain wt. (g)	Grain yield (t ha^{-1})
Nutrient Management				
T_1	185	96	23.0	4.26
T_2	239	117	23.6	6.60
T_3	221	121	23.6	6.15
T_4	202	126	24.3	6.27
T_5	218	113	23.9	6.12
T_6	232	110	23.4	5.96
T_7	237	104	23.5	5.99
$LSD_{(0.05)}$	32.3	14.6	NS	0.96
CV (%)	8.3	7.3	3.1	9.1

T_1 = Control (No fertilizer), T_2 = Recom. Dose of Fertilizer (RDF) (N-P-K-S @ 69-10.4-41-10.8 kg ha^{-1}) , T_3 = Vermicompost (1 t ha^{-1}) + 50% of RDF , T_4 = Cowdung (5 t ha^{-1}) + 50% of RDF, T_5 = AEZ Based Fertilizer Dose (N-P-K-S-Zn@ 76-15-42.5-8.1-1.8 kg ha^{-1}), T_6 = Tricho-compost (2 t ha^{-1}) + 50% of RDF, T_7 = Poultry Manure (3 t ha^{-1}) + 50% of RDF.

Table 17. Growth and yield of mechanically transplanted rice with different fertilizer management compared with traditional transplanted rice.

Treatment	CGR (g m^{-2}) at MT	Panicle m^{-2}	Grains $panicle^{-1}$	1000 GW (g)	GY (t ha^{-1})
M_1	30.36	309	92	24.35	6.96
M_2	36.50	336	101	24.76	7.70
M_3	34.36	316	95	24.47	7.27
M_4	23.23	311	94	24.45	7.10
$LSD_{(0.05)}$	ns	18.36	2.93	0.17	0.30
CV (%)	21.1	3.6	1.90	0.5	2.6

YIELD MAXIMIZATION

Yield maximization of T. Aus rice through integrated crop management

The experiment was conducted at BRRI farm Gazipur during T. Aus season 2020. The experiment was conducted following factorial RCB design with three replications. Three managements were: M_1= BRRI recommended fertilizer N-P-K (69-10.4-41 kg ha^{-1} and 2 seedlings $hill^{-1}$), M_2 = Integrated crop management N-P-K (80-10.4-49 kg ha^{-1} and 4 seedlings $hill^{-1}$) (Urea two splits 15% higher than M_1 at 15 DAT, 2nd split at 35 DAT and Mop 2/3 basal and 1/3 with 2nd top dress urea) and M_3 (Farmer's practice)= N-P-K (69-0-33 kg ha^{-1} and 2 seedlings $hill^{-1}$). The used varieties were BRRI dhan48 and BRRI dhan82. Initial soil status of the experimental field was pH= 6.4, N= 0.14%, P= 8.1 ppm, K= 0.21 me/100g, S= 24.1 ppm and Zn= 4.2 ppm.

Grain yield and yield components of BRRI dhan48 and BRRI dhan82 as affected by crop management were presented in Table 18. Interaction effect of variety and crop management was not significant, but individual effect of variety and nutrient management significantly varied. Irrespective of crop management, panicle m^{-2}, grains $panicle^{-1}$ and grain yield was significantly influenced by varieties. Significantly higher yield (5.22 t ha^{-1}) and yield components were observed in BRRI dhan82. Higher grain yield of ICM (5.49 t ha^{-1}) over BRRI recommended fertilizer and farmers practice was mainly attributed to higher grains $panicle^{-1}$, which was caused by the difference in panicles per m^2 and sterility (%) among the three treatments (Table 18). Thousand grain weight (g) and straw yield did not differed significantly among the treatments. The yield of BRRI dhan48 was lower than BRRI dhan82 due to bacterial leaf blight infestation before maturity. Integrated crop management approach (M_2) might be a good option to produce about 0.5 t ha^{-1} higher yield in Aus season than BRRI recommended management.

Table 18. Yield and yield components of BRRI dhan48 and BRRI dhan82 as affected by integrated crop management at BRRI farm Gazipur.

Variety	Panicle m^{-2}	Grain $panicle^{-1}$	1000 GW (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Sterility %
V_1	273	76	22.8	4.55	5.61	34.8
V_2	266	88	22.5	5.22	5.52	35.3
Crop Management (CM)						
BRF	272	82	22.4	5.01	5.59	34.6
ICM	280	87	22.8	5.49	5.51	32.7
FP	257	77	22.2	4.36	5.58	37.9
$LSD_{(0.05)}$ for V	NS	NS	NS	0.57	NS	9.89
$LSD_{(0.05)}$ for CM	15.19	NS	NS	0.70	NS	12.1
$LSD_{(0.05)}$ for V×CM	NS	NS	NS	NS	NS	NS
CV (%)	4.4	16	2.5	11.2	11.7	26.8

M_1= BRRI recommended fertilizer dose (N-P-K@69-10.4-41 kg ha^{-1} and two seedlings $hill^{-1}$), M_2 = Integrated crop management; (N-P-K@ 80-10.4-49 kg ha^{-1} and 4 seedlings $hill^{-1}$) (Urea two splits 15% higher than M_1 at 15 DAT, 2nd split at 35 DAT and Mop 2/3 basal and 1/3 with 2nd top dress urea) and M_3 (Farmer's Practice)= (N-P-K @69-0-33 kg ha^{-1} and 2 seedlings $hill^{-1}$); V_1= BRRI dhan48 and V_2= BRRI dhan82.

Effect of micronutrient and organic matter for growth and yield maximization of Boro rice

The study was taken to investigate the effect of micronutrients viz Zn, Cu, Mn along with NPK and additional organic matter on growth and yield of rice (BRRI dhan89). The objective of the study was to identify i) role of micronutrient for enhancing the growth and yield of rice and ii) the best combination of organic and inorganic fertilizer for yield maximization. The experiment was conducted at BRRI farm, Gazipur in Boro 2020-21. BRRI dhan89 was the test variety. There were five inorganic fertilizer treatments which included micronutrients in main plot and organic matter in the subplots. The treatments were as follows: A. Main plot (Inorganic fertilizer) :T_1 = Control (No fertilizer) ,T_2 = Recommended dose of fertilizer (RDF) (N-P-K-S-Zn @120-19.4-84-20- 4 kg ha^{-1}) , T_3 = NPKS + Zn from $ZnSO_4$ (4 kg ha^{-1}) (additional 4 kg ha^{-1} Zn), T_4 = NPKS + Zn + Cu from $CuSO_4.5\ H_2O$ (2 kg ha^{-1}) and T_5 = NPKS + Zn + Cu + Mn from $MnSO_4$, H_2O (3 kg ha^{-1}). B. Sub plot (Organic fertilizer): 1. No organic matter 2. Cowdung @ 1.5 t ha^{-1} 3. Vermicompost @ 0.5 t ha^{-1}. All the micronutrient treatments were applied at maximum tillering stage and organic matter (dry basis) was applied four days before transplanting.

The interaction effect of inorganic fertilizer (micronutrients) and organic fertilizer was not statistically significant. Table 9 discusses the individual effect of micronutrients and organic matter. Inorganic fertilizer differed significantly in yield and yield characters. Among the treatments, T_5 produced the highest yield (8.23 t ha^{-1}) and control treatment produced the lowest yield (4.81 t ha^{-1}). The treatments received micronutrients (Zn, Cu, Mn,) (T_2-T_4) produced statistically similar yield (7.99- 8.12 t ha^{-1}). Higher yield of these treatments was due to higher number of panicle, grains and TGW. Soil in the experimental plot supplied sufficient amount of micronutrients. So that the effect of micronutrient applied did not show any yield advantages.

Individual effect of organic matter significantly differs in case of grain yield. Applied organic matter cowdung and vermicompost produced significantly higher yield of 7.58 and 7.77 t ha^{-1} respectively. Application to micronutrients in association with NPKS showed better performance in respect to grain yield and yield components of BRRI dhan89. But any specific micronutrient did not have any precise influence on grain yield, rather organic matter like cowdung and vermicompost have positive influence to maximize grain yield.

Maximizing yield of BRRI developed new varieties through manupulating some Agronomic factors in Boro season

A study was taken at BRRI farm, Gazipur to find-out the effect of Agronomic critical factors for yield maximization of newly BRRI developed varieties in Boro 2020-21.

Different Agronomic critical factors based six management practices were considered as factor A: such as M_1= BRRI recommended practices, M_2= Agronomic critical factors based proposed

Table 19. Effect of micronutrient and different organic matter on yield and yield characters of BRRI dhan89, Boro 2020-21, BRRI Gazipur.

Treatment	Panicle m^{-2}	Grain $panicle^{-1}$	1000 Grain weight (g)	Sterility (%)	Grain yield (t ha^{-1})
Micronutrient					
T_1	273	88	23.34	15.30	4.81
T_2	325	101	24.12	16.71	8.12
T_3	327	104	24.30	17.82	8.04
T_4	326	106	24.37	15.79	7.99
T_5	329	109	24.43	17.15	8.23
LSD $_{(0.05)}$	6.23	6.23	0.11	ns	0.49
Organic Matter					
No organic matter	295	97	20.62	16.53	6.97
Cowdung	325	103	20.77	16.63	7.58
Vermicompost	327	104	20.65	17.01	7.77
LSD $_{(0.05)}$	4.82	2.18	0.91	ns	0.38
CV (%)	2.0	2.9	1.0	16.7	6.8

treatment, M_3= Agronomic critical factors based proposed treatment, M_4= Agronomic critical factors based proposed treatment, M_5= Agronomic critical factors based proposed treatment and M_6= Agronomic critical factors based proposed treatment. The varieties were: V_1= Short duration (BRRI dhan88), V_2= Long duration (BRRI dhan89) and V_3= Check variety (BRRI dhan29). Other recommended agronomic management were followed as and when necessary. Split plot design was followed where management in main plot and variety was in sub plot.

Results showe that significant yield differences were observed among the treatments (Table 20). The highest grain yield was observed in case of BRRI dhan89 in management M_3 treatment followed by BRRI dhan29 in management M_5 than BRRI dhan29 in management M_1. It was observed that long duration varieties were more responsive to the different management practeecs than short the duration variety. Long duration two varieties produced identical higher yield irrespective of short duration variety in all management treatments. Short duration variety produced highest grain yield in management M_3 followed by M_4.

Yield maximization of Boro rice through good agricultural practice (GAP)

Among the GAP components few were evaluated on three rice varieties. The varieties were BRRI dhan89, BRRI dhan88 and BRRI dhan50. Good agricultural practice (GAP) and conventional management were considered as treatments. Management of GAPs were a) Soil test based fertilizer (N,P,K,Zn), b) Alternate wetting and drying (AWD), c) BRRI weeder at 20 DAT + 1 HW at 45 DAT, d) Integrated insect and disease management. Conventional management were: a) BRRI recommended fertilizer, b) Normal irrigation practice, c) Herbicide at 8 DAT + 1 HW at 45 DAT, d) Insect and disease management by applying pesticide. Factorial RCB design was followed in the exacrineul with three replications during Boro 2020-21 at BRRI farm, Gazipur.

Table 21 shows that the interaction effects of varieties and management were non-significant on grain yield and yield components. Individual effect of varieties differed significantly on yield and yield components but management had no significant effect on grain yield and yield components. But GAP management showed higher yield. Higher grain yield was observed in BRRI dhan89×GAP (7.72 t ha^{-1}). BRRI dhan88 and BRRI dhan50 also produced higher yield with GAPs. Higher grain yield was supported by higher number of panicle m^{-2}, grains $panicle^{-1}$ and TGW. Although interaction effect of variety and management was significant but the management effect was insignificant.

Table 20. Effect of Agronomic critical factors for maximizing grain yield of BRRI developed new varieties in Boro seasons at BRRI farm, Gazipur.

Management	V1=BRRI dhan88	V2=BRRI dhan89	V3=BRRI dhan29
M_1	6.09	7.8	7.93
M_2	6.56	7.76	7.83
M_3	7.20	8.29	7.66
M_4	6.86	7.49	7.35
M_5	6.02	7.67	7.95
M_6	6.27	7.8	7.7

$LSD_{(0.05)}$ for Variety = 0.4025
$LSD_{(0.05)}$ for Management = 0.6826
$LSD_{(0.05)}$ for V × M = 1.0548

CV(Rep*Management*Variety) = 7.96

Table 21. Yield and yield characters of BRRI varieties as affected by two management practices at BRRI farm Gazipur during Boro 2020-2021.

Variety (V)	Management (M)	Panicle m^{-2}	Grain Panicle^{-1}	1000 GW (g)	GY (t ha^{-1})	SY (t ha^{-1})
BRRI dhan89	GAP	292	110	24.21	7.72	8.95
	TM	288	102	24.14	7.32	8.79
BRRI dhan88	GAP	240	93	22.86	6.58	7.78
	TM	230	91	22.69	6.34	7.42
BRRI dhan50	GAP	280	83	21.82	5.75	7.13
	TM	278	76	21.56	5.51	6.75
LSD $_{(0.05)}$ for V		10.43	7.42	0.26	0.41	0.47
LSD $_{(0.05)}$ for M		ns	ns	ns	ns	ns
LSD $_{(0.05)}$ for V × M		15.19	9.68	0.39	0.58	0.68
CV (%)		3.2	5.44	1.0	5.0	4.9

GAP=Good agricultural practices,CM= Conventional BRRI recommended management

PROJECT ACTIVITIES

Determination of economic Nitrogen rate for popular transplanted Aus rice varieties (Crop modelling and weather forecasting Project)

The experiment was conducted at BRRI farm Gazipur in Aus season, 2020. Ddifferent N rates N_0, N_{40}, N_{60}, N_{80} and N_{100} were applied in BR26, BRRI dhan48 and BRRI dhan82. The experiment was conducted following factorial RCB design with three replications. 20-day-old seedlings were transplanted on 7 May 2020.

The interaction effect of variety and N fertilizer rate was not significant in grain yield and yield components but significant in individual effect of variety and N rates (Table 22). The highest grain yield of 5.46 t ha^{-1} was produced in BRRI dhan48 followed by BR26 (5.00 t ha^{-1}) with N_{80} treated plots. The grain yields of different varieties in different nitrogen levels would be explained by its panicle density, grains panicle^{-1} and 1000 grain weight. The variation of grain yield of BR26, BRRI dhan48 and BRRI dhan82 at different nitrogen rates was determined through regression equation (Fig 1).

Table 22. Growth, yield and yield components of BR26, BRRI dhan48 and BRRI dhan82 as affected by different N rates T. Aus 2020 BRRI farm, Gazipur.

Variety	N rate (kg ha^{-1})	Panicle m^{-2}	Grain Panicle^{-1}	1000 GW (g)	GY (t ha^{-1})
BR26	N_0	214	66	21.07	2.62
	N_{40}	220	85	21.52	3.76
	N_{60}	258	92	21.66	4.81
	N_{80}	279	94	21.63	5.00
	N_{100}	245	90	21.42	4.43
BRRI dhan48	N_0	186	69	22.89	2.79
	N_{40}	226	85	23.34	4.00
	N_{60}	248	91	23.39	4.97
	N_{80}	263	97	23.65	5.46
	N_{100}	230	96	23.42	4.70
BRRI dhan82	N_0	151	71	22.69	2.35
	N_{40}	189	84	22.81	3.47
	N_{60}	235	92	23.13	4.64
	N_{80}	218	96	23.11	4.59
	N_{100}	207	92	22.76	4.06
LSD $_{(0.05)}$ for V		16.61	1.53	0.17	0.21
LSD $_{(0.05)}$ for N rate		21.45	1.98	0.23	0.26
LSD $_{(0.05)}$ for V × N rate		ns	ns	ns	ns
CV (%)		9.9	2.05	1.0	6.7

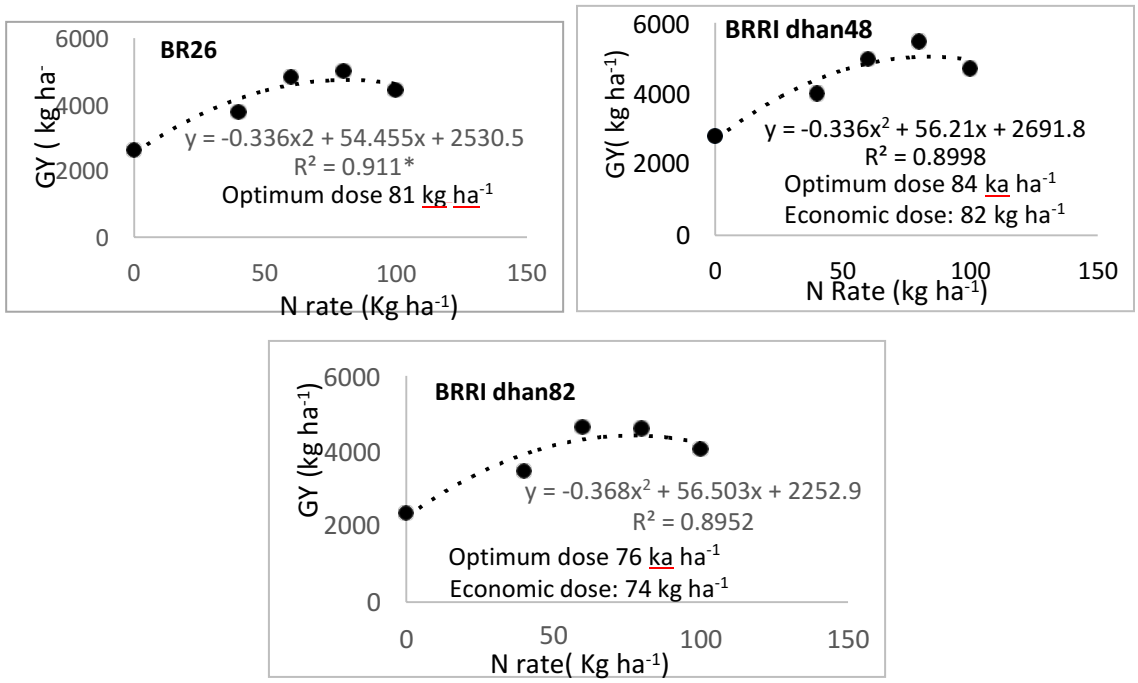

Fig 1. Determination of optimum and economic nitrogen rate of different Aus varieties, T. Aus 2020 BRRI farm, Gazipur

Differentiating the quadratic equation of yield response with respect to applied N doses the optimum N rate and economic N rate appeared as 81, 80 kg ha^{-1} for BR26, 84 and 82 kg ha^{-1} for BRRI dhan48 and 76 and 74 kg ha^{-1} for BRRI dhan82, respectively. After calculation of regression model the economic N rate appeared as 80, 82 and 74 kg ha^{-1} for BR26, BRRI dhan48 and BRRI dhan82, respectively where initial soil total N was 0.15% and organic matter was 1.5%.

BRRI'S Agronomy Division development and research strengthening program

Improvement of soil health in four crops pattern through agronomic management

When 3 to 4 crops are grown in rice based cropping system, nutrient management is a crucial issue. It is difficult to maintain soil health when intensive crop cultivation is going on. Considering the above facts, present study was taken in farmers' field at Alimganj, Rajshahi and Amtoli, Borguna, from Kharip I to improve the soil health and to increase the cropping intensity and productivity.

Cropping pattern o be followed:

Mungbean (BARI Mung-6)- T. Aus (BRRI dhan48)-T. Aman* -Potato (Cardinal)

(*BRRI dhan56 in Amtoli and BRRI dhan71 in Alimgonj)

Agronomic management:

1. Incorporation of mungbean stubble with soil before T. Aus

2. Incorporation of poultry manure/ vermicompost @ 1.5 t ha^{-1} with soil before potato sowing

3. Recommended dose of chemical fertilizers will be applied for all crops as per schedule

At Alimganj, the yield of BRRI dhan48 in T.Aus, BRRI dhan71 in T. Aman and potato were satisfactory. But the yield of mungbean was very poor due to poor germination/ establishment.

At Amtoli, the yield of all crops were not satisfactory due to poor management in rice and potato. Heavy rainfall during T. Aman harvest delayed potato sowing and heavy rainfall after sowing of potato hampered the crop growth. But the growth and yield of mungbean was excellent (Table 23).

Productivity was compared at Alimgonj and Amtoli by calculating rice equivalent yield of 4 crops systems and farmers' existing practice. The highest REY was obtained (28.24 t ha^{-1}) at Alimganj while farmers' practice was only 4.15 t ha^{-1} (one rice: late Aus and early Aman). But at Amtoli, four crops systems obtained 17.86 t ha^{-1} while 14.85 t ha^{-1} in farmers' practice in that particular year (Table 27). Normally, farmers are growing only Aus and Aman rice. Sunflower cultivation was imposed by another project which was not regular practice of that area.

In case of economic analysis, net profit (Tk./bigha) was 26,660/- in Alimganj in four crops system while only 2,433/- in farmers' practice. On the other hand, at Amtoli, 15,425/- was in four crops system while 13,550/-was in farmers' practice- which was very close (Table 28).

Table 23. Yield of different crops in four crops systems in different locations, 2019-20.

Crop	Field duration	Variety	Yield (t ha^{-1})	Remark
Alimgonj, Rajshahi				
T. Aus	15 May to 10 Aug 2019	BRRI dhan48	4.25	-
T. Aman	15 Aug to 10 Nov 2019	BRRI dhan71	4.75	Poor management
Potato	25 Nov 19 to 22 Feb 2020	Cardinal	22.45	Rat damage
Mungbean	25 Feb 2020 (Sowing)	BARI mung6	-	Poor germination
Amtoli, Borguna				
T. Aus	15 May 19 to 10 Aug 2019	BRRI dhan48	4.43	-
T. Aman	15 Aug to 15 Nov 2019	BRRI dhan56	3.75	Damaged by Bulbul
Potato	1 Dec 19 to 16 Feb 2020	Cardinal	6.75	Late sowing & submergence
Mungbean	25 Feb to 21 and 30 Apr 2020	BARI mung6	1.15	-

Table 27. Productivity of different crops in 4 crops Systems in different locations, 2019-20

Alimganj, Rajshahi.

Cropping pattern	1st crop	2nd crop	3rd crop	4th crop	REY/productivity
4 crops systems	4.25	4.75	22.45~20.72	-	28.24
Farmers' practice	-	4.15*	-	-	4.15
(22.45 t/ha potato = 20.72 t/ha rice, Rice = Tk 16.25/kg, Potato = Tk 15/kg, *only one crop (late Aus and early Aman).					
Amtoli, Borguna					
4 crops systems	4.43	3.75	6.75	1.15~3.45	17.86
Farmers' practice	4.00	4.50	2.40~7.20	-	14.85
(6.75 t/ha potato=6.75 t/ha rice, 1.15 t/ha Mungbean=3.45 t/ha rice, 2.4 t/ha Sunflower=7.2 t/ha rice; Rice=Tk 15/kg, potato=Tk 15/kg, Mungbean=Tk 45/kg, Sunflower=Tk 45/kg)					

Table 28. Economic analysis of four crops compared to farmers' practice 2019-20

Alimganj, Rajshahi.

Crop	Yield (t/ha)	Input cost (Tk/Bigha)	Gross return (Tk)	Net profit (Tk)	REY	Remark
T. Aus	4.25	9,395	12,500	3,105	4.25	Damaged by duck
T. Aman	4.75	9,105	13,160	4,055	4.75	Damaged by duck
Potato	22.45	24,900	46,000	21,100	19.24	Rat damage
Mungbean	0	1,600	0	-1,600	-	Damaged (poor germination and high weed infestation)
Total	-	45,000	71660	26,660	28.24	
Control						
T. Aman	4.15	8,400	10,833	2,433	4.15	Only one rice

(Price of rice= Tk 700/mound, Price of potato= Tk 600/mound)

Amtoli, Barguna 2019-20

Crop	Yield (t/ha)	Total input cost (Tk/Bigha)	Gross return (Tk/Bigha)	Net profit (Tk/Bigha)	REY	Remark
T. Aus	4.43	5,710	9,260	3,550	4.43	
T. Aman	3.75	5,700	9,125	3,425	3.75	Lodging (Bulbul)
Potato	6.75	9,000	13,500	4,500	6.23	Poor crop mgt. & rain
Mungbean	1.15	2,350	6,300	4,950	3.45	
Total	-	22,760	38,185	15,425	17.86	
Control						
T. Aus	4.00	5,500	9,000	3,500	4.00	Gota IRRI
T. Aman	4.50	5,700	10,750	5,350	4.50	BR23
Sunflower	2.40	5,900	10.900	5,000	6.35	Hysun (hybrid)
Total	-	16,900	28,750	13,550	14.85	

(Price of rice=Tk 650/mound (Aus), Tk 680/mound (Aman), Price of potato=Tk 600/mound Munbean=Tk 1800/ mound (Tk 45/kg), Sunflower=Tk 1800/ mound (Tk 45/kg)

- In all cases, family labour and irrigation cost were not considered.

Initial soil of each crop was collected before starting sowing/ transplanting. The results showed that there was not so clear increasing or decreasing trend in soil OM, total N, P, K, S and Zn with few exceptions (Table 29). However, despite of cultivation of four crops in same land, are not harmful for soil fertility if the proper management is given. Textural class of soil of each location was determined; Alimganj soil was silty loam and Amtoli was silty.

Table 29. Initial Soil status of each location in 4 crops system.

Crop	pH	OM	Total N	P (ppm)	K (meq/ 100 g)	S (ppm)	Zn (ppm)
Alimganj							
T. Aus	7.5	1.89	0.11	14.45	0.11	19.8	1.48
T. Aman	7.8	1.61	0.09	12.23	0.13	29.2	1.94
Potato	7.6	1.75	0.10	18.23	0.15	30.2	3.10
Mungbean	6.9	1.45	0.08	13.56	0.17	9.34	2.80
Amtoli							
T. Aus	5.1	1.91	0.11	9.28	0.21	17.5	1.78
T. Aman	5.5	1.98	0.12	10.57	0.25	20.8	1.88
Potato	5.7	1.85	0.11	11.67	0.24	22.1	1.87
Mungbean	5.8	1.75	0.11	6.38	0.22	10.23	2.90

Soil Science Division

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SUMMARY

The optimum N requirement of RLR: BR9571-13-1-9-1-1, BR9574-9-5-3-1-1, BRRI dhan49 (ck.), BRRI dhan87 (ck.), BR10001-94-2-B Zn. enriched rice (ZER) and BRRI dhan72 (ck.) were 34, 71, 27, 52, 50, and 40 kg ha^{-1}, respectively. The highest grain yield (7.84 t ha^{-1}) was obtained at 160 kg N ha^{-1} in BR 8526-38-2-1-HR1 Premium quality rice (PQR). The IR 105837-8-95-2-1 (ZER) produced statistically similar grain yield from 160 to 200 kg N ha^{-1} application. Optimum N doses for BPH resistant lines BR 9880-40-1-3-34, BR 9881-24-2-2-25, BR 9880-27-4-1-18, BR 9880-2-2-2-1, check BRRI dhan93 and T27A were 56, 63, 47, 55, 57 and 45 kg N ha^{-1}, respectively. The economic optimum N dose for DRR (BB) line BR 8938-19-4-3-1-1-P2-HR3 and BRRI dhan28 (ck) was 153 and 162 kg N ha^{-1}, respectively. Identified N use efficient Bengal Assam Aus Panel rice population (BAAP) populations were IRGC ID: 29368, 34737, 29361 and 29007.

Urea-HA nanohybrid save up to 50% urea use providing comparable N use efficiency with widely applied prilled urea. Considering yield, AE_N and NH_3-N loss, 105 kg N ha^{-1} from USG and PU + Bioorganic fertilizer could be the most suitable N management interventions that reduce environmental harm from Nr. The estimated value of critical limit of P, K, S and Zn for rice was 8.7 $mgkg^{-1}$, 0.09 meq /100 g soil, 16.1 mg kg^{-1} and 0.70 mg kg^{-1}, respectively. The optimum N and K rates for BRRI dhan87 were 63 kg N ha^{-1} and 116 kg K ha^{-1}, while, for BRRI dhan89 it was163 kg N ha^{-1} and 158 kg K ha^{-1}. Economic dose of K was 106 kg ha^{-1} for the Old Himalayan Piedmont soil. After 5th crop cycles, it was revealed that AEZ (Agroecological zone) or STB based chemical fertilizers (CF) seemed sufficient to obtain potential yield of each crop in Mustard-Boro-T. Aus-T. Aman or Mustard-Mungbean-T. Aus-T. Aman cropping pattern. In case of annual yield, organic with IPNS based CF showed an increasing trend compared to balanced CF application. In the continuous wetland, additional application of Zn and Cu once in a year with NPKS increased annual grain yield by more than 1.0 t ha^{-1} than NPKS alone. In double cropping pattern, 100% STB and 50% STB + MM fertilizer produced statistically similar grain yield. About 25% extra CF application in conservation agricultural practices significantly increased grain yield irrespective of residue management and crop establishment method. In Dumuria, Khulna about 6 to 22% grain yield increased due to 2 t ha^{-1} vermicompost application with CF. At charland, 2 to 4 t ha^{-1} biochar along with CF had positive impact on grain yield. The industrial polluted soils of Gazipur and Sripur have high organic matter (OM), Fe and toxic level of Pb (44 to169 ppm) and Cd (0.63 to 4.38 ppm). There was no or little effect of added OM on grain yield and heavy metal uptake by plant. The total and beneficial microbial population, biomass C (100 to 123 mg kg^{-1}) was very low due to toxic heavy metal in such soil. Bio-organic fertilizer (1-2 t ha^{-1}) along with 30% reduced N and 100% removal of TSP fertilizer increased about 5.7 to 18.2 % grain yield over CF at different farmers' field of Gazipur, Madhupur, Tangail and Manikganj. The highest N_2 fixing (28 mg kg^{-1} N) strain B61and IAA (144 mg kg^{-1}) producing strain B59 were isolated from AEZ-15, while, the highest P solubilization strain B64 (3582 mg kg^{-1} P) found in AEZ-11.

SOIL FERTILITY AND PLANT NUTRITION

Determining N requirement of ALART materials. Before releasing a variety, N requirements of ALART materials need to be adjusted as N is the most limiting nutrient for rice production. Separate field trials were conducted at BRRI HQ, Gazipur for six ALART materials viz two RLR (BR9571-13-1-9-1-1 and BR9574-9-5-3-1-1) with standard checks as BRRI dhan49 and BRRI dhan87, PQR (BR 8526-38-2-1-HR1) with the check Lata Balam, and three ZER genotypes BR10001-94-2-B with check BRRI dhan72, BR 8912-12-6-1-1-1-1 and IR 105837-8-95-2-1 with check BRRI dhan89 during T. Aman 2020 and Boro 2020-2021. The trials were set up following split-plot design with three replications, where fertilizer doses were assigned in the main-plot and rice genotypes in the sub-plot. The respective N

fertilizer doses (kg ha^{-1}) for T. Aman season was N_0, N_{30}, N_{60}, N_{90} and N_{120}, and for Boro was N_0, N_{40}, N_{80}, N_{120}, N_{160} and N_{200}. Standard doses of P, K, S nutrients were applied along with N doses.

Grain yield and N requirements. In the T. Aman, RLR line BR9574-9-5-3-1-1 yielded the highest 4.84 t ha^{-1} at 60 kg N ha^{-1} which was significantly higher than the assigned check varieties at the same N rate. The average yields of the BR9574-9-5-3-1-1 and BR10001-94-2-B were not statistically higher than their respective checks at different N levels. Among all the genotypes, BRRI dhan72 yielded the highest grain (4.94 t ha^{-1}) at 60 kg N ha^{-1}. The optimum N requirement of the BR9571-13-1-9-1-1, BR9574-9-5-3-1-1, BRRI dhan49 (ck) BRRI dhan87 (ck), BRRI dhan87 (ck), BR10001-94-2-B and BRRI dhan72 (ck) were 34, 71, 27, 52, 50, and 40 kg ha^{-1} respectively. At Boro the highest grain yield (7.84 t ha^{-1}) was obtained at 160 kg N ha^{-1} in BR 8526-38-2-1-HR1 (PQR) which was insignificant with 200 kg N ha^{-1}. Moreover, insignificant grain yield was obtained at 140, 160 and 200 kg N ha^{-1} in Lata Balam (6.34, 6.63 and 7.20 t ha^{-1}). Grain yield was increased with the incremental dose of N (up to 200 kg N ha^{-1}) in IR 105837-8-95-2-1 (ZER) and check variety BRRI dhan89. The highest grain yield (9.09 t ha^{-1}) was obtained at 200 kg N ha^{-1} in IR 105837-8-95-2-1 (ZER) which was similar (8.46 t ha^{-1}) with 160 kg N ha^{-1}. Check variety BRRI dhan89 was produced the highest grain yield (9.80 t ha^{-1}) among all the tested ZER genotypes.

Determining N requirement of disease and pest resistant ALART materials. Four BPH resistant lines: BR 9880-40-1-3-34, BR 9881-24-2-2-25, BR 9880-27-4-1-18 and BR 9880-2-2-2-1 were compared with the check variety BRRI dhan93 and resistant check T27A, and DRR (BB) line BR 8938-19-4-3-1-1-P2-HR3 was compared with BRRI dhan28. The trials were set up following split-plot design with three replications, where fertilizer doses (N doses: N_0, N_{20}, N_{40}, N_{60}, N_{80} and N_{100} kg ha^{-1}) were assigned in the main-plot and rice genotypes in the sub-plot. Standard doses of P, K, S were applied along with N doses.

Grain yield and N requirements. Grain yield increased with increasing N dose of up to 60 kg ha^{-1} in most genotypes than it declined. The lines BR 9880-40-1-3-34 (4.19 tha^{-1}) and BR 9881-24-2-2-25 (4.30 t ha^{-1}) gave maximum grain yield with the N rate of 60 kg ha^{-1} and the yields were higher than the other four rice genotypes. The other two lines i.e. BR 9880-27-4-1-18 and BR 9880-2-2-2-1 gave significantly lower grain yield than the check BRRI dhan93. The calculated optimum N doses for BPH resistant advanced lines BR 9880-40-1-3-34, BR 9881-24-2-2-25, BR 9880-27-4-1-18, BR 9880-2-2-2-1 , and check BRRI dhan93, and T27A were 56, 63, 47, 55, 57 and 45 kg N ha^{-1} respectively. Significant grain yield was obtained at 160 kg N ha^{-1} in DRR (BB) line BR 8938-19-4-3-1-1-P2-HR3 (6.87 t ha^{-1}) with check variety BRRI dhan28 (7.23 t ha^{-1}). The economic optimum N dose for DRR (BB) line BR 8938-19-4-3-1-1-P2-HR3 and the check variety BRRI dhan28 was 153 and 162 kg N ha^{-1}, respectively.

Increasing N use efficiency and determining nutrient requirements of MV rice. A pot trial was conducted using terrace paddy soil of BRRI Gazipur greenhouse in Boro 2020 to 2021 with the objective to investigate the N use efficiency of typically synthesized urea-HA (hydroxyapatite) nanohybrid and urea plus purified natural zeolite (71% SiO_2) over prilled urea. Five treatments viz. T_1: PKSZn, T_2: Urea-N_{120} PKSZn, T_3: Nano fert.-N_{120} PKSZn, T_4: Nano fert.-N_{60} PKSZn and T_5: Urea-N_{120} PKSZn + purified natural zeolite (71% SiO_2) @ 2.5 t ha^{-1} were tested in a complete random design with 3 replications. Urea-HA nanohybrids was synthesized according to method by Kottegoda et al. (2017). Transplanted rice (BRRI dhan89) was grown under continuous flooding for 128 days.

Yield and N use efficiency. Among the studied parameters, the number of effective tiller and panicle, filled grain weight, grain and straw yields were significantly ($p<0.01$) greater in all N fertilizer treated pots (T_2, T_3, T_4 and T_5) than N untreated pot (T_1) (Table 1). All these parameters were also statistically identical between the N fertilizer treatments with N applied at 120 kg ha^{-1} from urea (T_2), nano fertilizer (T_3), and urea + zeolite (T_5). In nano fertilizer N applied at 60 kg N ha^{-1} i.e. in T_4, the no. of tiller and panicle were statistically identical

with that in N applied at 120 kg N ha^{-1} from urea (T_2), nano fertilizer (T_3) and urea + zeolite (T_5). However, the filled grain weight and grain yield in T_4 only statistically identical with that in T_3 (Nano fert. N_{120}-PKSZn) but differed from T_2 and T_5. The agronomic N use efficiencies (AE_N) (kg grain kg^{-1} applied N) were alike in T_2 (28) and T_4 (28) but greater in T_5 (31) and lower in T_3 (21). Therefore, Urea-HA nanohybrid may save up to 50% urea use providing comparable N use efficiency with widely applied prilled urea. Also application of urea-plus zeolite may increase N use efficiency over prilled urea and urea-HA nanohybrids.

Nutrient management for growing four crops in a year. Experiment has been initiated in T. Aus 2016 to grow four crops in a year to sustain soil fertility and increase productivity. Three fertilizer treatments viz, Soil test based (STB) fertilizer (T_1), crop residues (CR) + STB fertilizer (T_2) and fertilizer control i.e. native soil nutrients (T_3) were tested with Mustard-Boro-T. Aus-T. Aman (CP-1) and Mustard-Mungbean-T. Aus-T. Aman (CP-2) patterns. Experimental design was randomized complete block with 3 replicates. First crop Mungbean was incorporated in T_2 treatment. After two crop cycle, T_1 and T_2 treatments produced statistically identical grain yield in each crop. In the 3rd year and 3rd crop cycle, both cropping patterns showed their potential yield with AEZ based chemical fertilizer application (T_1) as well as with crop residue incorporation (T_2). After 4th and 5th crop cycles, it is revealed that AEZ based or soil test based (STB) chemical fertilizers seemed sufficient to obtain potential yield of each crop under both patterns (Table 2). In all cases, incorporation of crop residue had some positive impact on yield and hopefully on soil fertility than chemical fertilizer only. Considering rice equivalent yield (REY), CP-1 (15.4 t ha^{-1}) performed better than CP-2 (10.1 t ha^{-1}), but requires long-term evaluation to observe the sustainable yield trends and soil fertility status.

Table 1. Typical yield attributes, grain and straw yields, and agronomic N use efficiency (AE_N) of the studied greenhouse rice growth pot experiment during Boro 2020 to 2021.

Treatment	Parameter						
	Plant height (cm)	Tiller no. (pot^{-1} $hill^{-1}$)	Panicle no. (pot^{-1} $hill^{-1}$)	Filled grain wt. (g pot^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	AE_N (kg grain kg^{-1} N applied)
T_1: PKSZn	94	22b*	22b	35c	8.9c	8.7b	
T_2: Urea N_{120}-PKSZn	94	31a	31a	49a	12.2a	12.0a	28
T_3: Nano fert. N_{120}-PKSZn	97	29a	28a	45ab	11.4ab	11.8a	21
T_4: Nano fert. N_{60}-PKSZn	93	30a	30a	42b	10.5b	9.9b	28
T_5: Urea N_{120}-PKSZn + Zeolite (2.5 t ha^{-1})	99	32a	31a	51a	12.6a	13.2a	31

*Different lower case letters within the column denote significant differences ($p<0.01$) between the treatments according to ANOVA and Duncan's Multiple Range Post-Hoc Test.

Table 2. Grain yield and rice equivalent yield (t ha^{-1}) of T. Aus (BRRI dhan82), T. Aman (BRRI dhan62), Mustard (BARI sharisa14), Boro (BRRI dhan28) and Mungbean (BARI Mung-6) during 2020-21 (5th crop cycle).

Treatment	T. Aus 2020		T. Aman 2020		Mustard 2020-21		Boro 2021	Mungbean 2021
	CP-1	CP-2	CP-1	CP-2	CP-1	CP-2	CP-1	CP-2
T_1: STB fertilizer	2.76a* (2.8)	3.00a (3.0)	2.54a (2.5)	2.58a (2.6)	0.87a (2.4)	0.85a (2.4)	6.31a (6.3)	0.22a (0.8)
T_2: Crop residues (CR) + T_1	3.12a (3.1)	3.41a (3.4)	2.70a (2.7)	2.76a (2.8)	1.01a (2.8)	1.07a (3.0)	6.75a (6.8)	0.28a (1.0)
T_3: Native nutrient	1.54b (1.5)	1.75b (1.8)	1.27b (1.3)	1.59b (1.6)	0.04b (0.1)	0.21b (0.6)	2.09b (2.1)	0.12b (0.4)

*Lower case letters within the column denote significant differences of grain yields between the treatments according to ANOVA and DMRT- Post-Hoc Test. Mustard-Boro-T. Aus-T. Aman cropping pattern (CP-1) and Mustard-Mungbean-T. Aus-T. Aman cropping pattern (CP-2). Values in the parenthesis are rice equivalent yield (t ha^{-1}).

Determining N doses for modern rice varieties. The experiment was conducted at the experimental field of BRRI HQ, Gazipur during T. Aman 2020 and Boro, 2020-21 seasons to determine the optimum N requirement of BRRI dhan87 and BRRI dhan92, respectively. The experiment was laid out in a RCB (Randomized Complete Block) design with three replications. The applied N doses (kg ha^{-1}) were 0, 30, 60, 90, 120, 150 in T. Aman and 0, 40, 80, 120, 160, 200, in Boro season, respectively along with flat doses of P, K, S fertilizer. Study results showed grain yields of BRRI dhan87 and BRRI dhan92 were significantly influenced by N rates. The economically optimum N dose for BRRI dhan87 was 85 kg ha^{-1} and 209 kg ha^{-1} for BRRI dhan92.

Screening of Bengal Assam Aus Panel rice population (BAAP) for N use efficiency. Within the global rice germplasm the BAAP accessions are phenotypically diverse containing the donors of a number of abiotic stress resistance-related traits. A study was conducted at BRRI HQ farm, Gazipur to find out the N use efficient traits of 150 BAAP populations. BRRI dhan28 was used as check variety. Two N- fertilizer doses; N_{50} and N_{100} kg ha^{-1} were tested among the BAAP populations following split plot design where, N doses were assigned in the main-plot and BAAP populations in the sub-plot. Flat doses (kg ha^{-1}) of P-K-S @ 20-50-10 were applied along with N doses.

Grain yield and partial factor productivity (PFP_N) of applied N. There were significant variations found in grain yield among the tested BAAP populations. The interaction effect between N dose and BAAP population was also significant. The highest grain yield 27.33 g $plant^{-1}$ obtained in IRGC ID 29295 at N_{100} treatment. However, at a glance, the N use efficient BAAP populations were IRGC ID: 29368, 34737, 29361 and 29007 that yielded 23, 18, 17.06 and 17.13 g grain $plant^{-1}$, respectively at 50 kg ha^{-1} N application. BRRI dhan28 produced 16.96 g grain $plant^{-1}$ in N_{100} and 7. 34 g grain $plant^{-1}$ in N_{50} treatment. The PFP_N (grain kg kg^{-1} applied N) due to application of 50 kg N ha^{-1} were 115, 90.2, 85.3, 85.65, and 36.7 in IRGC ID: 29368, 34737, 29361, 29007 and BRRI dhan28, respectively. On the other hand, PFP_N (grain kg kg^{-1} applied N) was 68.33 for IRGC ID 29295 and 42.25 for BRRI dhan28 in N_{100} treatment.

Performance of rice varieties under P deficit conditions. Acute P deficiency reduces rice yield depending on internal and/or external mechanisms that allow greater soil P extraction. The experiments were conducted at BRRI HQ farm, Gazipur during T. Aman 2020 and Boro 2020-2021 season having deficit soil available P condition. Six treatments of P doses calculating from soil test value (STB) viz T_1= P control, T_2= 50% of STB P (11 kg ha^{-1}), T_3= 75% of STB P (16.5 kg ha^{-1}), T_4= 100% of STB P (22 kg ha^{-1}), T_5= 125% of STB P (kg ha^{-1}) and T_6= 150% of STB P (27.5 kg ha^{-1}) were applied in both the seasons. The experiments were conducted in RCBD with three replications. BRRI dhan87 and BRRI dhan89 were used as tested rice varieties for T. Aman and Boro season, respectively. Each plot received a flat dose of N-K-S-Zn (kg ha^{-1}) @ 90-42-10-1 in T. Aman and 60-20-10-2 in Boro season.

Grain yield. In the P deficient soil, P fertilizer had significant effect on grain yield. The grain yield in the P fertilized plot progressively increased with the increasing level of P fertilizer in both the seasons. In T. Aman, yield increasing trend was observed up to T_6 treatment. The highest grain yield was obtained in T_6 treatment (5.57 t ha^{-1}), and it was statistically similar with T_4 (5.47 t ha^{-1}) and T_5 (5.55 t ha^{-1}) treatment. The P control plot yielded only 2.91 t ha^{-1}. In Boro, under control P condition, grain yield was only 2.22 t ha^{-1} and with 50% or 75% application of fertilizer P, grain yield increased significantly. The highest grain yield in BRRI dhan89 (7.22 t ha^{-1}) was recorded in the T_4 treatment where 100% STB dose of P was applied followed by T_5 (7.17 t ha^{-1}) and T_6 (7.15 t ha^{-1}) treatment. Response of added phosphorus was much lower in wet season than in dry season.

Influence of N and K on the performance of modern rice. The study was conducted to observe the effect of nitrogen (N) and potassium (K) on the yield and nutrition of modern rice at BRRI farm, Gazipur during T. Aman 2020 and Boro 2020-21 season. The experiment was laid out in split-plot design with three replications assigning the rates of

K in the main plots and that of N in the subplots. Soil test based flat rates of P and S were applied to all the plots. The application rate of K was 0, 50, 100, 150 and 200 kg ha^{-1} both in T. Aman and Boro seasons. Nitrogen was applied @ 0, 50, 75 and 100 kg ha^{-1}, in T. Aman season, while in Boro season, the rate of N was 0, 100, 150 and 200 kg ha^{-1}. The test varieties were BRRI dhan87 and BRRI dhan89 in T. Aman and Boro seasons, respectively.

Grain and straw yield. In T. Aman, the effect of K was significant on grain yield, but that of N was not significant (Table 3). The interaction effect of N and K was not significant. The highest mean grain yield (4.28 t ha^{-1}) of BRRI dhan87 was achieved with 100 kg K ha^{-1} averaged over all N doses. The straw yield of BRRI dhan87 was also significantly affected by N and K application with the highest yield being recorded with 75 kg N and 150 kg K ha^{-1}. In Boro 2020 to 2021, grain and straw yield of BRRI dhan89 was significantly affected by the interaction of N and K addition. The effect of N on grain yield was distinctly dominant over K during Boro season. Sharp increases were observed in grain yield (~2.5 t) due to the addition of N over the N control (i.e., no added N) in all K doses. The highest grain (6.62 t ha^{-1}) and straw yields were achieved with 200 kg N and 150 kg K ha^{-1}. The response of BRRI dhan87 and BRRI dhan89 to N and K addition was generally quadratic in nature with the yield being increased with the addition of the nutrients up to a maximum and then declined with further increase. Accordingly, the optimum N and K rates were 63 and 116 kg ha^{-1}, respectively, for BRRI dhan87 during T. Aman, while for BRRI dhan89 in Boro season, the rates were 163 kg N and 158 kg K ha^{-1}.

Effect of different micro and beneficial nutrients on rice growth and yield. A pot experiment was conducted in the glasshouse of Soil Science Division, BRRI, Gazipur in sandy soil to determine the effect of micronutrients and beneficial nutrients on completely randomized block design growth and yield of rice. The study was laid out in RCBD with three replications and five treatments: T_1= NPKSZn, T_2= T_1 + CuNiSeSi, T_3= T_1 + CuNiSi, T_4= T_1 + CuSi and T_5= T_1 + Si. All the treatments received a blanket dose of chemical fertilizer i.e. N-P-K-S-Zn @ 120-15- 60-10-1.5 kg ha^{-1}. The Cu, Ni, Se and Si were applied as foliar spray @ 1%, 0.2%, 10 ppm and 0.2%, respectively. In the T. Aman season, the growth and yield of BRRI dhan87 significantly differed with the applied treatments. The highest plant height (114.56 cm), number of panicles per hill (13) panicle length (21.44 cm) number of filled grains per panicle (122), grain (78.18 g pot^{-1}) and straw yield (77.05 g pot^{-1}) were obtained in the T_2 treatment. In T. Aman, it appeared that the increased growth and yield was either the effect of Se alone or the combined effect of Cu, Ni, Se and Si. In Boro, the highest number of filled grains per panicle (151) and grain yield (94.55 g pot^{-1}) were found with T_5 treatment where, Si was sprayed in combination with recommended chemical fertilizer.

IDENTIFICATION AND MANAGEMENT OF NUTRITIONAL DISORDER

Long-term use of organic and inorganic nutrients in Boro-Fallow-T. Aman rice. A long-term experiment was initiated on a permanent

Table 3. Effect of N and K on the grain yield of BRRI dhan87 in T. Aman 2020 and BRRI dhan89 in Boro 2020-2021 at BRRI, Gazipur.

K rate (kg ha^{-1})	N rate (kg ha^{-1})							
	0	50	75	100	0	100	150	200
	Grain yield (t ha^{-1})							
	BRRI dhan87 (T. Aman)				BRRI dhan89 (Boro)			
0	3.84ab	3.63c	3.34c	3.80b	2.59abc	3.94c	4.51c	4.09d
50	3.88ab	4.30a	4.39a	4.03ab	2.27c	5.21a	5.46b	6.11bc
100	4.06a	4.40a	4.47a	4.17a	2.38bc	4.74b	5.88ab	6.07c
150	3.67b	3.84bc	4.28ab	4.14a	2.90a	5.43a	5.77b	6.62a
200	3.91ab	4.02b	4.07b	3.92b	2.75ab	5.60a	6.28a	6.53ab

Values followed by same letter are not significantly different at 5% level.

layout at BRRI HQ farm Gazipur in 1985 Boro season having 12 treatments assigned in RCB design with four replications. The objective of the study was to find the impact of long-term nutrient management on grain yield and soil health. The treatments were revised according to the requirement of the objectives (see BRRI, 2016 and BRRI, 2019). The recent STB doses of N,P,K,S,Z,n were 150-12-80-5-2 kg ha^{-1} and 100-10-80-5-2 kg ha^{-1} for Boro and T. Aman rice, respectively.

Grain and straw yield. In the T. Aman and Boro seasons, omission of N, P, K and S decreased grain yield significantly compared to complete fertilizer treatment (Table 4). In T. Aman 2020, among the applied organic materials, PM+IPNS (4.23 t ha^{-1}), CD+ IPNS (4.13 t ha^{-1}) and VC+ IPNS (4.08 t ha^{-1}) treated plots were produced similar grain yield compared to complete chemical fertilizer (4.27 t ha^{-1}). In Boro 2020-2021, the highest grain yield 7.01 t ha^{-1} was obtained from PM + IPNS, which was statistical identical with all other tested organic + IPNS treatments i.e. CD +IPNS (6.70 t ha^{-1}) and VC + IPNS (6.60 t ha^{-1}). In both the seasons, sulfur omitted plot produced significantly lower grain yield compared to full dose of chemical fertilizer plot but there was no significant yield difference obtained in Zn omitted plot. Moreover, significant yield difference was found between reduced K dose (40 kg ha^{-1}) and complete K fertilizer treatment (K 80 kg ha^{-1}) but in case of moderate K dose (K 60 kg ha^{-1}) and complete K dose (K 80 kg ha^{-1}) the yield difference was insignificant. In case of annual yield, organic with IPNS based chemical fertilizer treatment showed an increasing trend compared to complete chemical fertilizer treatment (Fig. 1).

Table 4. Effect of organic and inorganic amendments on rice grain yield (t ha^{-1}) of BRRI dhan87 and BRRI dhan89 at BRRI HQ, Gazipur, in 2020-2021.

Treatment	Grain yield (t ha^{-1})	
	T. Aman 2020	Boro 2020-21
T_1 = NPKSZn@150/100-12/10-80-5-2 kgha^{-1}	4.27	6.52
T_2 = NPSZn (-K)	3.45	4.88
T_3 = NKSZn (-P)	3.57	3.36
T_4 = PKSZn (-N)	3.45	2.98
T_5 = CD (3 t ha^{-1}) + IPNS	4.21	6.70
T_6 = NPKS (-Zn)	4.07	6.48
T_7 = NPKZn (-S)	3.95	5.88
T_8 = PM (2 t ha^{-1}) + IPNS	4.23	7.01
T_9 = NPKSZn @150/100-12/10-60-5-2 kgha^{-1}	4.06	5.92
T_{10} = VC (2 t ha^{-1}) + IPNS	4.08	6.60
T_{11} = NPKSZn@150/100-12/10-40-5-2 kgha^{-1}	3.85	5.67
T_{12} = Control (native nutrients)	3.10	1.80
$LSD_{0.05}$	*0.28*	*0.45*

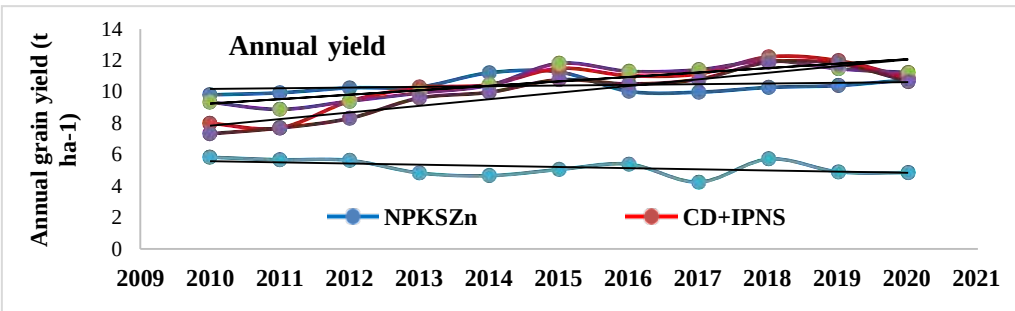

Fig. 1. Annual yield trend of IPNS based treatment compared with complete chemical fertilizer and control treatment, 2020-21, BRRI HQ, Gazipur.

Effect of intensive rice cropping on rice yield under continuous wetland condition. The experiment was designed to harvest three rice crops per year with evaluation of the consequences of intensive rice cropping under continuous wet land conditions and to monitor soil fertility changes over time. This experiment was initiated in 1971 in a permanent layout with NPK fertilizer application. Since Boro 2000, the experiment was modified to accommodate six treatments viz control (native nutrient), reverse control (NPKSZnCu), NPK, NPKS, NPKSZn and NPKSZnCu after several revisions in 1982, 1984 and 1991. In Boro 2020-2021, the experiment was revised again the N and K fertilizer from 140 to 160 and 80 to100 kg ha^{-1}, respectively. The varieties tested in T. Aus, T. Aman and Boro seasons were BRRI dhan48, BRRI dhan87 and BRRI dhan84, respectively. The NPK doses used were 160-25-100, 60-15-80 and 60-10-60 kg ha^{-1} for Boro, T. Aman and T. Aus, respectively. Sulfur, Zn and Cu were applied at 10, 4 and 1 kg ha^{-1} in the Boro season only.

Grain yield and yield trend. The annual rice production trend from 1981 to 2020 was decreasing in the control treatment, however, from 2001 the reverse control treatment produced grain yield almost similar to complete fertilized treatment (Fig. 2). In 2020, annual rice production in control plot was 4.41 t ha^{1} while its reversed management (addition of NPKSZnCu fertilizer) resulted in 13.59 t $ha^{-1}yr^{-1}$ grain production, which was close to complete fertilizer treatment (14.14 t $ha^{-1}yr^{-1}$). It indicates that complete fertilization can recuperate soil productivity even after a long period of rice cultivation. Results indicate that additional use of Zn and Cu once in a year with NPKS increased annual grain yield by more than 1.0 t ha^{-1} than the application of NPKS alone. A similar increasing grain yield trend was observed in complete fertilizer (NPKSZnCu) treatment in Boro season 2020-21.

Regional yield maximization trial (RYMT) under different management practices. The experiment was initiated at BRRI, Gazipur in Boro season in 2020-2021 to validate the effect of integrated improved management practices (IIMP) and BRRI recommended practices on grain yield and proper grain filling in a panicle. Two selected genotypes (BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B) and a check (BRRI dhan63) were evaluated under both practices following factorial randomized design with three replications. IIMP were: healthy seedling raising using 60 g seeds per square meter seed bed, urea fertilizer application using four splits as basal, 25-30 DAT, 55-60 DAT (before PI) and 75-80 DAT (beginning of heading), and harvesting at 90% maturity. BRRI recommended practices were: traditional seedling raising using 100g seeds per square meter seed bed, urea fertilizer application using three splits as 10 DAT, 30-35 DAT, 55-60 DAT, and harvesting at 80% maturity. Result of Boro 2020-21 show that, considering grain yield and sterility percentage, interaction effect between IIMP and BRRI recommended practices were insignificant. IIMP produced significantly the highest grain yield but sterility percentage were insignificant. Tested genotype, BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B produced significantly the highest grain yield 8.7 and 8.6 t ha^{-1} respectively, compared to check BRRI dhan63 (7.6 t ha^{-1}). Similar trend was also observed in case of sterility percentage.

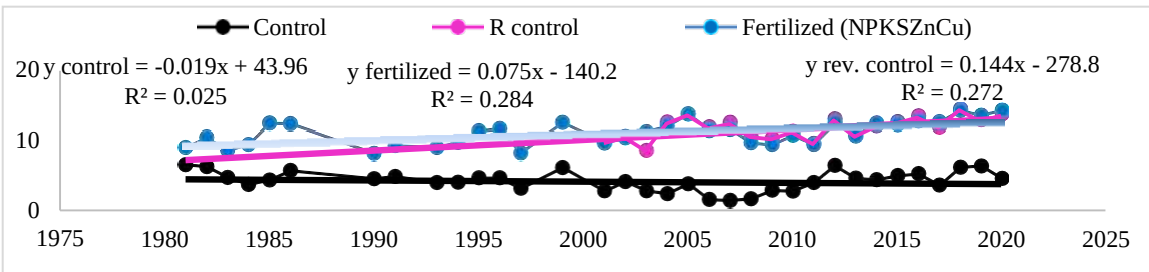

Fig. 2. Annual rice production trend under intensive wetland conditions in BRRI HQ, Gazipur during 1981-2020.

Response of rice to K fertilizer rates in rice-based cropping pattern in the Old Himalayan Piedmont soil. An experiment was conducted at Hazi Mohammed Danesh Science and Technology University (HSTU) farm soil, Dinajpur (AEZ-1) in Boro 2020-2021 to identify the optimum K rate for Boro rice and to maintain soil fertility especially for K nutrient. The soil of the experimental field was sandy loam in texture having pH 5.8, organic carbon 1.2%, total N 0.09%, available phosphorus 12 ppm and exchangeable K 0.10 meq/100g soil. Six K rates including control were assigned in RCBD design with three replications. The treatments were; K control, 50% STB K (40 kg ha^{-1}), 75% STB K (69 kg ha^{-1}), 100% STB K (92 kg ha^{-1}), 125% STB K (115 kg ha^{-1}) and 150% STB K (138 kg ha^{-1}). Flat doses of N-P-S and Zn were used @ 140-20-10 and 2 kg ha^{-1}, respectively. The tested variety was BRRI dhan88. Study result showed that the grain and straw yield were influenced significantly with increasing the K doses up to 100% STB dose and further increasing the k doses, grain yield did not increase significantly. From the quadratic equation, the economic optimum dose of K was found 106 kg ha^{-1}. So, soil test-based fertilizer especially K fertilizer should be applied in the Old Himalayan Piedmont soil for obtaining higher rice yield with maintain soil fertility.

Determining critical limit (CL) of rice for soil nutrients. The study was conducted with the objective to determine the CL of soil P, K, S and Zn for rice cultivation. Based on land type, cropping pattern and soil texture, 180 soil samples were collected from three AEZs (viz 18, 19 and 20). Soil samples were analyzed for different macro and micro-nutrients and selected for low, medium and highly fertile soils.

Pot trial at net house. Pot experiments for P, K, S and Zn were conducted for each nutrient (with and without respective nutrients) following RCB design with three replications. The test crop was BRRI dhan89. Critical limits of P, K, S and Zn were derived by plotting the relative crop yield (%) on the Y axis for each crop per nutrient following Cate and Nelson method (1965). The study result revealed that the estimated value of critical limit of P, K, S and Zn for rice was 8.7 mg kg^{-1}, 0.09 meq /100 g soil, 16.1 mg kg^{-1} and 0.70 mg kg^{-1}, respectively (Fig. 3).

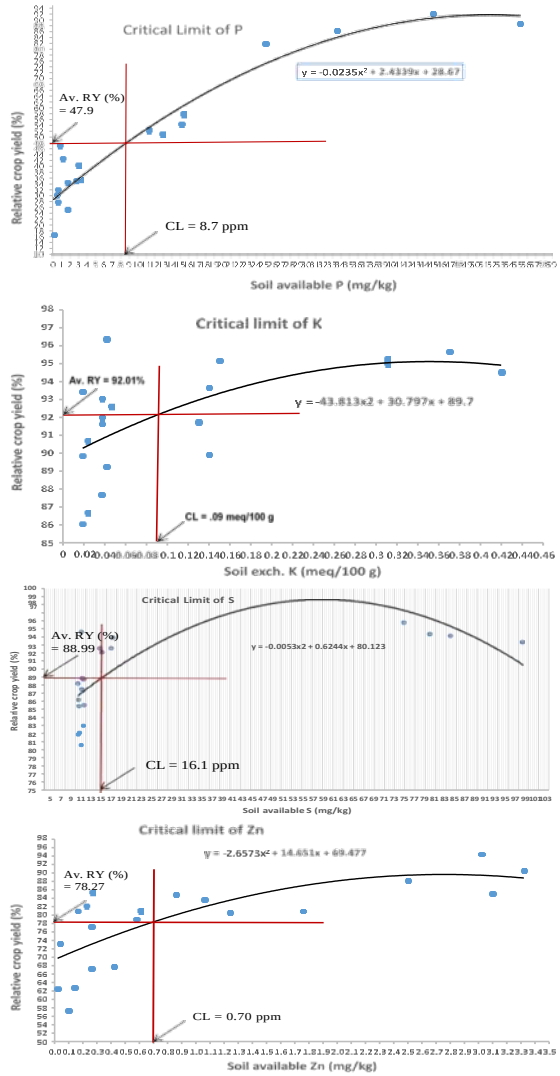

Fig. 3. Critical Limit of P, K, S and Zn for rice cultivation in Bangladesh.

Farmers' field trials. In the Boro 2020-21, the estimated CL values of P, K, S and Zn for rice soil were evaluated in farmer's field (deficient soil for each nutrient status). Six treatment combinations were assigned in RCBD with three replications on soil test based dose (STB). The treatments were; nutrient control, 50% STB, 75% STB, 100% STB, 125% STB and 150% STB for each nutrient. Here, the 100% STB dose was calculated from the respective critical value of

nutrients. The tested rice variety was BRRI dhan28. The P and S experiments were conducted in Companiganj of Sylhet district (AEZ-20) and the K and Zn experiments were conducted in Katchua of Chandpur district (AEZ-19). From the response curve the economic optimum dose of P, K, S and Zn were 42, 115, 24 and 2.72 kg ha^{-1}, respectively. The calculated optimum dose of each nutrient was found almost similar in compared to STB dose.

INTEGRATED NUTRIENT MANAGEMENT

Integrated nutrient management for double and triple rice cropping. The experiment was initiated in Boro 2008-09 at BRRI HQ, farms Gazipur in a clay loam soil to find the suitable fertilizer management for double and triple rice cropping system and to find out the impact of triple rice cropping on soil health. In Boro-Fallow-T. Aman pattern, BRRI dhan58 and BRRI dhan49 were tested. In Boro -T. Aus-T. Aman pattern, BRRI dhan74, BRRI dhan48 and BRRI dhan46 were included as test varieties. Fertilizer treatments used were: T_1: control, T_2: STB dose NPKS @ 160-25-60-20 kg ha^{-1} for Boro, 70-12-48-10 kg ha^{-1} for T. Aus and 84-21-32-06 kg ha^{-1} for T. Aman, T_3: STB (50%) + Mixed manure (MM) as CD @ 2 t ha^{-1} + ash @ 1 t ha^{-1} oven dried, T_4: farmers' practice (FP) as NPKS @ 80-10-20-10 kg ha^{-1} for Boro, 70-10-15-0 kg ha^{-1} for T. Aus and 70-10-15-0 kg ha^{-1} for T. Aman, respectively. The experiment was laid out in RCB design with three replications.

Annual grain yield. The study result of Boro 2019-20 and T. Aman 2020 under double cropping pattern, 100% STB and 50% STB + MM fertilizer produced statistically similar grain yield. In the same year under triple rice cropping pattern, treatments 100% STB and 50% STB + MM fertilizer also produced statistically identical grain yield in all three seasons. However, both in double and triple rice cropping pattern, 100% STB and 50% STB + MM fertilizer produced significantly higher grain yield than farmers' practice and native nutrient. Cumulative yield of triple rice cropping was always higher than double rice cropping pattern irrespective of treatment (Table 5).

Rice yield improvement in the coastal land through vermicompost (VC) amendments. Six experiments were conducted at three farmer's field of Dumuria, Khulna and Amtali, Borguna, in both T. Aman in 2020 and Boro 2020-2021 season to find out the effect of different doses of VC on grain yield. Treatments were as; VC @ 0, 1, 2 t ha^{-1} (oven dry basis) with full dose of chemical fertilizer (FRG, 2018). Grain yield increased significantly due to different doses of added VC at Dumuria, Khulna in both T. Aman 2020 and Boro 2020-2021season, however statistically similar grain yield obtained due to application of either 1 or 2 t ha^{-1} of VC. In the Dumuria, Khulna about 6% grain yield was increased in T. Aman and 22 % in Boro

Table 5. Annual grain production (t ha^{-1}) of double and triple cropping pattern under continuous wetland condition, BRRI HQ Farm, Gazipur, 2020.

Treatment	Double cropping			
	Boro 2019-20	Fallow	T. Aman 2020	Annual yield (t ha^{-1})
	(BRRI dhan58)		(BRRI dhan49)	
Native nutrient	1.26c	-	2.15c	3.41
STB (100%)	5.04a	-	4.08a	9.12
STB (50%)+MM	4.57a	-	4.18a	8.75
FP	3.54b	-	2.87b	6.41
CV (%)	8.55	-	4.05	
	Triple cropping			
	Boro 2019-20	T. Aus 2020	T. Aman 2020	Annual yield (t ha^{-1})
	(BRRI dhan74)	(BRRI dhan48)	(BRRI dhan46)	
Native nutrient	0.98d	1.92c	1.99c	4.89
STB (100%)	5.07a	4.81a	4.03a	13.91
STB(50%)+MM	4.34a	4.74a	3.96a	13.04
FP	3.68c	3.72b	3.23b	10.63
CV (%)	5.94	5.09	7.16	

season at 2 t ha^{-1} VC application over control. In the Boro season, at Amtali Borguna, application of 2 t ha^{-1} VC produced significantly the highest grain yield (7.06 t ha^{-1}) followed by VC 1 t ha^{-1} (6.52 t ha^{-1}). The lowest grain yield 5.72 t ha^{-1} was recorded in the control treatment.

Nutrient management under conservation agriculture (CA) in double rice cropping system. This experiment was initiated at Paba, Rajshahi, in Boro 2018-19 seasons with the objectives to determine the nutrient requirement of rice in Boro-Fallow-T. Aman cropping pattern, and to improve soil health under conservation agriculture practices. Two crop establishment methods (unpuddled and puddle) in main plot, two residue management practices (straw retained and straw removed) in sub plot and four fertilizer doses as recommended fertilizer (RD) 100%, 125% of RD. 75% of RD, and 50% of RD were assigned in split-split plot design with three replications.

Grain yield. In Boro 2020-21, grain yields were significantly higher under puddled cultivation than un-puddled condition (Table 6). Rice straw (RS) incorporation significantly increased the rice yield in Boro season. Twenty-five percent extra fertilizer application significantly increased the grain yield irrespective of residue management and crop establishment methods. In T. Aman 2020, grain yields were insignificant under unpuddled and puddled cultivation. However, RS incorporation significantly increased the rice yield in T. Aman season. Moreover, 125%, 100% and 75% of RD of fertilizer produced statistically identical grain yield irrespective of residue management and crop establishment methods.

Rice yield and soil health improvement through organic and inorganic amendment. The experiment was initiated at the experimental farm of BRRI, Gazipur in T. Aman season in 2019 to investigate the effect of vermicompost (VC) and silicon (Si) on rice grain yield and soil health. The soil was silty clay loam in texture having pH 7.1, organic carbon 13 g kg^{-1}, total N 1.2 g kg^{-1}, Olsen available P 10.1 mg kg^{-1}, exchangeable K 44 mg kg^{-1} and available S, 31 mg kg^{-1}. The experiment was laid out in a split- plot design with three replications, where main plots comprised of four levels of VC (0, 2.5, 5, 10 t ha^{-1}) and sub-plots had four Si rates (0, 100, 200, 400 kg ha^{-1}). The variety was BRRI dhan87 in T. Aman and BRRI dhan89 in the Boro season. Results of Boro 2020-21 showed that, grain yield of BRRI dhan89 with different VC rates increased significantly from control. The highest grain yield (7.44 t ha^{-1}) of BRRI dhan89 was obtained at 2.5 t ha^{-1} VC application which was statistically similar with 5 and 10 t ha^{-1} VC rates. Among Si rates, 100 kg ha^{-1} performed better which was statistically similar with 200 and 400 kg ha^{-1}. In T. Aman 2020, the highest grain yield (4.57 t ha^{-1}) of BRRI dhan87 was obtained with 2.5 t ha^{-1} VC application which was statistically similar with 5 and 10 t ha^{-1} VC. But among Si rates, insignificant grain yield was found.

SOIL AND ENVIRONMENTAL PROBLEMS

Management interventions to improve NUE and reduce N losses. A field experiment was conducted during Boro 2020-2021 at BRRI Gazipur to quantify the fate of N fertilizer (crop, soil and losses) and N fertilizer use efficiency (NUE) under various N management options. The tested seven treatments were: T_1: no N fertilizer (N_0), T_2: 140 kg N ha^{-1} from prilled urea (N_{140}PU), T_3: T_2+25% N (N_{175}PU), T_4: T_2-25% N (N_{105}PU), T_5: Cow dung (2 t ha^{-1}) + IPNS with T_2 (N_{140} PU+CD), T_6:

Table 6. Effect of crop establishment methods (EM), rice straw incorporation (RS) and fertilizer rates (FR) on grain yield (t ha^{-1}) of Boro and T. Aman rice, Paba, Rajshahi.

EM	Grain yield (t ha^{-1})							
	Boro 20120-21	T. Aman 2020	RS	Boro 2019-2020	T. Aman 2020	FR	Boro 2020-21	T. Aman 2020
Unpuddled	5.06 b	4.09a	Yes	5.64 a	4.18a	125%	6.32 a	4.41a
Puddled	5.54 a	4.18a	No	4.95 b	4.09b	100%	5.78 b	4.47a
						75%	5.03 c	4.29a
						50%	4.07 d	3.39b

Bioorganic fertilizer (2 t ha^{-1}) + IPNS with T_4 (N_{105} PU+ Bioorganic fert.) and T_7: Deep placed Urea Super Granule (USG) alike T_4 (N_{105} USG) were tested following RCBD with four replications. A blanket rates of P-K-S-Zn (@ 25-80-10-1 kg ha^{-1}, respectively were applied. Seedlings of BRRI dhan89 has been tested. Gas samples were collected to analysis CH_4 and N_2O emission. Measurement of NH_3 emission (volatilization) was performed by using close chamber technique and Boric Acid Trap method.

Grain yield and agronomic N use efficiency. N fertilizer application significantly increased grain yield over control. Among the N fertilizer applied treatments the higher grain yield (6.3 t ha^{-1}) and AE_N (35 kg grain kg^{-1} N) was attained from the N fertilizer applied at the rate of 105 kg N ha^{-1} from PU+ Bioorganic fertilizer (T_6) followed by USG (T_7) treatment where about 31 kg grain kg^{-1} N (AEN) and 6.0 t ha^{-1} grain yield was obtained.

Time course of NH_3 emission fluxes after urea application. The NH_3 emission peaks were usually observed on day 1-3, day 3 and day 1 after the 1st, 2nd and 3rd split application of urea, respectively **(Fig. 4a and b)**. In case of all three splits, the peak NH_3 emissions were greater in the treatment with higher rate of N application i.e. in the N175PU (T_3) resulting 86, 54 and 51 mg NH_3-N m^{-2} d^{-1} after 1st, 2nd and 3rd splits of urea application, respectively. The lowering of NH_3-N emission peaks was found with reducing rate of N fertilizer application ensuing 55, 34 and 39 mg NH_3-N m^{-2} d^{-1} in N_{140}PU and 52, 27 and 23 in N_{105} PU, after 1st, 2nd and 3rd splits of urea application, respectively**.** Except the higher value after 1st topdressing of 40% urea in T_6 treatment (N_{105} PU + Bioorganic fert.), the overall peak NH_3 emissions were lower (13 and 23 mg NH_3-N m^{-2} d^{-1}) than in the CD applied plots (N_{140} PU+CD) (22 and 62 mg NH_3-N m^{-2} d^{-1}). Among the N fertilizer treatments, the NH_3-N emission was the lowest in USG applied treatment T_7 (N_{105}USG) (38 and 9, mg NH_3-N m^{-2} d^{-1}, after 1st and 2nd applications, resp.) In N_0 treatment, some NH_3-N emission was recorded initially which possibly ensued from native soil organic matter mineralization with lesser plant N uptake after two weeks of crop establishment, later on the emission was below the detection. Across the N fertilizer application treatments, the NH_3-N emission was declined to below detection limit on day 10 after 1st split, day 6 after 2nd split and day 7 after 3rd split. Similar to NH_3 emission fluxes, the cumulative NH_3-N emission was significantly ($p<0.01$) greater in the treatment with higher urea-N application rate T_3: N175PU (6.7 kg ha^{-1} $season^{-1}$) and lower in the treatment with lower urea-N application rate T_4: N105PU (3.2 kg ha^{-1} $season^{-1}$). The total NH_3-N emission (in kg ha^{-1} $season^{-1}$) was significantly ($p<0.01$) lowest in the N0 (0.6) and N105USG (1.1) treatments. Among N_{140}PU, N_{140} (PU+CD) and N_{105} (PU+ Bioorganic fert.) treatments, the total NH_3-N emission was statistically identical but significantly lower ($p<0.01$) than that in T_3: N175PU (Fig. 4c).

Effect of different organic sources for amelioration of industrial polluted area of Sripur, Gazipur. The rice soils of Sripur, Mirzapur and Pirojali were irrigated with contaminated industrial water. The soils of the area contained organic matter (>2.5%), high level of Fe (87 to 580 ppm), Mn (7 to150 ppm), Cu (1 to 7 ppm), and Zn (3 to 65 ppm). Three farmers field experiments were conducted in Boro 2020-21 at each location of Mirzapur and Pirujali and Sripur to ameliorate such soil with different amendments for improve rice productivity. Treatments were as T_1: Inoculum + full chemical fertilizer (kg ha^{-1}) N-P-K-S @ 100-20-80-10, T_2: Biochar + full chemical fertilizer (kg ha^{-1}) N-P-K-S@ 100-20-80-10, T_3: Vermicompost (VC) + IPNS based chemical fertilizer (N-P-K-S @40-0-48-10), T_4: Full chemical fertilizer, T_5 : Control. Treatments were laid out in RCB design with three replications.

Effect of amendments on rice grain yield and heavy metal uptake. In the Sripur, insignificant effect was found due to application of soil amendments over chemical fertilizer treatment for the number of tiller, panicle, grain and straw yield of BRRI dhan89. However, a little higher grain yield (4.67 t ha^{-1}) was recorded when Plant Growth Promoting Bacteria (PGPB) inoculum was applied with chemical fertilizer compared to other treatment. At Mirzapur, BRRI dhan74 was cultivated. The significant highest amount of grain yield (5.45 t ha^{-1}), tillier number m^2 (305) panicle number m^2 (291) was obtained in the inoculum +

full dose of chemical fertilizer treatment, though it was statistically similar to the biochar + full dose of chemical fertilizer (5.41 t ha^{-1}) and only full dose of chemical fertilizer (5.27 t ha^{-1}) application. The negative impact of VC + chemical fertilizer application was found on grain yield (4.81 t ha^{-1}) at Mirzapur. At Pirujali, application of full dose of chemical fertilizer yielded 7.21 t ha^{-1} grain though it was statistically similar with PGPB inoculum, biochar and VC applied treatment. At all sites, the lowest grain yield was recorded in the control treatment. In Sripur, among the heavy metals the lowest Pb uptake (37 g ha^{-1}) was found in the biochar (T_2) and Inoculum applied treatment (T_1). Conversely, the highest Cd uptake (2.5 g ha^{-1}) was found in the biochar (T_2) and lowest (1.0 g ha^{-1}) in the chemical fertilizer applied treatment (T_4). At Mirzapur, uptake of Fe (4.54 kg ha^{-1}), Pd (138 g ha^{-1}) and Cd (10.2 g ha^{-1}) increased due to chemical fertilizer application. However, the lowest Fe (2.18 kg ha^{-1}), Pb (115 g ha^{-1}), Cd (6.7 g ha^{-1}) and Ni (2.6 g ha^{-1}) uptake found in the control treatment. At Mirzapur, application of treatment significantly increased Fe uptake over control. At Pirujali, chemical fertilizer increased Pb uptake (157 g ha^{-1}), however application of biochar (125 g ha^{-1}) and inoculum (119 g ha^{-1}) significantly reduced Pb uptake. The lowest Cr (18.4 g ha^{-1}) and Ni (2.0 g ha^{-1}) uptake was found in the control treatment.

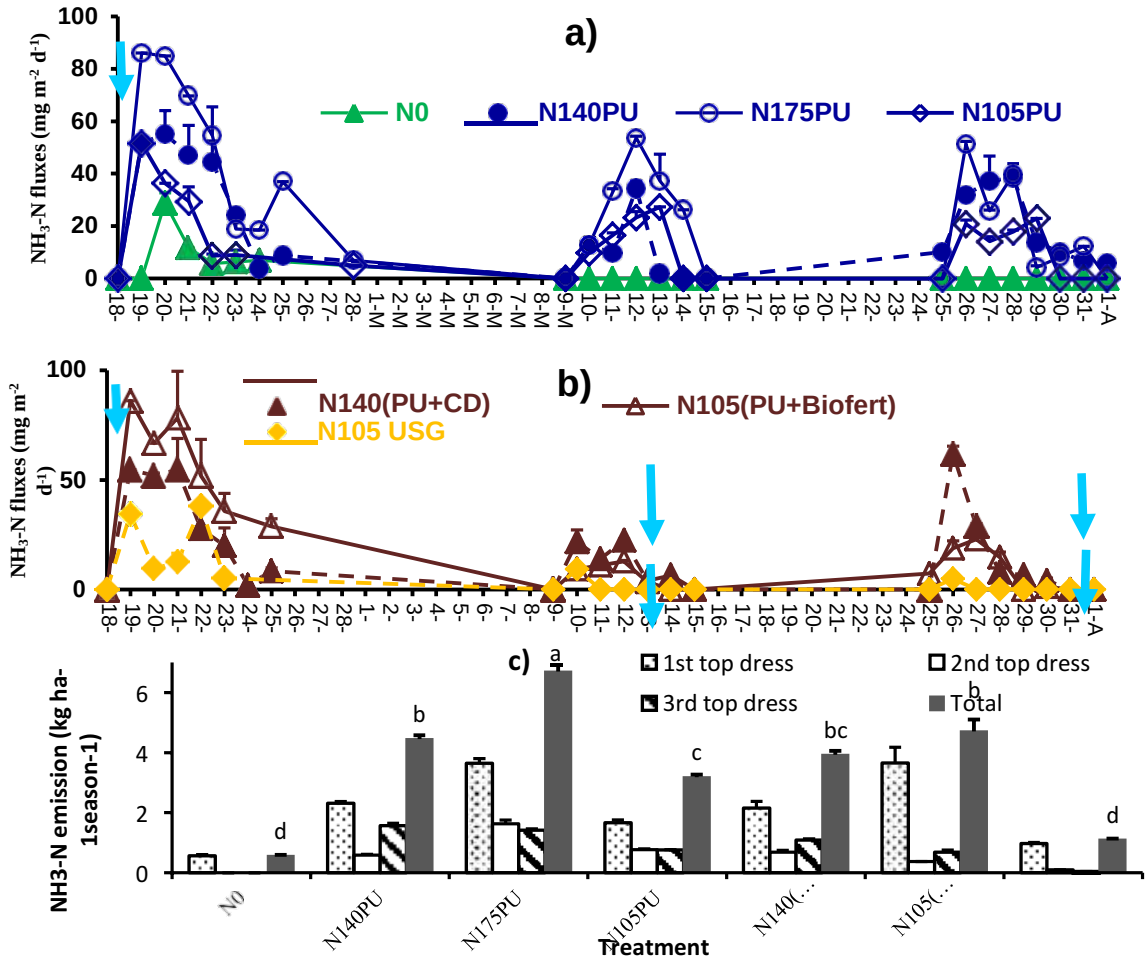

Fig. 4. Daily NH_3 fluxes (mean ± SE; n = 4) (a, b) and cumulative NH_3 fluxes (c) at different N management options in Boro rice during 2021; arrow shows the day of split application of urea or USG. Lower case letters after group mean of total NH_3-N fluxes indicate the significant ($p<0.01$) differences according to Duncan's Multiple Range Post Hoc Test.

Effect of biochar on rice yield in the charland. The study was conducted at BRRI RS, Sirajganj to determine the effect of biochar on rice growth, yield and soil health in charland. The experiment was initiated in Boro 2019-20 and consisted of four treatments: T_1= control, T_2= recommended fertilizer (RF), T_3= RF + biochar @ 2 t ha^{-1} and T_4= RF + biochar @ 4 t $ha^{-1.}$ The treatments were arranged in RCB design with three replications. The biochar was produced from *chita dhan* (unfilled grain). Flat doses of NPKS were applied @ 100-15-40-10 in T. Aman and 138-21-75-18 in Boro season. Biochar was applied only in Boro season and incorporated with the soil before seven days of transplanting. In T. Aman season, 30 % fertilizer was reduced from recommended dose in the biochar treated plots. In the Boro season, application of biochar @ 4 t ha^{-1} with recommended fertilizer resulted the highest grain yield (8.96 t ha^{-1}) of BRRI dhan89 compared to the other three treatments. In the T. Aman season, reduction of 30% chemical fertilizer in treatments that received biochar either @ 2 t ha^{-1} or 4 t ha^{-1} in the previous Boro season produced grain yield statistically similar to the full dose of chemical fertilizer (5.03 t ha^{-1}) treatment.

SOIL MICROBIOLOGICAL STUDIES

Field evaluation of BRRI bio-organic fertilizer. BRRI bio-organic fertilizer was developed with the objectives to reduce synthetic N and P fertilizer use in rice cultivation and improve soil health. To evaluate its field performance, one field experiment was conducted at BRRI HQ in both the season of T. Aman 2020, and Boro 2020-21. Bio-organic fertilizer (BoF) was used at 2 t ha^{-1}. The treatment combinations were NPKS (100%), BoF + 70% (N) +100% (KS), BoF +100% NPKS and fertilizer control. Recommendation rates of chemical fertilizers for T. Aman and Boro were (kg ha^{-1}) N-P-K-S @ 67-10-41-10 and 140-20-80-10, respectively. BRRI dhan87 at T. Aman and BRRI dhan89 was grown in the Boro season. Study result proved bio-organic fertilizer (BoF_1@ 2t ha^{-1}) has potential to supplement 30% N and 100% P requirement for HYV rice without sacrificing yield. In T. Aman, application of BoF with 70% (N) +100% (KS) produced the highest grain yield of 5.82 t ha^{-1}. Statistically similar grain yield was obtained in 100% NPKS (5.24 t ha^{-1}) and BoF +100% NPKS (4.91) treatment. However, in Boro season, the highest grain yield was recorded (7.32 t ha^{-1}) in the BoF with 100% NPKS treatment and statistical similar grain yield was obtained in both 30% reduced N and 100% NPKS applied treatments. Significantly the lowest grain yield was found at the control treatment.

Effect of bio-organic fertilizer on grain yield in the farmers' field. Six field demonstration trials were conducted to evaluate the performance of Bio-organic fertilizer at the farmers' field. In the field trials, BoF + 70% (N) +100% (KS) treatment was compared with standard NPKS (100%) doses. In the Gaziprur site, application of bio-organic fertilizer 2 t ha^{-1} (dry weight basis) along with 30% reduced urea and 100% removal of TSP fertilizer gave 5.7 to 10.52 % yield improvement. Similarly, the same treatment gave 9.52 to 18.2% yield increment at Dhanbari, Tangil. Whereas, in Madhupur, Tangail site, bio-organic fertilizer increased yield 67% compared to standard chemical fertilizer application.

Effect of balanced fertilizer on grain yield in the farmers' field. Four field demonstration trials were conducted to evaluate the performance of balanced fertilizer at the farmers' field. In the field trials, balanced fertilizer dose was compared with farmers' fertilizer doses. Field demonstration trials have been conducted at Kamarkhada, Sirajganj, Sonagazi, Feni, Bashial, Tangail and Asasoni, Satkhira, respectively. In all the demonstration trials balanced fertilizer dose treatment produced the highest grain yield compared to farmers' dose alone.

Microbial characterization of different AEZs soil. Soil biology dictates soil health. The study was initiated in 2019 to determine the microbial properties of different AEZ soils of Bangladesh. A total of 120 sample (composite of 1100 soil sample points) were collected (0-15 cm) from seven AEZ's using GPS and analyzed for total and beneficial bacteria, fungus and actinomycetes.

Microbial populations were determined using spread plate count technique with specific growth media. Soil samples were collected from AEZ-8 (Kishoreganj), AEZ-21(Kishoreganj), AEZ-10 (Faridpur sadar), AEZ-16 (Munshiganj), AEZ-19 (Cumilla), AEZ-22 (Habiganj and Moulovibazar), and AEZ-27 (Rangpur) district. Study report showed that among the tested AEZ's, the highest total bacteria found in Kishoreganj (AEZ-21), followed by Habiganj (AEZ-22) and Faridpur sadar (AEZ-10) (Fig. 5a). Total fungus population was higher in Cumilla (AEZ-19) (Fig. 5b). Actinomycetes population was low and almost similar in all tested AEZ's soil. The population of free-living N_2 fixing, Rhizobium and phosphate solubilizing bacteria were lower in number compared to any healthy agricultural soil **Biochemical properties of the isolated strain.** A total of 81 potential strains were isolated from 10 AEZ's (AEZ-19, AEZ-21, AEZ-8, AEZ-16, AEZ-22, AEZ-10, AEZ-27, AEZ-15, AEZ-11, AEZ-13) soil. Biological nitrogen fixation was determined in Kjeldahl method and it ranged from 7 to 28 mg kg^{-1} N. Among them the highest N_2 fixing strain B61 was isolated from AEZ-15. The second highest value (21 mg kg^{-1} N) was obtained in AEZ-21 (B9), AEZ-16 (B14) and AEZ 11 (B70). Phosphorus solubilization was determined using tri-calcium phosphate broth. The highest P solubilization (3582 mg kg^{-1} P) was recorded in the strain B64, which was isolated from AEZ-11. Strain B59 (AEZ-15) solubilized the second highest P (2961 mg kg^{-1}). Indoleacetic acid (IAA) was determined by using spectrophotometer and it was ranged from 2 to 144 mg kg^{-1}. The highest IAA was produced by strain B59 (AEZ-15). Strain identification is in progress.

Effect of industrial pollution on soil microbial biomass C and total microbial population. A benchmark survey was done with 30 rice soil samples to characterize the effect of heavy metal pollution on soil microbial biomass C and total population. The soils of Mirzapur and Pirujali were acidic in nature and contained high level of Fe (87 to 838 ppm), Pb (44 to169 ppm), and Cd (0.63 to 4.38 ppm). In most cases, Pd and Cd concentrations were above WHO toxic level. Zn (3-65 ppm) status is found significantly higher than the flood plain soil of other AEZs. Total bacteria population ranged from 7.7×10^7 to 2.2×10^5 cfu g^{-1} dry soil respectively. The free-living N_2 fixing (NFB) and phosphate solubilizing bacteria (PSB) population were very low ranging from 1.2×10^7 to 1.1×10^3 cfu g^{-1} dry soil for NFB and 1.3×10^6 to 2.2×10^5 cfu g^{-1} dry soil for PSB respectively. Heavy metals such as Cd, Cr etc. were reported to inhibit the growth, morphology and activities of such bacteria. Fungus and actinomycetes populations were also very low and most of the cases missing. Average biomass carbon ranged from 100 to 123 mg kg^{-1}. Furthermore, total and beneficial microbial populations and biomass C were lower than any other healthy agricultural soil.

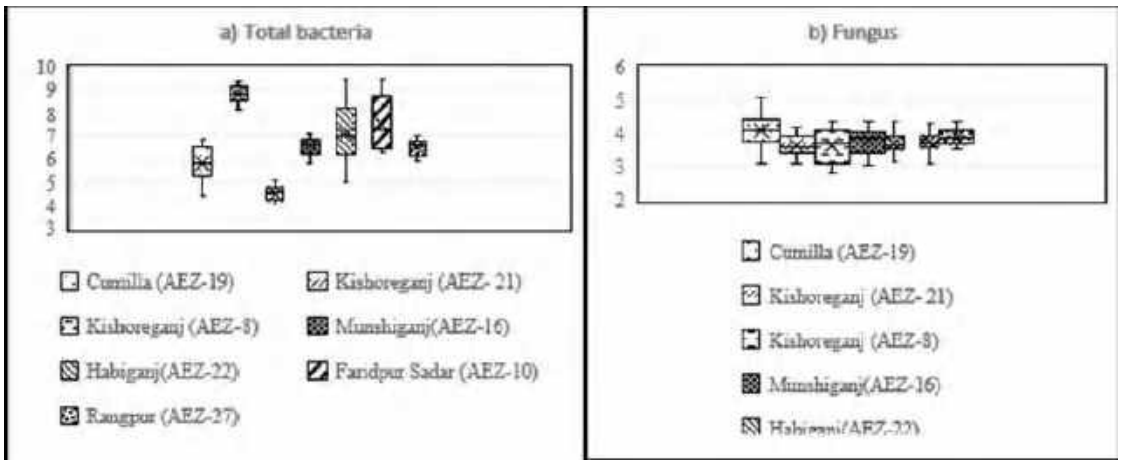

Fig. 5. Soil microbial populations of different AEZs a) Total bacteria, b) Fungus.

Irrigation and Water Management

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SUMMARY

During 2020-21, Irrigation and Water Management Division reported 15 programmes of basic and applied research as well as two major programmes of technology validation and adaptation in different agroecological zones with a target to generate and extend water efficient technologies in rice water management for increasing land and water productivity which would lead to sustainable food security and improved livelihood. For improving water use efficiency in irrigated agriculture, Boro establishment method of wet direct seeding with thin irrigation practice performed better in terms of irrigation water savings, yield, and water productivity. The newly developed Boro verities, BRRI dhan89 and BRRI dhan92, produced better yield for alternate wetting and drying (AWD) irrigation method. During Boro season, ALART BR8912-12-6-1-1-1-1 genotype showed adequate tolerance to -10 kPa of water stress. Boro rice could be transplanted up to 30 January, however, late transplanting saved irrigation water with 8-10% yield loss. Irrigation scheduling by CROPWAT model was found effective to save irrigation water in both Boro and T. Aman seasons. As a climate change mitigation technique, irrigation suspension followed by AWD method could significantly reduce 66-68% global warming potential (GWP) and 43-63% greenhouse gas intensity (GHGI) but increased total N2O flux. In Charland agriculture, different amendment practices improved soil physical properties and increased soil water retention capacity. A soil physical property analysis indicated that general textural class of BRRI R/S Rangpur farm is predominantly loam and silty loam having plough pan at 15-30 cm depth from ground surface. In rainfed environment, drought simulation model (DSM) predicted accurate amount of irrigation demand for agricultural drought considering soil moisture and meteorological conditions. To improve the land and water productivity in coastal region, cropping intensification by Boro rice cultivation could be a potential scope in Polders 30 and 31 by excavating poor and bad canals as well as trapping fresh water in those canals before dry season. About 135 ha fallow land in Barishal and Khulna regions were brought under Boro cultivation by using less saline or fresh river water. Beside this, integrated rice-vegetable system with modified vegetable establishment method was economically viable in salt affected coastal zone. For the sustainable management of water resources, conjunctive use of municipal wastewater with fresh water would be a good irrigation option in Boro season. All tested groundwater and surface water samples from different locations in the reporting year were safe to use in irrigation according to recommended quality indicator ranges. However, groundwater level depletion was about 39.70 m in last 23 years at BRRI farm Gazipur showing an alarming average declining rate of 1.65 m per year. In case of profitable utilization of renewable energy in irrigation pumping, return from solar pump was higher due to longer service period but needed to irrigate more than 1.75 ha per year. In Haor region, AWD method successfully saved irrigation water which helped to mitigate water demand in reproductive stage during Boro season. Also, drum seeding saved establishment cost and time, check valve installation in Shallow Tubewell (STW) removed pump starting drudgery, and improved distribution system saved 18-20% irrigation water.

WATER USE EFFICIENCY IMPROVEMENT IN IRRIGATED AGRICULTURE

Determination of physical and hydraulic properties in different soil types

The study was conducted in BRRI RS, Rangpur. Soil samples were collected from different soil profiles at 0-15, 15-30, 30-45, and 45-60 cm using standard protocols. Twenty-four samples were collected from BRRI RS, Rangpur from six locations across the research field. GPS coordinates were recorded for all soil sample collection points. Table 1 presents the soil textural class information along with sand, silt and clay percentages for Rangpur farm. Irrespective of depths, the general textural class of Rangpur farm was predominantly loam and silty loam. However, the soil was loam textured at 0-15 cm depth. The soil texture varied

among loam, silty loam, and sandy loam at 15-30 cm depth. The soil was mostly silt loam at 30-45 and 45-60 cm depth below ground surface. The average soil bulk density of Rangpur farm was 1.09 gm/cc, 1.51 gm/cc, 1.47 gm/cc, and 1.39 gm/cc at 0-15, 15-30, 30-45, 45-60 cm depths, respectively. The distribution of bulk density showed that the plough pan was situated at 15-30 depth of soil profile below the ground level.

Study on water-stress tolerance for different advanced rice genotypes of BRRI

There were two ALARTs named BR8526-38-2-1-HR1 and Lata Balam along with the check BRRI dhan50, BRRI dhan63 and BRRI dhan81under PQR supplied from Plant Breeding Division, BRRI during Boro season, 2020-21 (Table 2). None of the ALART had stress tolerance capacity. ALART BR8526-38-2-1-HR1 produced higher yield (7.5 t/ha) with continuous standing water treatment. Yield was decreased by 5.73, 6.67 and 9.6% than that of continuous standing water with the water stress of -10, -30 and -60 kPa, respectively. Similarly, ALART Lata Balam produced higher yield (5.3 t/ha) with continuous standing water treatment. Yield was decreased by 11.7%, 20.4% and 23.2% than that of continuous standing water. Check variety BRRI dhan50 produced 0.52% higher yield with -10 kPa water stress. ALART BR8912-12-6-1-1-1-1 and IR105837-8-95-2-1 along with the check BRRI dhan74 and BRRI dhan89 under ZER were tested to determine water stress tolerance capacity during Boro season, 2020-21. Statistically significant difference was observed in grain yield by genotype and water stress. ALART BR8912-12-6-1-1-1-1 produced 0.75% higher yield with – 10 kPa water stress than that of continuous standing water. Therefore, water stress tolerance capacity was -10 kPa. But the yield was decreased by 10.13% and 34.88% with -30 and -60 kPa water stress.

Optimization of irrigation water use for Boro cultivation under different establishment methods

The experiment was conducted in BRRI HQ farm, Gazipur during Boro season 2020-21 with four treatments. The treatments were: T_1- Transplanting with maintaining continuous standing water (TP-CSW); T_2- Transplanting with alternate wetting and drying irrigation practice (TP-AWD); T_3- Wet direct seeding with maintaining continuous standing water (WS-CSW); T_4- Wet direct seeding with thin irrigation practice (WS-TIP). Under transplanting method, shifting to AWD practice from CSW practice saved 100 mm irrigation water (Table 3). Under wet direct seeding method, shifting to TI practice from CSW practice saves 75 mm irrigation water. On the other hand, shifting from transplanting to wet direct seeding (WS) establishment method saved irrigation water. Shifting from TP method to WS method under CSW and TI practice saved 51 mm and 106 mm irrigation water, respectively. Treatment T_2 produced 2% higher yield with 11.2% less irrigation. Among the other treatments, T_3 produced 0.4% higher yield with 5.7% less irrigation water. Treatment T_4 produced 10% less yield with 11.9% less irrigation water. The highest water productivity in treatment T_2 was due to higher yield with less irrigation water. Despite lowest irrigation water use, the water productivity in T_4 was the lowest due to much lower yield. The experimental results showed that good yield could be achieved with wet direct seeding by drum seeder. Amount of irrigation was less in wet direct seeded plots compared to the transplanted plots. Maintaining continuous standing water condition was found good for both transplanting and direct seeding. Thin irrigation practice with wet direct seeding was found better for both irrigation water saving and satisfactory yield. Higher water productivity could be achieved from wet direct seeding with thin irrigation practice by improving the of crop yield.

Performance evaluation of the proposed rice varieties under different water regimes

The study was conducted to find out suitable water regimes for rice varieties and proposed lines. The experiment was conducted during Boro season 2020-21 in a brick wall tank at BRRI farm, Gazipur. Three long duration high yielding varieties BRRI dhan29, BRRI dhan89 and BRRI dhan92 were grown under four water regimes as: T_1 = Maintaining continuous standing water (CSW) from 1 to 5 cm; T_2 = AWD irrigation practice (+5 to -15 cm); T_3 = Aerobic condition (AWD: 0–25

cm) up to booting stage; and T_4 = Aerobic condition (AWD: 0–25 cm) during the entire crop period. Table 4 shows the amount of irrigation applied, rainfall occurred, and total water use during the growth duration along with grain yield. As January to March 2021 was almost rainless, huge amount of irrigation was applied to the treatments during this period. The amount of irrigation water in different treatments was comparatively less due to brick wall protection. The amount of rainfall was 85 mm for all the varieties and treatments. BRRI dhan89 had the tolerance to non-ponding condition. The experimental results showed that good yield could be achieved by maintaining CSW and AWD practice. Irrespective of variety, yield was declined considerably under aerobic condition.

Improving soil-water availability for crop production in Charland by amendment practices

The study has been carried out in BRRI farm Sirajganj, during Aman, 2020 and Boro 2020-21 to improve soil physical properties, soil water retention capacity of the root zone depth and to identify a suitable soil amendment practice to increase water use efficiency and the crop productivity of the char land. The study consists of five amendment practices as: T_1 = Compaction with clay soil at the layer of 20-30 cm, T_2 = Vermicompost added at the topsoil (0-10 cm) @ 5 t/ha, T_3 = topsoil (0-10 cm) mixed with 50% of clay soil, T_4 = Biochar added at the topsoil (0-10 cm) @5 t/ha, T_5 = Cow dung added at the topsoil (0-10 cm) @ 5 t/ha and T_6 = Control treatments in randomized complete block design with three replications. In Aman season, though higher sterility percentages (23.0%), but higher grain (4.2 t/ha) and straw yield (4.24 t/ha) was obtained from vermicompost added at top (0-10 cm) soil. Soil amendment practices like compaction with clay soil at the 20-30 cm soil layer, vermicompost applied at the top (0-10 cm) soil layer, about 50% clay mixing at top (0-10 cm) soil layer and biochar mixing at the top (0-10 cm) soil layer were helpful to increase the water availability for crop production (Fig. 1). Clay mixing (about 50%) at the top (0-10 cm) soil layer produced the better performance followed by vermicompost applied at the top (0-10 cm) soil layer and compaction with clay soil at the 20-30 cm soil layer. Cow dung applied at the top (0-10 cm) soil layer shows no response to increase the water availability in the soil. During Boro season, higher grain yield (8.25 t/ha) and straw yield (7.84 t/ha) was recorded in T_2.

Determining minimum irrigation water requirement of rice at different regions of Bangladesh through water balance from on-farm demand and model simulation

The experiment was conducted for three seasons (Aus, T. Aman and Boro) at BRRI RSs Kushtia, and Rangpur while it was executed in two seasons (T. Aman and Boro) at BRRI, Gazipur research farm during 2020-21. Table 5 presents seasonal irrigation amount applied as well as grain yield of different varieties according to three treatments (T_1 = Control, T_2 = AWD and T_3 = CROPWAT model simulation) for Kushtia, Rangpur and Gazipur. During Aus season, in Kushtia, there was no need to apply irrigation in any treatment due to huge rainfall throughout the growing period. In T. Aman season, both T_2 and T_3 treatment saved irrigation compared to continuous standing water treatment. During Boro season, yields were varied greatly in different treatments. In Rangpur, during Aus season, enormous rainfall occurred. So that there was no need to apply irrigation. In T. Aman season, drought occurred at the later part of the season as rain ceased. Treatment T_1 (i.e., continuous standing water in the field) received the highest amount while T_3 required comparatively less irrigation. Both T_2 and T_3 treatments saved irrigation compared to continuous standing water treatment. Yields were statistically similar in T_2 and T_3 but yield of T_1 was significantly different than other the two treatments. During Boro season, T_3 had the highest yield among the treatments. Both irrigation application and yields of T_2 and T_3 did not have any significant difference while T_1 was significantly different than that of other two treatments. In Gazipur, during T. Aman season, different amount of irrigation was applied as supplemental irrigation. In Boro season, T_3 treatment received the highest amount of irrigation and T_2 treatment received the lowest amount of irrigation, but it did not have significant impact on yields. Irrigation scheduling by CROPWAT model might be a potential

approach to save irrigation water but need in depth evaluation in terms of irrigation demand, irrigation received and yields.

Impact of delayed transplanting on irrigation requirement and yield of Boro rice at BRRI farm, Gazipur

The experiment was executed at BRRI farm, Gazipur during Boro season 2020-21 with four treatments such as T_1 - transplanting on 20 January; T_2 - Transplanting on 27 January; T_3 - transplanting on 3 February; T_4 - Transplanting on 10 February. BRRI dhan89 was used as a test variety. Different transplanting dates significantly affected the grain yield (Table 6). Treatments T_1 and T_2 had the highest yield (7 and 6.8 t/ha) and T_3 and T_4 had the lowest yield (6.5 and 6.3 t/ha). T_1 produced around 7-10% higher yield than T_3 and T_4. The reason for lower yield with the late transplanting (10 February) may be the shortened growth duration. The growth duration was 155 days for transplanting on 20 January, but growth duration of last sowing on 10 February reduced by 11 days than first sowing on 20 January. The total number of irrigations was 13 and 12 for transplanting on 20 and 27 January and 3 and 10 February. Therefore, sowing on 3 and 10 February just saved one irrigation. The total depth of irrigation water was 1,040 mm for first transplanting and 968 mm for last transplanting. The transplanting on 20 and 27 January received same irrigation water about 1,040 mm, whereas the following transplanting on 3 and 10 February had required 80-85 mm less irrigation. Transplanting before 30 January produced the highest yield. Transplanting after 30 January until 10 February reduced by 8-10% yield. However, late transplanting saved around 80 mm irrigation water. For getting potential yield, it is suggested to transplant rice before 30 January.

UTILIZATION OF WATER RESOURCES IN RAINFED ENVIRONMENT

Agricultural drought forecasting for mitigating drought in T. Aman rice

The experiment was conducted at BRRI farm Gazipur in T. Aman 2020. Amount of observed and forecasted rainfall was similar, but their weekly accumulated distributions were not similar (Fig. 2). Prediction error of seven days accumulated rainfall was found 32.9%. Prediction error of forecasted reference crop evapotranspiration (ET_0) was estimated 28% (Fig. 3). During growing period of BRRI dhan87, based on forecasted drought measured from DSM, one more supplemental irrigation applied compared to observed drought (Table 7). It depicted that the irrigation scheduling was similar determined by both models at reproductive and ripening stages. Only one additional supplemental irrigation at vegetative stage was determined by the drought simulation model (DSM) during T. Aman growing season. DSM considers existing soil moisture during calculating irrigation demand, but CROPWAT model does not consider existing soil moisture. So, DSM reflects agricultural drought considering both soil moisture and meteorological drought, but CROPWAT consider only meteorological drought. Therefore, DSM forecast small amount of irrigation water compared to CROPWAT. There is no significant yield difference between supplemental irrigation based on weather forecasting (I1) and supplemental irrigation based on observed (I2).

LAND PRODUTIVITY IMPROVEMENT IN THE COSTAL ENVIRONMENT

Water resources assessment for dry season crop cultivation in selected polders of coastal region

The study was conducted in the polder 30 and polder 31 at Khulna region. The polder 30 is situated in Batiaghata upazila and polder 31 is in Dacope upazila under Khulna district. Figure 4 shows good, poor, and bad canals were demarked from satellite image of polders 30 and 31. The gross area of polders 30 and 31 were found 6,523 ha and 11,842 ha of which 4,566 ha and 8,290 ha were estimated net cultivable area. In polder 30, total good, poor, and bad canals were found 136, 38 and 80 km long respectively. About 190, 101, 76 km good, poor, and bad canals were recorded in polder 31. In the good canals, total stored water during April were estimated 334 ha-m and 502 ha-m, respectively. Considering 30%, 50% and 100%

excavation of poor and bad canals the water storage was increased to 440, 511 and 688 ha-m in polder 30. Similarly, the projected amount of stored water for 30%, 50% and 100% excavation of poor and bad canals were found 660, 766 and 1,030 ha-m, respectively. With the existing water resource, for watermelon, the highest irrigated area coverage was estimated 6,680 ha and 10,040 ha, and the lowest area coverage was 334 and 502 ha of land in polders 30 and 31, respectively. Considering 30%, 50% and 100% canal excavation in polder 30, T. Aus area could be increased to 8,800, 10,220 and 13,760 ha whereas Boro area could be increased to 440, 511 and 688 ha, respectively. In Polder 31, Boro area was estimated 660, 766 and 1,030 ha for 30%, 50% and 100% canal excavation, respectively and this area for T. Aus rice was 4,402, 5,107 and 6,869 ha, respectively. Most of the secondary and tertiary canals in Polders 30 and 31 were in poor to bad condition. Excavation of these canals could significantly increase the stored amount inside the polder. Boro rice and dry season crop cultivation could increase by trapping fresh water into the canals by December. There is a large scope of crop intensification through Boro rice cultivation.

Boro area expansion by using less saline water resources for cropping intensification in Barishal region

During wet season, most of the lands cultivated long duration local rice variety to cope with the tidal pressure and water stagnation situation in Barishal region. Most of the lands remain fallow during dry season though there is many khals, and rivers crisscross the area with fresh water resources. This study was undertaken to increase the Boro rice production area and increase the cropping intensification and improve the land productivity of non-saline tidal region of Barishal region. The 28 block demonstrations were conducted at Bakerganj upazila of Barishal district, Sadar, Rajapur and Nalchiti upazilas of Jhalokathi district, Sadar upazila of Patuakali district, and Amtali and Taltolo upazilas of Borguna district with the latest popular Boro varieties of BRRI dhan47, BRRI dhan58, BRRI dhan67, BRRI dhan74, and BRRI dhan89 and covered about 110 ha lands (Fig. 5). The study results showed that the average yields of BRRI dhan47, BRRI dhan57, BRRI dhan67, BRRI dhan74, and BRRI dhan89 ranged from 5.9 to 6.5, 6.0 to 6.7, 6.5 to 6.8, 7.1 to 7.8, 7.8 to 8.2 t/ha, respectively for all selected locations. A total of 770 tons of rice grain of different varieties were harvested. Beside this, in Dakope upazila of Khulna district, 25 ha fallow land was cultivated with Boro rice that produced 175 tons of grain yield. In total the market value of these grains from 135 ha land was more than two crores in BDT by spending only about 27 lac BDT. This production will help ensuring the food security of that locations and contribute in employment generation. Most of the farmers produced their preferences on BRRI dhan47 and BRRI dhan74 due to the bold grains, which is preferred to those locations.

SUSTAINABLE MANAGEMENT OF WATER RESOURCES

Monitoring of groundwater fluctuation and safe utilization in different geo-hydrological regions

In this study, available the water level recorder was used for measuring groundwater fluctuation in BRRI, HQ Gazipur and all regional stations. Data were recorded weekly. Collected weekly records were calculated to obtain monthly average. In Gazipur, during 2020-21 period, maximum lowering of groundwater (-46.42 m) was observed in June and minimum (-44.91 m)) in August (Fig. 6). The fluctuation was within 1.5 m. The fluctuation was higher than the previous year. In 1998, the minimum groundwater level was about 5.23 m below the ground surface which was 44.91 m in 2021. Therefore, the lowering was about 39.68 m in 23 years. During the initial five years (1998-2002) the lowering (3.8 m) was not so high, but during the last five years (2017-2021) the lowering was about 8.87 m. Figure 7 presents monthly groundwater level of BRRI. Among 10 regional stations, the groundwater level was below the suction limit (> 8 m) during Boro season in Cumilla, Rajshahi and Habiganj.

Conjunctive use of wastewater and freshwater for irrigation in Boro rice cultivation

For determining the suitability of different wastewater treatments, a pot experiment was

conducted with five irrigation treatments namely T_1 = Irrigation with freshwater (control), T_2 = Irrigation with municipal wastewater (MWW), T_3 = Irrigation with industrial wastewater (IWW), T_4 = Irrigation with fresh water and industrial wastewater (50% FW and 50% IWW) and T_5 = Irrigation with fresh water and municipal wastewater (50% FW and 50% MWW). In total 18 times of irrigations were applied in every pot throughout the growth stages. Yield and yield contributing parameters were recorded (Table 8). Irrigation with freshwater (control) produced the highest yield (79.57g/pot) followed by irrigation with 50% FW and 50% MWW (67.51g/pot). So, along with freshwater, municipal wastewater with freshwater is a good option for irrigation practices in Boro season.

Assessment of surface and groundwater quality for irrigation in selected locations of Bangladesh

The experiment was conducted at BRRI HQ in Gazipur and five regional stations namely Rajshahi, Rangpur, Kushtia, Barisal and Habiganj in 2020-21. The water samples BRRI were collected from different sources of ground water and surface water. The quality of water for location was assessed for its irrigational purposes. In the present study, all the samples had Kelly's ratio (KR) less than 1.0 except Barishal (Table 9). So, KR showed full satisfaction in using for irrigation. Soluble sodium percentage values were found in satisfactory level. Magnesium absorption ratio was found satisfactory (< 50) for irrigation.

Effect of irrigation suspension on mitigating greenhouse gas emission in irrigated rice cultivation

The study was conducted in BRRI HQ farm, Gazipur during Boro 2020-21. The experiment was carried out with five irrigation management treatments as T_1 = Continuous standing water (CSW), T_2 = Alternate wetting and drying (AWD), T_3 = Irrigation suspension from 20-40 days after transplanting (DAT) + AWD water management (ISAWD), T_4 = Irrigation suspension from 20-50 DAT + AWD water management in rest of the period, T_5 = Intermittent drainage from 20-35 DAT and 40-55 DAT + CSW water management in rest of the period. Statistically similar grain yield was found both in T_1 (6.0 t/ha) and T_2 (5.9 t/ha), whereas the lowest 4.7 t/ha found in T_4. This may be the result of more water stress experienced in T_4 than the first two treatments. The results showed that no water stress was found in AWD condition, however 20 days and 30 days irrigation suspension experienced water shortage and consequently yield loss occurred. Fifteen days irrigation suspension (T_5) in two spells showed better yield performance than T_4, although significant yield loss was documented in CSW and AWD practices. All the four irrigation treatments saved irrigation water compared to T_1. However, the maximum (27%) irrigation was saved in T_4. The highest irrigation water productivity of 0.67 kg/m^3 was found in treatment T_3. The total CH4 flux were 253-148-145 kg/ha under CF-AWD-ISAWD irrigation system and N_2O flux were 0.23-0.66 kg/ha under different water condition during study period (Table 10). The AWD and ISAWD irrigation system significantly reduced total CH_4 fluxes by 72-75% over CF. The AWD and ISAWD irrigation systems were mainly responsible for increased total N_2O fluxes by 148% and 187% over CF system, respectively. The AWD and ISAWD irrigation system significantly reduced about 66-68% of total global warming potential (GWP) and 43-63% of greenhouse gas intensity (GHGI) than continuous flooding because of reducing CH_4 emission rates. Among the irrigation systems, AWD is one of the key techniques for reducing total CH_4 emission, and GWP and GHG intensity without sacrificing rice yield. Irrigation suspension by 20 days and 30 days saved irrigation compared to continuous standing water management. However, it sacrificed significant grain yield than the control treatment.

RENEWABLE ENERGY

Evaluation of smallholder surface water solar irrigation system for crop production

The financial analysis of solar pump was done from the viewpoint of machine owners. The marginal profit of single use of portable solar pump (only irrigation) was smaller than that of diesel pump

(only irrigation) but the same was the highest for multipurpose uses of portable solar pump (Table 11). The life cycle cost of diesel-operated pump was lower than that of solar pump up to eight years (Fig. 8). Thereafter, it increases linearly, and the solar pump becomes more economic. So, from the economic viewpoint, the investment on multipurpose uses of portable solar pump was more profitable than the single use of diesel pump or single use of portable solar pump. The break-even use of single use diesel pump and single use portable solar pump were estimated as 4.86 bigha and 12.55 bigha of land per year, respectively (Fig. 9a and 9b). This implies that a service provider must irrigate more than 4.86 bigha of land per year to make the diesel pump profitable. On the other hand, portable solar pump will be more profitable if the user irrigates more than 12.55 bigha of land per year.

TECHNOLOGY VALIDATION IN THE FARMERS' FIELD

Cropping systems intensification in the salt-affected coastal zones of Bangladesh and West Bengal, India

The ACIAR, Australia and KGF, Bangladesh jointly funded the project that has been conducted in polder #43/1 at Amtali, Barguna (medium salinity area) and polder #31 at Dacope, Khulna (high salinity area).

Growing vegetables crops with rice under waterlogged lowland condition. Plastic bags (0.5-0.75 m diameter) were filled up with soil and compost along with 50 gm TSP, 30 gm MoP and 1 kg of mustard oil cake and placed 3 m apart in the rice field. The height of the bag was about 0.3 m above the highest flood level or tidal water level. The integrated rice/vegetable system was not economically attractive under the initial method (plastic sac with bamboo). But after some modification by introducing durable plastic drum and concrete pillar and galvanized iron wire and synchronizing vegetable production with T. Aman rice, then two to three times vegetable production was possible. However, the system found to be the potential for ensuring nutritional security and regular cash income for the coastal dwellers. The current years' performance (2020) confirmed that the integrated rice/vegetable system was economically viable under the modified vegetable establishment method (Fig. 10).

Improved water management technologies for increasing agricultural production in the Haor areas (Phase-2)

BRRI core funded project was executed in Haor areas of greater Sylhet division to demonstrate the effectiveness of some water management technologies, to assess the existing land uses and potential for increasing production, and to assess the water resources availability and potential of irrigation expansion through improved management.

Performance of AWD irrigation scheduling on yield and irrigation water use for Boro rice. Performance of AWD irrigation scheduling on yield and irrigation water use for Boro rice areas was demonstrated in the Haor region. A total of 15 demonstrations were conducted in three locations such as- Baniachong (2), Nabiganj (5), and Chatak (8) upazilas. The mean number of irrigations in the demonstration and farmers practice plots were 12 and 14, respectively. This indicates that by adopting AWD irrigation practice the farmers could save two irrigations without sacrificing the yield. Optimum crop yield could be achieved by adoption of AWD irrigation scheduling in the Haor areas. Water scarcity in the reproductive phase is common in the Haor areas. Some water could be saved by adoption of AWD irrigation practice. Conservation of the saved water will provide the opportunity to mitigate the water stress in reproductive phase.

Performance of drum seeded rice in Haor areas of Bangladesh. The demonstrations were conducted in Chatak upazila, Sunamgianj and Nabiganj Upazila, Habiganj. Performance of some Boro varieties under drum seeding establishment method were evaluated and compared with conventional transplanting method. Drum seeding reduces the growth duration around 14-20 days which might be helpful for earlier harvest of crop by escaping flash flood in Haor areas. Labour requirement for crop establishment was less under

drum seeding method compared to the transplanting method. Grain yield in drum seeding method was like the transplanting method. Adoption of drum seeding method may help low cost and time saving establishment of Boro rice in the Haor areas.

Performance of check valve in STW irrigation. Two types of check valve- single chamber and double chamber were constructed. Three double chamber (one 4"×5" and two 4" × 4") and two single chamber (4" × 4" and 4" × 3") check valves were constructed. All the installed check valve worked properly in the STWs. The drudgery of the pump operator reduced significantly after installation of the check valves. Installation of check valve did not reduce pump discharge considerably. It took 3-15 seconds to start discharge from the pump delivery. To attain full discharge, it took 12-40 seconds.

Performance of low cost polyethene pipe for irrigation water distribution. To evaluate the performance of low-cost polythene pipe water distribution system, two LLPs and 2 STWs were selected in Chatak and Nabiganj, respectively. The irrigation water loss per 100 m polythene pipe in two LLP schemes of Chatak were 3.03% and 3.37%. The irrigation water loss per 100 m polythene pipe in 2 STW schemes of Nabiganj were 3.02% and 3.57%. The water loss for earthen canal in LLP and STW schemes in the Haor area was found 25.7% and 21.8%, respectively, during Boro season 2018-19. The above results indicate that around 18-22% irrigation water could be saved by using polythene pipe instead of earthen canal.

Table 1. The soil texture of BRRI RS, Rangpur.

Longitude	Latitude	Depth (cm)	Bulk density (gm/cc)	Sand%	Silt%	Clay%	Textural Class
25°41´47″N	89°16´11″E	0-15	1.22	36	48	16	Loam
		15-30	1.54	31	53	16	Silt Loam
		30-45	1.42	28	61	11	Silt Loam
		45-60	1.54	28	59	13	Silt Loam
25°41´45″N	89°16´11″E	0-15	1.00	44	45	11	Loam
		15-30	1.42	48	44	9	Loam
		30-45	1.49	36	51	13	Silt Loam
		45-60	1.31	32	57	11	Silt Loam
25°41´45″N	89°16´09″E	0-15	1.11	45	46	9	Loam
		15-30	1.46	53	38	9	Sandy Loam
		30-45	1.47	37	50	13	Silt Loam
		45-60	1.40	35	54	11	Silt Loam
25°41´44″N	89°16´06″E	0-15	1.03	44	44	12	Loam
		15-30	1.52	43	44	13	Loam
		30-45	1.53	50	43	7	Loam
		45-60	1.42	51	45	4	Sandy Loam
25°41´44″N	89°16´04″E	0-15	1.10	49	42	9	Loam
		15-30	1.54	47	38	15	Loam
		30-45	1.52	30	55	15	Silt Loam
		45-60	1.41	27	58	15	Silt Loam
25°41´44″N	89°16´03″E	0-15	1.05	47	40	13	Loam
		15-30	1.56	26	51	23	Silt Loam
		30-45	1.40	24	59	17	Silt Loam
		45-60	1.27	28	59	13	Silt Loam

Table 2. Grain yield of tested varieties as affected by different levels of water stress at whole growing season during Boro, 2020-21.

ALART and check variety	Grain yield (t/ha)				Stress tolerance capacity
	CF	-10	-30	-60	
ALART-PQR, Boro 2020-21					
BR8526-38-2-1-HR1	7.50	7.07 (-5.73%)	7.00 (-6.67%)	6.78 (-9.6%)	
Lata Balam	5.30	4.68 (-11.7%)	4.22 (-20.4%)	4.07 (-23.2%)	
BRRI dhan50 (Ck)	5.80	5.83 (+0.52%)	5.40 (-6.9%)	5.29 (-8.8%)	-10 kPa
BRRI dhan63 (Ck)	6.86	6.22 (-9.33%)	5.88 (-14.3%)	4.57 (-33.4%)	
BRRI dhan81 (Ck)	7.41	6.76 (-8.77%)	6.18 (-16.6%)	6.13 (-17.3%)	
F-value					ns
lsd0.05					0.95
cv%					9.5
ALART-ZER, Boro 2020-21					
BR8912-12-6-1-1-1-1	8.0	8.06 (+0.75%)	7.19 (-10.1%)	5.21 (-34.88%)	-10 kPa
IR105837-8-95-2-1	6.47	5.72 (-11.6%)	5.09 (-21.3%)	4.59 (-29.06%)	
BRRI dhan74 (Ck)	7.22	6.29 (-12.88%)	5.95 (-17.6%	5.42 (-24.93%	
BRRI dhan89 (Ck)	9.21	7.8 (-15.3%)	7.88 (-14.4%)	6.68 (-27.5%)	
F-value					*(0.012)
lsd0.05					0.713
cv%					6.4

Table 3. Irrigation applied, growth duration and yield obtained under different crop establishment treatments along with water management during Boro season 2020-21 at BRRI farm, Gazipur.

Treat	Method	Irrigation applied (mm)	Rainfall (mm)	Total water use (mm)	Yield (t/ha)	Irrigation water saving than T1 (%)	Yield change than T1 (%)	Water productivity (lit/kg)	
								Irrigation water	Total water
T_1	TP-CSW	891	54	945	5.57	-	-	1212.1	1696.9
T_2	TP-AWD	781	54	835	5.68	11.22	1.97	1012.6	1488.1
T_3	WS-CSW	840	85	925	5.59	5.72	0.40	1198.3	1653.6
T_4	WS-TIP	785	85	870	5.01	11.90	-10.07	1228.2	1736.5

Table 4. Irrigation, rainfall, and grain yield of the selected varieties under different treatments during Boro season 2019-20 at BRRI farm, Gazipur.

Treat	Variety	Total growth duration (days)	No. of irrigations	Irrigation applied (mm)	Rainfall (mm)	Total water use (mm)	Yield (kg/ha)	Mean yield (kg/ha)
T_1V_1	BRRI dhan29	158					8770.0	
T_1V_2	BRRI dhan89	159	16	858	85	943	9367.9	9207.6
T_1V_3	BRRI dhan92	161					9484.8	
T_2V_1	BRRI dhan29	158					8673.3	
T_2V_2	BRRI dhan89	159	14	772	85	857	9576.7	9242.3
T_2V_3	BRRI dhan92	162					9476.7	
T_3V_1	BRRI dhan29	158					8316.4	
T_3V_2	BRRI dhan89	160	19	746	85	833	8429.9	8463.7
T_3V_3	BRRI dhan92	162					8659.3	
T_4V_1	BRRI dhan29	161					8138.0	
T_4V_2	BRRI dhan89	162	21	702	85	787	8280.2	8270.6
T_4V_3	BRRI dhan92	162					8393.6	

Table 5. Treatment wise irrigation applied and average yield in different locations during different seasons 2020-2021.

Treatment	Irrigation (mm)			Avg. Yield (t/ha)		
	Aus	T. Aman	Boro	Aus	T. Aman	Boro
			Kushtia			
T_1 (Control)	0	300a	913a	4.7a	4.1a	8.0a
T_2 (AWD)	0	200b	688a	3.9a	3.9a	6.7ab
T_3 (CROPWAT)	0	255.7c	709a	4.2a	3.9a	5.5b
CV%	0	5.83	264.7	16.76	7.64	12.53
$LSD_{0.05}$	0	24.97	19.88	1.24	0.53	1.46
			Rangpur			
T_1 (Control)	0	254a	510a	3.7a	3.45b	6.51b
T_2 (AWD)	0	223b	363b	3.9a	4.20a	7.47a
T_3 (CROPWAT)	0	113c	394b	3.8a	4.43a	7.55a
CV%	0	10.4	11.47	8.69	6.79	1.69
$LSD_{0.05}$	0	28.4	83.80	0.57	0.48	0.21
			Gazipur			
T_1 (Control)		96a	488a		7.4a	6.63a
T_2 (AWD)		72b	350b		6.65a	6.33a
T_3 (CROPWAT)		61c	599c		5.6a	6.53a
CV%		2.27	3.01		17.74	10.31
$LSD_{0.05}$		5.55	24.97		2.01	1.16

Table 6. Number of irrigations, amount of irrigation applied for different transplanting dates in Boro season 2020-21 at BRRI farm, Gazipur.

Treat	Number of irrigation	Amount of irrigation (mm)			Total water use (mm)	Growth duration (day)	Yield (t/ha)
		Land preparation	Growing Period	Total			
T_1	13	180	860	1040	1040	155	7.0^{a}
T_2	13	180	855	1035	1035	152	6.8^{ab}
T_3	12	180	780	960	960	147	6.5^{bc}
T_4	12	180	788	968	968	144	6.3^{c}

Table 7. Comparison of forecasted irrigation scheduling between CROPWAT and DSM.

Date of irrigation	Day to irrigate	Stage	Net irrigation (mm)	Gross irrigation (mm)*
		CROPWAT		
17-Sep-2020	71	Reproductive	50.0	53.0
20-Oct-2020	104	Ripening	50.0	53.0
29-Oct-2020	113	Ripening	50.0	53.0
Total	3		150.0	159.0
		Drought simulation model (DSM)		
02-Sep-2020	56	Vegetative	6.2	6.5
23-Sep-2020	77	Reproductive	16.0	16.8
28-Oct-2020	112	Ripening	18.2	19.2
04-Nov-2020	119	Ripening	24.2	25.5
Total	4		64.6	68.0

*Irrigation efficiency was taken as 95% due to plastic hose pipe used for distributing water.

Table 8. Yield and yield contributing parameters of different irrigation treatments during Boro 2020-21.

Treatment	Plant height (cm)	Panicle length (cm)	Tiller/hill	Panicle/hill	Yield/pot (g)	1000 GW (g)
T_1	94.17a	24.67a	12a	10.67a	79.57a	21.50
T_2	89.83a	23.00a	13a	8.00b	57.62bc	17.20
T_3	90.83a	24.33a	13a	9.00ab	64.03b	18.60
T_4	91.50a	23.33a	11a	7.33b	50.52c	16.20
T_5	92.33a	23.83a	10a	8.67ab	67.51ab	18.40
CV	5.41	5.97	22.39	13.7	10.98	13.
LSD	9.35	2.68	5.08	2.25	13.2	

Table 9. Water quality indicator of different sources of water in different locations during 2020-21.

Indictor	Kushtia	Rajshahi	Location		Gazipur	Habiganj	Recommended limit (FAO)
			Barisal	Rangpur			
			Ground water				
MAR	34.32±2.25	46.87±3.61	45.64±3.6	32.22±4.4	26.02±4.28	35.7±0.57	<50
SAR	0.79±0.028	0.91±0.09	1.72±0.14	0.62±0.062	0.88±0.035	0.4±0.081	<10
KR	0.57±0.05	0.68±0.12	1.2±0.18	0.47±0.049	0.58±0.076	0.3±0.08	<1
TH	49.47±5.26	49.47±8.17	49.47±6.77	45.83±5.10	58.33±10.41	58.3±0.08	<500
SSP	39.97±1.89	41.27±4.42	56.95±3.28	34.39±2.27	38.86±3.25	22.8±0.16	20-40
			Surface water				
		Kushtia				Habiganj	
MAR		34.96±4.02				46.9±4.29	<50
SAR		0.83±0.026				0.75±0.052	<10
KR		0.55±0.034				0.56±0.049	<1
TH		58.33±3.60				45.83±2.40	<500
SSP		37.70±1.45				38.13±2.01	20-40

Table 10. Total GHGI and GWP under varying irrigation management during Boro, 2020-21.

Treatment	Greenhouse gas emission (kg/ha)			
	CH_4	N_2O	GWP	GHGI
T_1 (CF)	254	0.23	7140	1.19
T_2 (AWD)	148	0.57	4289	0.73
T_3 (ISAWD)	145	0.66	4242	0.83
LSD (0.05)	52	0.21	339	0.08

Table 11. Estimated major cost and return items of diesel pump, portable panel based solar pump and versatile use of portable panel based solar pump operation.

Cost Item	Unit	Diesel pump	Solar pump-1*	Solar pump-2*
Purchase price/initial cost with installation cost	Tk.	23275	172950	251930
Annual use in area	bigha	15	15	15
Economic life, L	year	10	25	25
Depreciation, D	Tk./yr.	2364	7300	14539
Fixed cost, FC	Tk./bigha	4710	24885	40124
Variable cost, VC	Tk./bigha	29590	14540	48190
Total cost of operation, TOC= FC+VC	Tk./bigha	34300	39425	88314
Payment for replacement, PFR	Tk./yr.	1716	3786	8779
Rent out charge	Tk./bigha	2940	2940	2940
Revenue, R	Tk./yr.	44100	44100	127025
Marginal profit, PM= R-TOC	Tk/yr.	9800	4675	38712
Benefit cost ratio, BCR	-	1.29	1.12	1.44
Break Even Point, BEP	bigha/yr.	4.86	12.55	-
Pay Back Period, PBP	year	7	15	8

* Solar pumps 1 and 2 indicate single use and multipurpose uses, respectively.

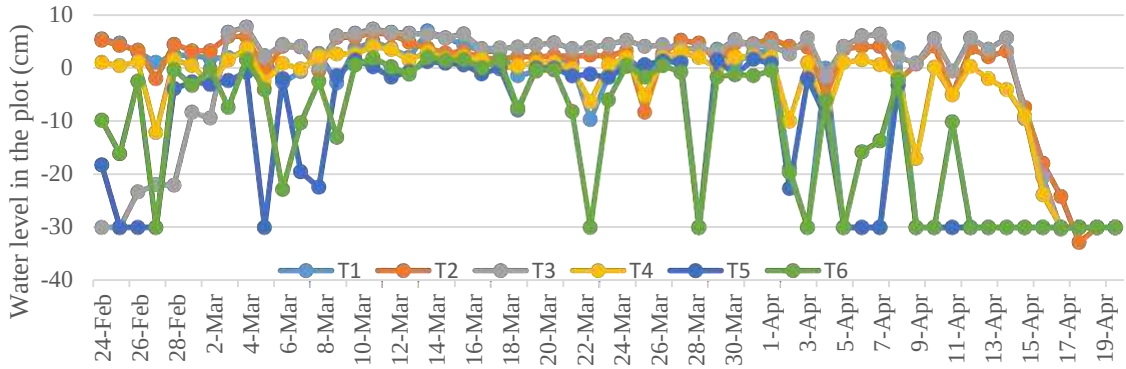


Fig. 1. Water level (cm) in the plot at BRRI farm, Sirajganj during Boro 2020-21.

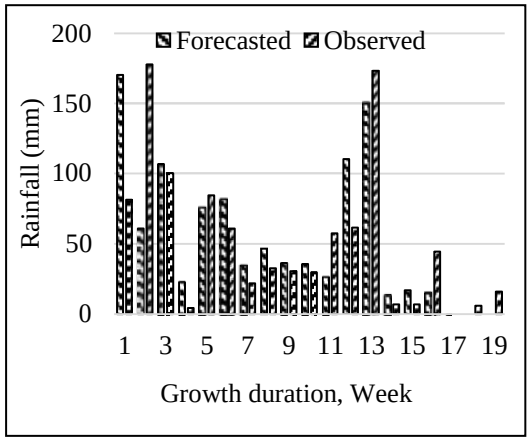


Fig. 2. Weekly accumulated observed vs forecasted crop evapotranspiration (ET0).

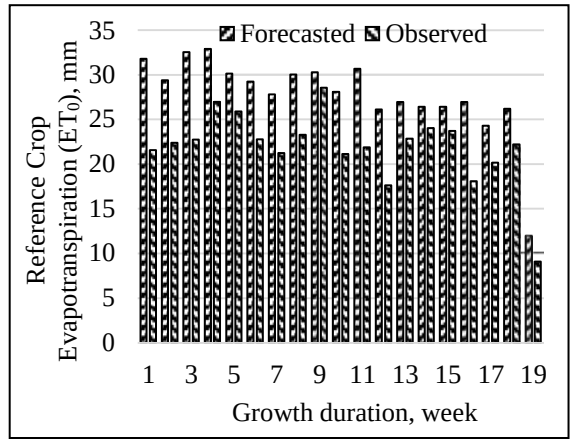


Fig. 3. Weekly accumulated observed vs forecasted rainfall.

Fig. 4. Canal network inside the polders 30 and 31 in Khulna region.

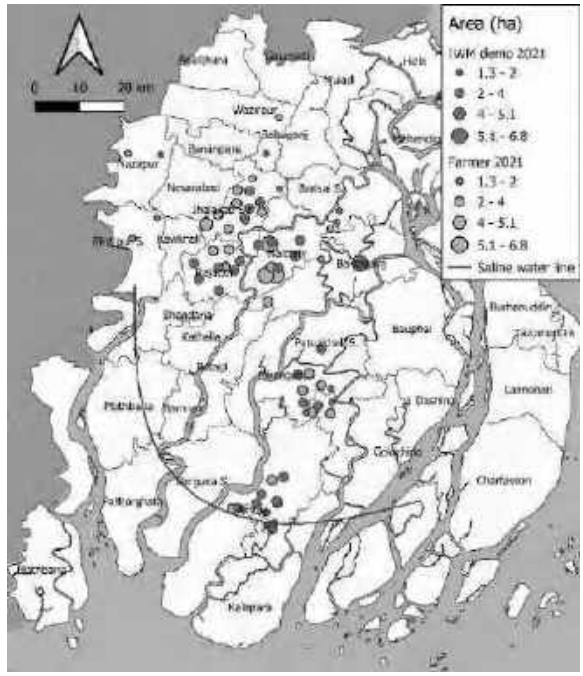
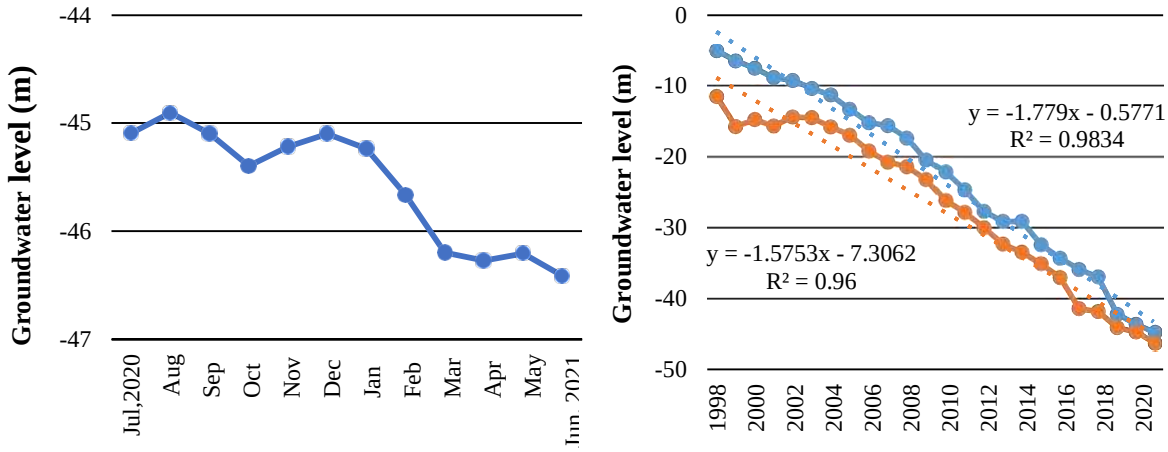


Fig. 5. Map showing locations and land coverage (ha) under BRRI demonstrations during Boro 2020-21 in six upazilas of Barishal region.



a) **Monthly GWL fluctuation** b) **Long-term GWL declination**

Fig. 6. GW fluctuation (2020-21) and long-term GW declination (1998-2021) at BRRI farm, Gazipur.

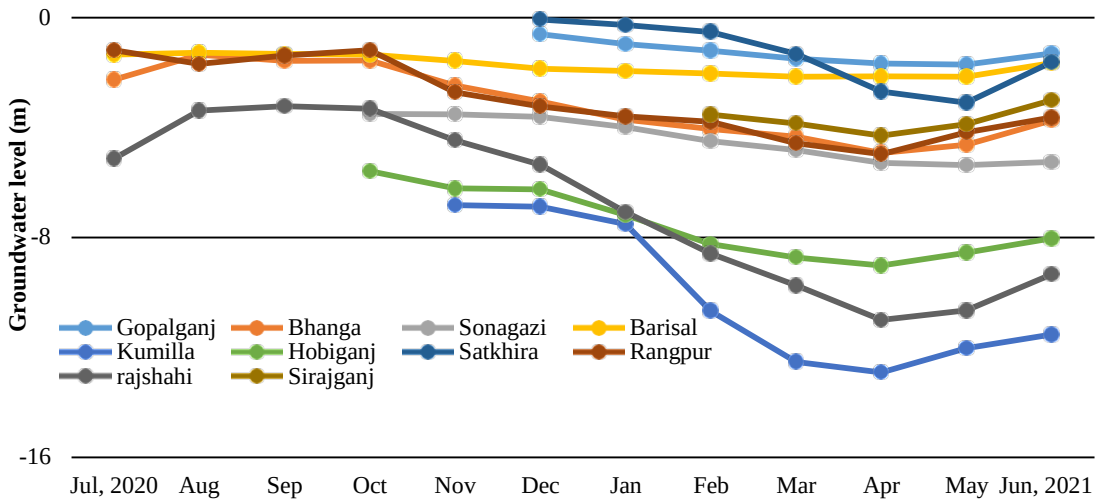


Fig. 7. Yearly GW level fluctuation at different BRRI RS during 2020-21.

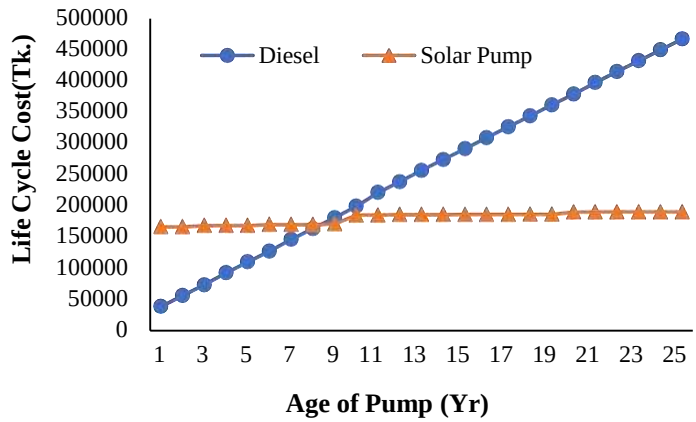


Fig. 8. Life cycle costs of diesel and multipurpose use solar pumps.

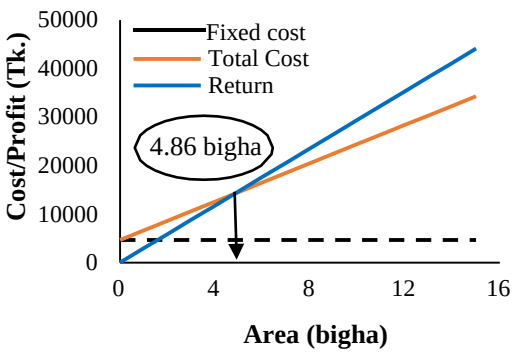


Fig. 9(a): BEP of diesel pump

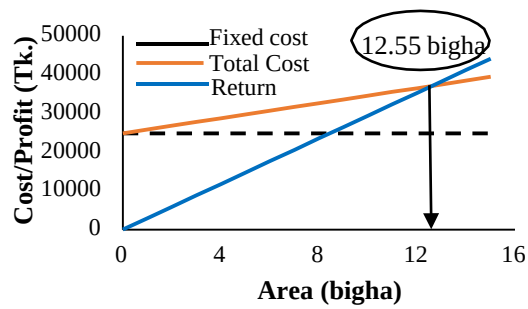


Fig. 9(b): BEP of solar pump

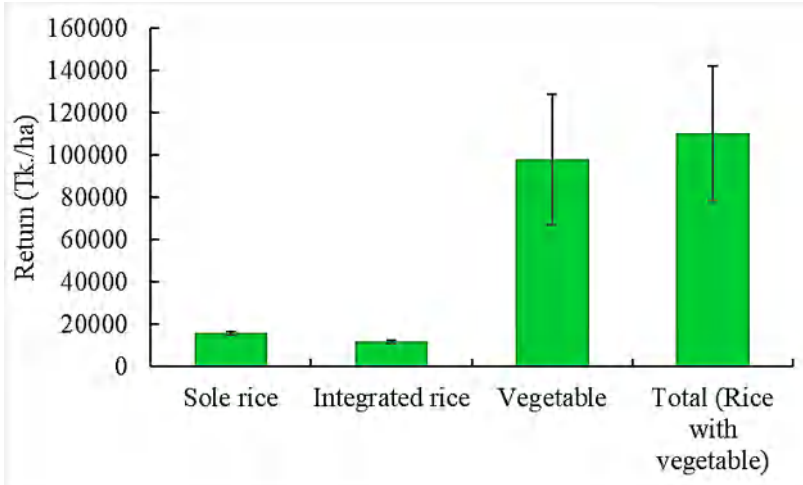


Fig. 10. Economic performance of integrated rice and vegetable with sole rice at Dacope, Khulna during 2020.

Plant Physiology Division

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SUMMARY

Thirty experiments under seven different projects have been carried out during 2020-21 in the Plant Physiology Division of BRRI. In salinity stress, around 400 rice germplasm and 687 breeding lines were characterized out of them 155 genotypes were found tolerant to moderately tolerant at seedling stage. For improving salinity tolerance of rice a CRISPR/Cas9 targeting the *OsRR22* gene in rice was designed where a 19bp guide sequence (5′-AGAGGGATCAATTCCCCGT-3′) was a protospacer adjacent motif lying within the *OsRR22* coding sequence (LOC_Os06g08440). The guide sequence was properly cloned into the binary vector pC1300-Cas9. The binary vector pC1300-Cas9 harboring Cas9/*OsRR22* sgRNA was mobilized into *Agrobacterium tumefaciens* LBA4404 by freeze-thaw method and confirmed through PCR-gel electrophoresis. Salinity tolerant QTLs of Ashfal balam were validated for whole growth period under control saline condition. A total of 39 significant QTLs were identified for plant height (2), panicle number (3), filled grain number (10), filled grain weight (14), spikelet fertility (7) and plant survivability (3). In all mapping, one cluster of QTL in chromosome 6 was found consistent for filled grain number and filled grain weight within the marker interval id6007312- K_id6011324. Salt tolerance of a backcross population was characterized at seedling stage. The results revealed that seedling stage salt tolerance is a polygenic trait which is governs by a number of minor genes, increased recurrent alleles in the backcross population causing negative skewness (more number of sensitive progenies). Significant marker-trait linkages for all tested markers revealed due to the presence of all markers within the Saltol QTL region. In drought tolerance, 300 germplasm and 12 advanced breeding lines were tested of which 43 germplasm and three advanced breeding lines (IR118194-B-17-3, IR1181194-B-51-1 and IR118194-B-6-4-HR2) performed better compared to others. Under control drought condition in the rainout shelter, out of 41 germplasm BRRI GeneBank Acc. no. 2276 yielded the highest followed by Acc. no. 1800, 1905 and 1907. The sterility percentage of these genotypes was less than 50%. Some 100 germplasm and 29 advanced breeding lines were screened for two weeks of complete submergence where seven genotypes were found moderately tolerant. Out of 50 advance lines 12 genotypes were selected as moderately tolerant to stagnant flood condition on the basis of per cent survivability and tillering ability. BRRI dhan78 was screened for duel stress tolerance of salinity and submergence. It had around 80% survivability for 10 to 12 days submergence along with 6 to 8 ds/m salinity. But, check variety BRRI dhan79 had 100% survivability at 8 ds/m salinity along with 10 days complete submergence. Elongation ability of BRRI dhan91 was evaluated under deep flooding condition. Per cent elongation of the BRRI dhan91 (39.47%) was significantly lower than Higol Digha (100%). Likewise, its survivability (57.14%) was much lower than BRRI dhan52 (100%). Plant height of BRRI dhan91 was 232.65 cm while it was 99.82 and 257.88 cm in BRRI dhan51 and Higol Digha respectively under medium deep water condition. Among 50 BRRI Gene bank germplasm, four accessions (BRRI Acc. numbers 1782, 1783, 1797 and 2085) were found tolerant to heat at reproductive phase with more than 60% spikelet fertility. A high temperature spikelet fertility QTL introgression line in the background of BRRI dhan28 along with BRRI dhan28, BRRI dhan81 and BRRI dhan88 were tested for preliminary yield evaluation during Boro 2020-21. It yielded the highest (6.57 tha^{-1}) with 1-5 days earlier with improved or similar grain quality traits except intermediate amylose content (21.9%) than BRRI dhan28. High temperature tolerant spikelet fertility QTL introgression lines were screened in control condition. Tested lines scored 3-7 having spikelet fertility ranged from 32-68% while, BRRI dhan28 scored 7 with spikelet fertility 21% and donor N22 scored 5 with fertility 53%. Some 250 rice genotypes were screened for seedling stage cold tolerance of which 32 germplasm and BRRI dhan84 were selected as moderately tolerant. Out of 17 advanced breeding lines seven genotypes were selected as moderately cold tolerant at reproductive phase. Some 21 advanced breeding lines and four varieties were

characterized in natural field condition where four genotypes were found as moderately cold tolerant at reproductive phase. Five different types of polythene covering on Boro rice seedbed along with control were evaluated. The highest seedling strength was recorded from seedbed having polythene covering for 24 hrs during cold wave followed by covering for whole night and covering for all time with opening at both end. Polythene covering for all time at seedbed had lower seedling strength but higher seedling mortality. Two separate experiments were conducted for reducing growth duration of Boro rice through accumulation of degree days using polythene covering at seedling stage and vernalization. Results showed that none of them reduced growth duration of Boro rice. Determined duration of different growth phases of eight BRRI varieties BRRI dhan87, BRRI dhan90, BRRI dhan 91, BRRI dhan 93, BRRI dhan 94, BRRI dhan 95, BRRI hybrid dhan4 and BRRI hybrid dhan6 at various planting times. Some 71 advanced breeding lines along with Nazirsail, BR22 and BR11 as check varieties were tested to measure the level of Photosensitivity at net house of plant physiology division. Among them 14 advance breeding lines were strongly photosensitive, while six and 37 lines were found moderately and weakly photosensitive, respectively. Density of stomata in the leaves of cultivated high yielding rice varieties and related C4 species were investigated. It was the highest in Uri dhan leaves but lowest in Maize. Rice and Shayma had intermediate number of stomatal density. Kaoun and Shayma showed an equal distribution in the number of stomata in the both surfaces of leaves. Rooting dynamics of 84 BRRI rice cultivars/varieties were evaluated against different nitrogen concentrations. Three root traits viz. total root length (TRL), maximum root length (MRL), root number (RN) were measured. Among 84 varieties, 36 in cluster Ia, 26 in Ib and 22 in II. Varieties under cluster II had higher MRL, TRL and RN than other varieties of Ia and Ib. Edited *TMS5* gene using CRISPR/Cas9 system for generating male sterile rice line of two-line hybrid system. Designed a CRISPR/Cas9 targeting the *TMS5* gene in rice and cloned the guide sequences into the binary vector pC1300-Cas9. The binary vector pC1300-Cas9 harboring Cas9/*TMS5* sgRNA was mobilized into *Agrobacterium tumefaciens* LBA4404 by freeze-thaw method and confirmed through PCR-gel electrophoresis.

SALINITY TOLERANCE

Exploring new sources of salinity tolerance from BRRI Gene bank germplasm at the seedling stage. Some 400 germplasm were screened for seedling stage salinity tolerance at 12 dS m^{-1} according to Gregario *et. al.,* (1997) along with standard tolerant check IR58443-6B-10-3 and sensitive check IRRI154. Among them 46 germplasm (Acc. no. 2712, 2729, 2747, 2755, 2768, 2772, 2775, 2779, 2780, 2796, 2821, 2828, 2834, 2840, 2844, 2860, 2890, 2904, 2905, 2926, 2958, 2961, 2963, 2970, 2971, 2972, 2973, 2974, 2975, 2976, 2977, 3004, 3005, 3006, 3037, 3051, 3052, 3072, 3076, 3078, 3083, 3085, 3126, 3127, 3128 and 3130) were found tolerant to moderately tolerant (SES score ranged from 3.0-5.0).

Screening of advanced breeding lines for tolerance to salinity at the seedling stage. A in total 687 advanced lines from different sources (Plant Breeding and Biotechnology Division) were screened according to Gregario *et. al.,* (1997) along with standard tolerant check IR58443-6B-10-3 and sensitive check IRRI154 for seedling stage salinity tolerance at 12 dS m^{-1}. Among them nine genotypes (BR9626-1-2-12, BR9625-B-1-4-6, BR(BIO)8961-AC26-16-3, BR(BIO)8961-AC26-16-4, IR103783-B-B-6-2, IR15T1319, SVIN468, SVIN164 and SVIN160) were tolerant (SES 3) and 101 genotypes (IR12A173, BR9625-B-2-4-9, BR11714-5R-49, BR11714-5R-74, BR11714-5R-125, BR11714-5R-148, BR11714-5R-176, BR11715-5R-62, BR11716-5R-2, IR13N115, IR86385-276-2-2-B, SVIN162, SVMET140, SVMET140, SVIN162, SVIN467, BR9926-7-7-6, TP1231, TP30668, BR9625-B-2-4-8, BR9626-B2-3-15, SVIN355, BR(BIO)11310-AC1-2, BR(BIO)11310-AC2-2, BR11712-5R-87, BR11723-5R-18, BR11714-5R-84, BR11714-5R-88, BR11714-5R-17, BR11714-5R-145, BR11714-5R-201, BR11714-5R-203, BR11715-5R-22, BR11715-5R-59, BR11715-5R-90, BR11716-5R-19,

BR11718-5R-8, BR11027-5R-5, IR92522-45-3-1-4, IR15L1504, IR103390-B-B-2-3, IR103419-B-B-1-3, IR103791-B-B-3-1, IR103795-B-B-2-1, IR16F1079, IR54447-3B-10-2, IR09M120, IR13A107, IR15A1103, PIR-26>C0-2071-1-4-2-1, IR108289-B-AJY 1-2-B-1, IR86385-80-1-2-B, IR86385-84-1-1-B, IR15T1303, IR15T1469, IR15T1473, BRRI DHAN 55, IR101793-1-1-1-3-5-4, IR15L1203, SVIN467, SVIN163, SVMET294, SVIN164, SVIN165, SVMET294, SVMET134, SVMET111, SVMET125, BR11925-4R-186, BR11940-4R-123, BR11940-4R-126, BR11921-4R-335, BR11933-4R-273, BR11940-4R-119, BR11925-4R-108, BR11911-4R-313, BR11923-4R-355, BR11940-4R-115, BR11925-4R-48, BR11388-4R-292, BR11910-4R-61, BR11919-4R-53, BR11911-4R-160, BR11920-4R-3, BR11910-4R-99, BR11919-4R-55, BR11910-4R-133, BR11910-4R-12, BR11910-4R-243, BR11910-4R-247, BR11919-4R-21, BR11920-4R-447, BR11920-4R-476, BR11933-4R-387, BR11911-4R-386, BR11920-4R-521, BR11921-4R-100, BR11940-4R-24, BR11940-4R-61, BR11940-4R-167 and BR11920-4R-478 were moderately tolerant (SES score ranged from 3.5 -5.0)

CRISPR-Cas9 mutagenesis of the *OsRR22* gene for improving salinity tolerance of rice. Salinity is one of the most important abiotic stress affecting the world rice production. Numerous salt tolerance quantitative trait loci were identified and few of them had been transferred into popular rice varieties via marker-assisted selection (MAS) but none of them showed greater promise. The *OsRR22* gene encodes a 696–amino acid B-type response regulator transcription factor that is involved in both cytokinin signal transduction and metabolism; its loss of function has been reported to significantly increase salt tolerance. To design a CRISPR/Cas9 targeting the *OsRR22* gene in rice, a 19bp guide sequence (5′-AGAGGGATCAATTCCCCGT-3′) was a protospacer adjacent motif lying within the *OsRR22* coding sequence (*LOC_Os06g08440*). The guide sequence was properly cloned into the binary vector pC1300-Cas9 (Fig. 1). The binary vector pC1300-Cas9 harboring Cas9/*OsRR22* sgRNA was mobilized into *Agrobacterium tumefaciens* LBA4404 by freeze-thaw method and confirmed through PCR-gel electrophoresis (Fig. 2).

Validation of Ashfal balam salinity tolerant QTLs for whole growth period under control saline condition. A linkage map of 105 KASP SNP markers in 200 $F_{2:3}$ population of the cross between BR11/Ashfal balam was constructed and subsequent QTL mapping was also carried out by Inclusive Composite Interval Mapping method reported 2016-2017. Previous remapping identified 20 significant QTLs for plant height, filled grain number, unfilled grain number, spikelet fertility and shoot dry weight reported during 2018-2019. In both of the previous mapping, one cluster of QTL in chromosome 6 was found consistent for filled grain number, filled grain weight and spikelet

Fig. 1. Confirmation of vector constructs by alignment of sequence of recombinant pC1300-Cas9 harboring Cas9/*OsRR22* sgRNA with guide sequence.

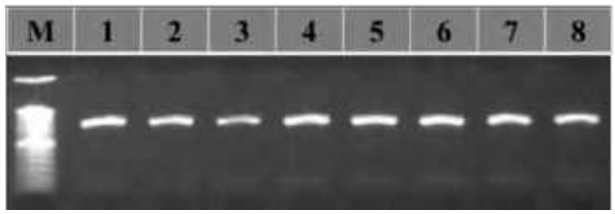

Fig. 2. Confirmation of *Agrobacterium* transformation through PCR-gel electrophoresis. *Agrobacterium tumefaciens* LBA4404 with recombinant pC1300-Cas9 harboring Cas9/*OsRR22 sgRNA* (Lane 1-8). M: marker (50 bp DNA ladder).

fertility traits. The present study was undertaken again to validate the effects of previously identified salinity tolerance QTLs from Ashfal balam. A total of 129 F_7-RIL populations (BR11/Ashfal balam) were transplanted in the salinity tank having soil salinity @ 6 dS m^{-1} along with parents and standard check IRRI154 and IR58443. Seedlings were raised in non-saline condition and transplanted at 25 days of age during T. Aman 2020 season. The soil salinity of the tank was monitored daily and maintained 6 dS m^{-1} by adding saline solution or flushing soil by sweet water as and when necessary. Yield and yield component data were recorded after harvesting of the lines. A total of 39 significant QTLs were identified for plant height (2), panicle number (3), filled grain number (10), filled grain weight (14), spikelet fertility (7) and plant survivability (3). In all mapping, one cluster of QTL in chromosome 6 was found consistent for filled grain number and filled grain weight within the marker interval id6007312- K_id6011324 (Table 1). This QTL region could be the key target for developing future reproductive stage salinity tolerance from Ashfal balam.

Table 1. Significant QTLs identified for whole growth salinity tolerance from Ashfal balam.

Trait name	Chro. no.	Position (cM)	Left marker	Right marker	LOD	PVE (%)	Add	Dom
PH	6	36	K_id6001535	id6000009	3.21	3.21	-19.09	44.84
PH	9	145	K_id9007001	K_id9007287	3.10	1.79	-25.38	21.96
PN	4	126	id4005212	id4005825	4.39	1.23	-6.86	-8.15
PN	6	89	id6000009	id6012115	6.79	1.08	-5.08	-4.23
PN	6	97	id6012115	id6006868	6.25	1.06	-4.73	-4.06
FGN	3	76	K_id3003557	K_id3007320	10.03	4.65	152.21	-155.03
FGN	4	17	id4010800	id4000734	6.63	2.64	-208.27	-184.00
FGN	6	88	id6000009	id6012115	6.97	3.55	-190.97	-126.36
FGN	6	106	id6012115	id6006868	3.69	2.33	-173.16	-147.95
FGN	6	151	id6007312	K_id6011324	4.58	3.25	168.10	-170.89
FGN	6	204	K_id6015421	K_id6016941	3.26	2.18	-128.15	-127.92
FGN	7	46	id7002711	id7005036	5.31	3.44	-161.36	-155.83
FGN	10	99	id10003686	id10001118	3.29	3.64	135.81	-143.31
FGN	11	41	id11009456	id11010544	4.73	3.26	-159.22	-187.44
FGN	12	7	id12001582	id12006327	6.88	3.44	15.74	360.88
FGW	1	35	K_id1024973	id1024167	10.31	1.87	-14.56	-14.81
FGW	3	82	K_id3003557	K_id3007320	3.20	0.79	2.14	-2.07
FGW	4	9	id4010800	id4000734	26.08	3.01	-15.05	-8.74
FGW	4	125	id4005212	id4005825	13.66	1.87	-14.57	-14.79
FGW	6	89	id6000009	id6012115	14.37	2.17	-15.02	-12.73
FGW	6	99	id6012115	id6006868	16.20	2.12	-14.94	-12.72
FGW	6	145	id6006868	id6007312	14.82	2.05	13.64	-16.00
FGW	6	150	id6007312	K_id6011324	11.85	1.92	14.27	-15.29
FGW	6	203	K_id6015421	K_id6016941	16.76	2.93	-12.27	-17.88
FGW	7	34	id7002711	id7005036	11.51	1.94	-14.87	-13.82
FGW	8	91	id8006707	id8007265	11.01	2.12	13.78	-16.08
FGW	10	82	id10003870	id10003686	12.67	1.90	14.28	-15.18
FGW	11	48	id11009456	id11010544	13.52	1.88	-14.54	-15.02
FGW	12	3	id12001582	id12006327	25.97	2.99	-15.03	-8.63
FERT	2	40	id2010481	K_id2000618	5.52	2.62	-6.49	-35.18
FERT	3	72	K_id3003557	K_id3007320	3.04	1.92	3.89	-31.88
FERT	4	37	id4010800	id4000734	6.00	2.77	-26.50	6.72
FERT	6	43	K_id6001535	id6000009	4.74	2.46	-1.77	37.78
FERT	7	48	id7002711	id7005036	4.88	2.63	-24.61	9.27
FERT	9	34	K_id9002563	id9000783	4.69	2.43	-0.40	36.54
FERT	12	43	id12006327	id12004974	5.54	2.56	-5.35	-39.30
SUR	1	38	K_id1024973	id1024167	4.12	1.38	26.35	16.46
SUR	7	40	id7002711	id7005036	3.40	2.27	-0.44	-41.44
SUR	12	38	id12006327	id12004974	3.04	2.34	-0.63	-41.87

Characterization for salt tolerance of a backcross population at seedling stage. The present investigation aimed to study marker-trait linkages for seedling stage salinity tolerance of a backcross population. A total of 1,569 BC_2F_2 progenies were characterized phenotypically in hydroponic for seedling stage salinity tolerance and tolerant progenies were then further characterized genotypically by molecular markers to reveal marker-trait linkage. Under high salt stress (12 dS m^{-1}) at seedling stage the tested progenies were distributed non-normally from tolerant to sensitive classes with negative skewness towards sensitivity (Fig. 3). Genotyping by 4 polymorphic markers (RM10694, RM8094, AP3206f, RM493) across *Saltol* QTL region of 20 tolerant and moderately tolerant lines showed a highly significant marker-trait linkage reveal by single marker analysis through one sample t-test (Fig. 4). The results revealed that seedling stage salt tolerance is a polygenic trait which is governs by a number of minor genes, increased recurrent alleles in the backcross population causing negative skewness (more number of sensitive progenies). Significant marker-trait linkages for all tested markers revealed due to the presence of all markers within the *Saltol* QTL region. The following markers could be useful to track seedling stage salt tolerance in the breeding of salinity tolerance when BRRI dhan47 or derived lines are used.

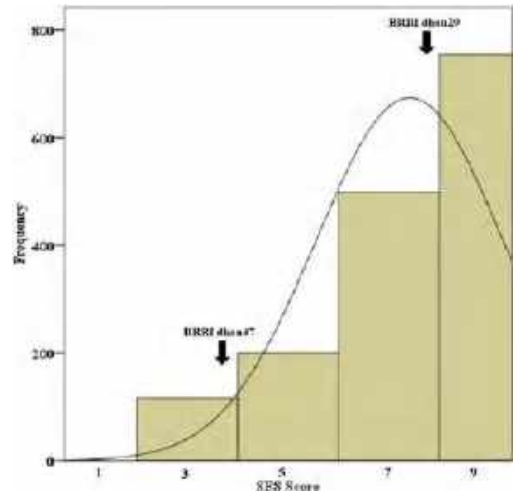

Fig. 3. Histogram representing the distribution of progenies according to SES score.

SUBMERGENCE TOLERANCE

Screening of rice germplasm for two weeks flash flood submergence tolerance. An experiment was conducted to identify tolerant germlasm for two weeks complete submerged condition at vegetative stage. One hundred germplasm and three advance lines along with check varieties BR5, BRRI dhan79 and FR13A were tested for two weeks flash flood

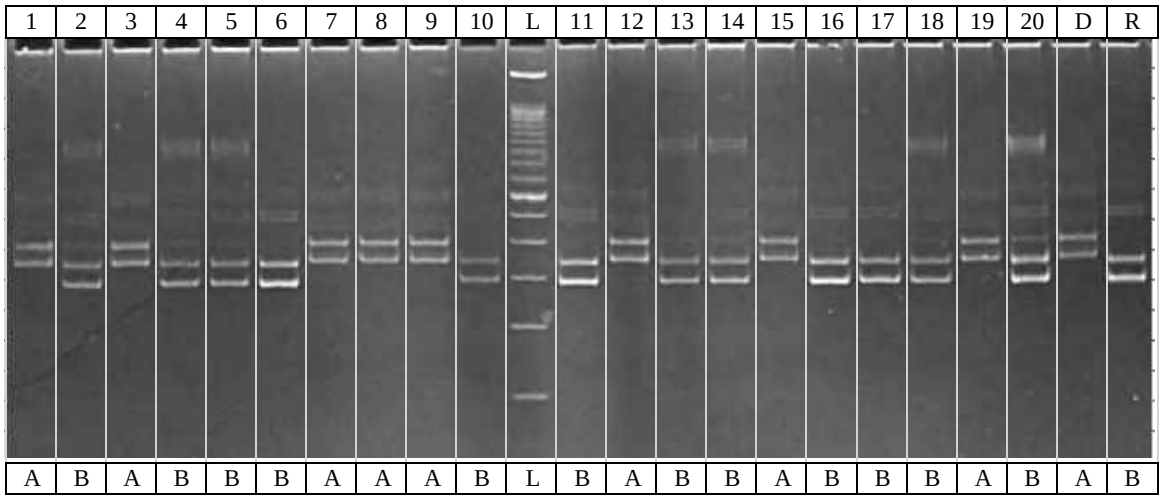

Fig. 4. Polyacrylamide 10% gel of the marker RM10694 representing DNA band in different level for parents indicating polymorphism. Where SL 1-20 is the tested progenies, D = BRRI dhan47 (donor parent), R = BRRI dhan29 (recurrent parent), L = DNA weight marker 50 bp, A and B denotes donor & recurrent parent allele.

submergence tolerance. Twenty-day old seedlings were transplanted in a submergence tank. Two weeks after transplanting plants were completely submerged for 14 days. The water level was up to 1m. After 14 days of drain out of water recovery and survivability score was taken. Out of 100 germplasm only one germplasm found non-elongating types (Acc. No. 1465) having survivability percentage was 50% (SES score 7) and rest of the germplsms were elongating type. Survivability of the tolerant check varieties FR13A and BRRI dhan79 was 100% while susceptible check BR5 showed only 15% survivability.

Identification of rice advance breeding line for two weeks flash flood submergence tolerance. Twenty-six advance breeding lines along with BR22, BRRI dhan71, BR5, BRRI dhan79 and FR13A as check varieties were screened out to identify submergence tolerant line at vegetative stage. Twenty five days old seedlings were transplanted in a concrete submergence tank. Two weeks after transplanting plant were submerged completely at 1-meter height and kept submerged condition for 14 days. After 21 days of drain out of water recovery or survivability score was taken. Water pH, temperature and dissolve O_2 of the submergence tank were 7.4-8.5, 29-31^{0}C and 5.5-8.0 mg/L respectively. Range of water turbidity of the tank was 32-80 FNU. Out of 26 advance lines seven genotype (BR10190-3-7-3-2-10-1-14, BR10190-3-1-19-5-1-1-13, IR118194-B-3-3-HR3, IR118194-B-6-4-HR1, IR118194-B-6-4-HR2, IR118194-B-17-3 and IR118194-B-10-1) found moderately tolerant (SES score 5) and their range of survivability percentage were 75 -86%. Therefore, the survability percentage of tolerant (FR13A) and standard check (BRRI dhan79) were 90 and 83% respectively (Table 2).

Screening for stagnant flooding tolerance of advance breeding lines and germplasm at whole growth period during T. Aman season. Fifty advanced breeding lines were tested in water stagnant condition to identify their stagnant tolerance and tillering ability. Twenty one day old seedling were transplanted at one seedling per hill with 20 x 20cm spacing. The stagnant flooding treatment was started from 7 DAT with 5 cm water depth and was increased weekly by 5 cm up to 40 cm at 56 DAT and then increased to 50 cm at 63 DAT and 60 cm at 70 DAT and maintained till maturity. Out of 50 genotypes on the basis of survivability (%) and tillering ability two germplasm and 12 advance lines (Table 3) were selected as moderately tolerant to stagnant flood condition.

Table 2. Survivability and SES score of the tested advance line for 2 weeks complete submerged condition in 2020.

Sl No.	Genotypes Name	Surviv ability%	SES Score	Sl. No.	Genotypes Name	Surviv ability%	SES Score
1	BR10190-3-7-3-2-3-1-6	50	7	1	IR118194-B-6-3-HR1	47	9
2	BR10 190-3-7-3-2-3-1-6	43	9	2	IR118194-B-6-3-HR2	42	9
3	BR10190-3-7-3-2-8-1-7	63	7	3	IR118194-B-3-3-HR2	70	7
4	BR10190-3-7-3-2-8-1-12	63	7	4	**IR118194-B-3-3-HR3**	**78**	**5**
5	BR10190-3-7-3-2-2-1-8	67	7	5	**IR118194-B-6-4-HR1**	**75**	**5**
6	BR10190-3-7-14-7-1-2-1-16	70	7	6	**IR118194-B-6-4-HR2**	**78**	**5**
7	BR10190-3-1-19-5-5-1-11	63	7	7	IR118194-B-6-2	72	7
8	BR10190-3-1-19-5-5-1-15	63	7	8	IR118194-B-12-1	70	7
9	**BR10190-3-7-3-2-10-1-14**	**77**	**5**	9	IR118194-B-51-1	80	5
10	BR10190-3-1-19-5-1-1-7	70	7	10	**IR118194-B-17-3**	**86**	**5**
11	**BR10190-3-1-19-5-1-1-13**	**80**	**5**	11	**IR118194-B-10-1**	**75**	**5**
12	BR10190-3-1-19-5-1-1-12	60	7	12	IR118194-B-26-3	67	7
13	BR10190-3-7-14-7-7-1-3	57	7	13	BRRI dhan71 (CK)	46	9
14	BR10190-3-7-14-7-7-1-7	63	7	14	FR13 (Resistant CK)	100	1
15	BR22 (CK)	63	7	15	BR5 (Susceptible CK)	17	9
16	FR13 (Resistant CK)	90	5	16	BRRI dhan79 (Standard CK)	92	5
17	BR5 (Susceptible CK)	40	9				

Table 3. Survivability and productive tiller/hill of selected moderately water stagnant tolerant rice genotypes

Designation	Survivability %	Productive tiller/hill	Designation	Surviv ability %	Productive tiller/hill
Acc no. 1929	90	7	IR118194-B-3-3-HR2	85	7
Acc no. 1931	80	6	IR118194-B-12-1	75	6
BR10 190-3-7-3-2-3-1-6	90	6	IR118194-B-51-1	75	7
BR10190-3-7-3-2-2-1-8	100	6	IR118194-B-10-1	60	7
BR10190-3-1-19-5-5-1-15	80	6	IR118194-B-26-3	60	6
BR10190-3-7-3-2-10-1-14	100	6	BR22	100	6
BR10190-3-1-19-5-1-1-7	100	6	BRRI dhan 52	80	4
IR118194-B-6-3-HR1	85	8	BRRI dhan71	75	4
IR118194-B-6-3-HR2	75	7	BRRI dhan 79	90	3
LSD @ 5%	4.54	1.58	LSD @ 5%	4.54	1.58

Screening of BRRI dhan78 under saline submergence condition

An experiment was conducted to identify the tolerance level of BRRI dhan78 under saline submergence condition. Three different salinity levels (6, 8 and 12 dS/m) along with three different inundation periods (10, 12 and 14 days) was impose to know the tolerance level. BRRI dhan47 and BRRI dhan79 were used as saline and submergence tolerant check respectively. None of the variety survived under submerged condition along with salinity at 12dS/m. BRRI dhan78 had around 80% survivability for 10 to 12 days submergence along with 6 to 8 ds/m salinity. Interestingly, BRRI dhan79 had 100% survivability for duel stress of salinity at 8 ds/m and submergence for 10 days.

Evaluation of elongation ability of BRRI dhan91 under deep flooding condition

The study was conducted to see the elongation ability of BRRI dhan91 under deep flooding condition. BRRI dhan91 along with FR13A, BRRI dhan79, BRRI dhan51, BRRI dhan52, BR5, BR10260-7-19, Lal khama, Lal digha, Hbj A II, Higol digha, Laxmi digha, Hbj A IV and Hbj A VIII were tested for this study. Twenty days old seedling was transplanted following two environments. One was medium deep water condition. Under this condition two week after transplanting water level was increased @ 10 cm per week and stopped when the water level was up to 1.5 m. Another one was complete submergence condition. Under this condition two week after transplanting plants were submerged completely for 14 days. The water level was up to 1m. After 14 days of drain out of water percent elongation and survivability score was taken. The results showed that under submergence condition percent elongation of the tested varieties ranged from 13.91% in BRRI dhan79 to 100.27% in Higol Digha and survivability ranged from 10.71% in Lal Digha to 100% in BRRI dhan52. The percent elongation and survivability of the BRRI dhan91 was found 39.47 % and 57.14%, respectively. On the contrary, under medium deep water condition plant height of the tested varieties ranged from 99.82 cm in BRRI dhan51 to 257.88 cm in Higol Digha. The plant height of the attempt variety BRRI dhan91 was found 232.65 cm.

DROUGHT TOLERANCE

Screening of rice germplasm for drought tolerance at reproductive phase in T. Aman 2020. Three hundred rice germplasm collected from BRRI Gene bank along with check variety BRRI dhan71 and IR64 were tested during T. Aman season 2020 at BRRI farm Gazipur following Field-managed screening protocol (IRRI, 2008). Thirty day old seedlings were transplanted at a spacing of 20 cm x 20 cm. The experiment was laid out in Alpha lattice design with two replications. Standard agronomic management practices were followed.

Irrigation was withheld four weeks after transplanting and field were drained out properly for not allowing any standing water until maturity. Out of 300 germplasms, 43 genotypes showed better performance in relation to yield under drought stress at reproductive phase.

Confirmation of performance for advanced breeding lines under control drought condition at reproductive phase. Twelve advanced breeding lines along with check varieties BRRI dhan56, BRRI dhan71 and IR64 were evaluated in Plant Physiology net house shaded by polythene sheet at BRRI HQ, Gazipur during T. Aman season 2020. Twenty five day old seedlings were transplanted in drum (56 cm x 43 cm) containing 110 kg puddled soil in two sets where 1st set was grown in well-watered conditions and 2nd set under stress condition. At panicle initiation stage water was drained out from the 2nd set so that the plants experiences drought stress from the reduction division stage. The water table depth and soil moisture was recorded. At severe drought stress some life saving water was applied and calculated as follows: $= \Pi r^2 h$

Where, r = 56/2 = 28 cm (The radius of the circumference of pot at the base of the hill.)

h = 0.5 cm/day (the approximate evapotranspiration at the period of Nov-Dec.

Out of 12 advanced breeding lines IR118194-B-17-3 performed better followed by IR1181194-B-51-1 and IR118194-B-6-4-HR2.

Evaluation of previously selected germplasm under drought stress at reproductive phase in the rain-out shelter. This experiment was conducted in the rain-out shelter, Plant Physiology Division at BRRI HQ, Gazipur during T. Aman season 2020 to evaluate previously selected 41 germplasm with check variety BRRI dhan71 and IR64. Thirty day old seedlings were transplanted in puddled soil at a spacing of 20 cm x 20 cm. Standard agronomic management practices were followed. Weeds were controlled when needed. Four weeks after transplanting, the plots were drained out for inducing drought stress at reproductive phase. The water table depth was below 1 m and soil moisture was around 20%. Under control drought condition in the rainout shelter, out of 41 germplasm BRRI Gene bank Acc. no. 2276 yielded the highest followed by Acc. no. 1800, 1905 and 1907. The sterility percentage of these genotypes was less than 50% (Table 4**)**.

HEAT TOLERANCE

Screening of Aus rice germplasm for heat tolerance. About 50 Aus rice germplasm along with tolerant check N22 and susceptible check BRRI dhan28 were tested to identify heat tolerance donor at flowering stage. Twenty-five-day old seeding transplanted in earthen pot. Each entry had six pots and each pot has three plant. Out of six pots, from four pots selecting at least three tiller from each plant at just heading stage. The selecting plant immediately transferred into a green house where temperature and humidity control at 35^0C and 75 RH from 8:30 to 14:30 and rest of the time at 30^0C and 70% RH. The plant was kept here for seven days then transferred to normal environmental condition and continued to maturity. After harvesting of heat treated sample, count the spikelet for fertility percentage. Here results showed that out of 50 germplasm, four germplasm (Acc no. 1782, 1783, 1797 and 2085) were found medium heat tolerant with a SES score 3 and their fertility percentage were 67, 65, 71 and 62% respectively. Therefore the fertility percentage of the tolerant N22 and susceptible BRRI dhan28 were 74% and 11% respectively.

Preliminary yield trial of high temperature spikelet fertility QTL introgression line. High temperature spikelet fertility QTL introgression line in the background of BRRI dhan28 was tested for preliminary yield evaluation during Boro 2020-21. BRRI dhan28, BRRI dhan81 and BRRI dhan88 were used as check varieties. The individual plot size was 3.4 m × 12.8 m. The plots were arranged in randomized complete block design with three replications. The heat tolerant line yielded the highest 6.57 tha^{-1} with earliness about 1-5 days compared to the parent BRRI dhan28 and checks (Table 5). The line also showed improved or similar grain quality traits except intermediate amylose content (21.9%).

Table 4. Observed growth characteristics, yield and yield components of tested 43 genotypes.

BRRI Gene bank Acc. no.	Plant height (cm)	Tiller no./plant	Panicle no. /plant	Panicle length (cm)	Filled grain no./plant	Sterility (%)	Grain wt. (g)/plant	Straw wt. (g)/plant	HI
524	122.3	11.8	9.3	23.4	447	46.5	6.20	19.80	0.20
529	129.3	8.3	6.8	23.5	337	62.9	5.62	22.83	0.16
539	119.7	17.3	17.0	19.0	101	81.6	1.65	27.30	0.05
678	119.0	14.0	12.3	19.5	197	63.6	3.44	24.61	0.11
855	115.8	12.7	11.8	19.3	192	71.7	2.68	20.71	0.11
869	93.5	13.0	12.2	18.1	131	73.0	1.76	13.25	0.11
882	112.7	12.8	12.0	20.9	358	56.0	5.82	20.84	0.18
883	105.3	15.2	13.5	19.6	662	28.8	9.61	17.24	0.34
921	118.5	11.2	11.0	19.3	373	52.6	8.50	21.62	0.25
1618	105.8	12.2	10.8	18.7	268	45.1	4.02	17.03	0.18
1707	104.3	13.2	11.7	16.9	216	33.5	4.25	16.90	0.18
1716	128.7	12.0	4.7	13.6	62	46.5	1.03	16.05	0.05
1800	116.8	12.7	11.2	19.2	941	30.9	12.22	23.08	0.32
1867	106.8	20.8	13.2	15.7	199	67.4	2.60	17.24	0.12
1868	125.8	13.0	12.2	22.0	414	60.9	7.38	26.45	0.20
1869	124.7	10.8	8.2	21.7	318	59.6	5.66	22.37	0.18
1873	126.3	14.7	13.3	18.8	550	24.0	9.39	14.05	0.40
1874	116.5	15.7	13.2	18.7	281	62.4	4.38	26.15	0.13
1875	91.8	13.8	12.3	17.1	222	54.4	4.31	17.59	0.18
1877	96.3	8.3	7.3	15.8	55	82.9	0.82	6.54	0.18
1879	129.7	12.2	10.2	17.1	225	57.7	3.61	20.52	0.14
1887	109.7	14.8	12.7	8.1	179	73.1	3.09	16.41	0.15
1890	110.7	16.2	15.7	16.7	246	59.2	3.35	18.65	0.14
1894	122.5	9.8	8.0	15.3	141	57.1	1.13	13.73	0.07
1895	113.5	13.8	12.0	17.3	199	74.3	3.45	22.56	0.11
1905	113.0	14.8	13.2	18.8	786	29.2	12.03	21.30	0.35
1907	149.5	15.5	13.2	20.1	598	45.4	10.13	30.40	0.23
1910	293.3	12.3	11.2	18.5	84	60.4	1.45	10.07	0.12
1912	112.0	14.8	12.7	17.7	211	31.3	3.13	21.06	0.14
1921	115.5	15.3	14.3	18.4	372	45.5	6.32	20.68	0.22
2192	141.2	12.3	10.2	17.9	462	56.9	8.28	27.75	0.22
2199	113.0	11.7	4.0	13.8	25	77.3	0.32	19.22	0.01
2220	105.7	16.3	8.8	14.8	103	48.2	0.51	18.61	0.03
2226	120.3	7.7	1.7	13.4	3	94.8	0.31	12.18	0.02
2231	107.8	8.5	3.8	14.2	23	78.6	0.28	16.13	0.01
2237	117.8	7.5	4.7	26.8	17	79.2	0.32	11.18	0.03
2239	118.3	6.7	1.7	16.4	8	86.5	0.10	12.28	0.01
2240	160.5	12.3	10.2	21.7	234	67.6	3.94	32.01	0.10
2273	158.0	9.5	3.8	16.9	29	76.9	0.64	18.60	0.03
2276	77.7	13.7	12.7	18.0	810	27.3	14.83	20.31	0.40
2278	76.5	11.5	9.7	16.4	184	63.5	2.51	14.17	0.13
BRRI dhan71	111.2	12.7	11.5	23.1	884	29.4	17.06	20.24	0.43
IR64	98.7	14.8	12.7	18.5	252	47.6	4.68	13.95	0.23
--	72.9	7.4	4.4	5.4	255.6	27.9	4.2	8.9	0.1

Table 5. Growth duration, yield and grain quality parameters of heat tolerant line and check varieties under preliminary yield trial during Boro season 2020-21 (sowing date: 22 November 2020).

Line/Variety	Growth duration (days)*	Average Yield (t/ha) @ 14% MC*	Amylose content (%)	Thousand grain weight (gm)	L/B ratio	Size and Shape	Milling outturn (%)	Head rice recovery (%)
BR12266-44-11-32-5-1-1-HR10-B	146 c	6.57 a	21.90	19.50	3.70	LS	68	55
BRRI dhan28	148 b	6.46 ab	27.90	19.40	3.60	LS	68	53
BRRI dhan81	151 a	5.84 c	--	--	--	--	--	--
BRRI dhan88	147 b	6.14 bc	--	--	--	--	--	--
Level of Significance	0.00	0.01	--	--	--	--	--	--
CV (%)	0.44	3.16	--	--	--	--	--	--
Heritability	0.97	0.88	--	--	--	--	--	--

**Different letters within column indicate significant differences between means at the 5% level*

Screening of high temperature tolerant spikelet fertility QTL introgression lines in the control condition. Global warming is expected to result in the occurrence of high temperature-induced spikelet sterility in rice. Selection of tolerant breeding lines from current breeding materials is necessary for the development of new high temperature tolerant variety with high yield potential. To facilitate breeding for heat-tolerant rice varieties, two experiments were conducted. Fifty-five high temperature spikelet fertility QTL introgression lines were tested along with parents (BRRI dhan28, BRRI dhan29 and N22) under control glass house condition with high temperature (35 ± 3^0C) and high humidity (75±5%) condition during flowering. At harvest spikelet fertility for high temperature treated plants were compared and scored with control plants. Results revealed that the tested lines scored 3-7 having spikelet fertility ranged from 32-68%. However, the parents, BRRI dhan28 scored 7 with spikelet fertility 21% and donor N22 scored 5 with fertility 53%.

COLD TOLERANCE

Screening of rice genotypes for seedling stage cold tolerance. Some 250 BRRI GeneBank Germplasm and three BRRI varieties along with four check varieties namely BRRI dhan28, BRRI dhan36, Mineasahi and HbjB-VI were tested for seedling stage cold tolerance in cold water tanks at artificial condition. Seeds were sown in plastic trays (60 cm length x 30 cm breadth x 2.5 cm height) filled with granular soil tree frown gravels and crop residues and allowed to grow until 3 leaf stage. The plastic trays were then placed into cold water tanks adjusted to constant temperature at 13°C. Among the tested rice genotypes, 32 BRRI GeneBank germplasm (Acc. no. 2256, 2257, 2264, 2268, 2277, 2282, 2288, 2289, 2290, 2291, 2292, 2293, 2296, 2300, 2308, 2312, 2320, 2333, 2334, 2337, 2345, 2346, 2347, 2349, 2352, 2358, 2363, 2398, 2405, 2429, 2432, 2433) and BRRI dhan84 showed moderately cold tolerant at seedling stage.

Evaluation of advanced breeding lines for reproductive stage cold tolerance. Seventeen advanced breeding lines along with check varieties viz. BRRI dhan28, BRRI dhan67, BRRI dhan69 and BRRI dhan89 were evaluated for reproductive stage cold tolerance at natural field condition. There were two seeding times 18 October and 22 November (control). Thirty five-day-old seedlings were transplanted in main field. Early planting was done with a view to falling rice reproductive phase at cold stress. In early planting (18 October sowing) growth duration was increased by 16 to 26 days in different rice genotypes. In 22 November sowing growth duration of BR10717-5R-82, BR11001-5R-37, BR11001-5R-2, BR11000-5R-27, BR11662-11-5-3 and BR11000-5R-4 were 142 to 143 days which was statistically similar to BRRI dhan28 while TP30753, BR10715-5R-1 and BR10715-5R-9 were similar to BRRI dhan89. Among short duration lines BR10717-5R-82 had the highest yield in both two planting time, while among long duration lines

BR10715-5R-1 yielded most. Early planting caused significantly higher sterility in all tested genotypes over tolerant checks. Sterility of BR10717-5R-82 (29.38%), BR11000-5R-4 (30.93%), BR10715-5R-1 (32.02%) and BR11000-5R-27 (32.90%) were significantly lower than BRRI dhan28 (35.96%) but statistically similar to BRRI dhan67 (30.83%) and BRRI dhan69 (31.83%) (Table 6).

Considering growth duration, yield and sterility percentages six short duration lines (BR10717-5R-82, BR11001-5R-37, BR11001-5R-2, BR11000-5R-27, BR11662-11-5-3 and BR11000-5R-4) and three medium to long duration lines (TP30753, BR10715-5R-1 and BR10715-5R-9) were selected for further evaluation (Table 6).

Characterization and evaluation of some selected rice genotypes for cold tolerance. Some 21 advanced breeding lines, 18 exotic varieties, three BRRI varieties (BRRI dhan45, BRRI dhan92 and BRRI dhan96) along with five check varieties namely BRRI dhan28, BRRI dhan36, BRRI dhan67, BRRI dhan69 and HbjB-VI were characterized and evaluated in natural field condition. Three different seed sowing times viz. 15 October, 31 October and 15 November (control) were considered of three sets of sowing and designated as 1st set, 2nd set and 3rd set, respectively. Thirty-day-old seedlings were transplanted in the main field. Early planting (15 October and 31 October) was done with a view to falling rice reproductive phase at cold stress. Changes in different parameters of rice after natural cold treatment were compared with control treatment.

In early planting, all rice genotypes experienced cold stress at reproductive phase. Cold stress caused longer growth duration, shorter last internode length as well as plant height, poor panicle exertion and higher percentage of sterility over control treatment in all rice genotypes. Considering sensitivity level (gap between stress versus non-stress) of different growth and development parameter of different rice genotypes under cold stress condition three advanced rice genotypes BR11894-R-R-R-345, BR11338-5R-39 and BR11338-5R-12 were selected as moderately cold susceptible lines at reproductive phase as BRRI dhan67. Breeding line IR118194-B-6-4, BR12266-44-11-32-5-1-1-HR10-B and IR64Pi9L were found as highly cold susceptible while other lines were susceptible at reproductive stage. Out of 18 exotic rice varieties GB34 and other three black rice genotypes (Japan, Philippines and Indonesia) and BRRI dhan45 selected as moderately cold susceptible varieties which had higher tolerance than BRRI dhan28 and BRRI dhan36 . BRRI dhan96 was moderately cold tolerant at vegetative phase as like BRRI dhan67 and BRRI dhan69 but susceptible at reproductive phase. However, BRRI dhan92 escaped cold stress at reproductive phase due to its longer growth duration.

Table 6. Growth duration, yield and sterility of selected rice genotypes.

Genotype	Growth duration (day)		Yield (t/ha)		Sterility (%)	
	18Oct	22Nov	18 Oct	22Nov	18Oct	22Nov
BR10717-5R-82	163	142	4.97	7.24	29.38	15.01
BR11001-5R-37	164	142	4.26	7.13	33.86	14.44
BR11001-5R-2	166	143	4.27	7.06	34.83	17.71
BR11000-5R-27	164	143	4.50	6.89	32.90	15.28
BR11000-5R-4	166	142	4.25	6.84	30.93	15.36
BR11662-11-5-3	169	143	4.32	6.89	35.09	12.26
BR10715-5R-1	177	159	5.24	7.31	32.02	13.78
BR10715-5R-9	177	159	4.73	7.04	32.64	16.38
TP30753	174	154	4.12	6.96	38.87	14.71
BRRI dhan67 (ck)	164	147	4.27	7.05	30.83	14.67
BRRI dhan28 (ck)	165	142	3.91	6.44	35.96	16.14
BRRI dhan89 (ck)	176	158	5.14	7.53	37.61	13.56
BRRI dhan69 (ck)	169	153	4.01	6.24	31.83	15.51
LSD@ 5% genotype (G)	7.35		0.24		2.63	
LSD@ 5% sowing time (S)	3.24		0.15		0.81	
LSD@ 5% G*S	14.86		0.45		3.72	

Effect of polythene covering on seedling raising in Boro season. An experiment was conducted to identify the most suitable technique for protecting Boro rice seedling from cold injury. Sprouted seeds of BRRI dhan81 were shown in puddle seedbeds on 13 December 2020. It was covered by transparent polythene sheet. Five different types of polythene covering treatment at seedbed viz. covering for all time, covering for 24 hrs during cold wave, covering from 11.0 am to sun set, covering for whole night and covering for all time with opening at both end of the seedbed cover along with control were used. The longest seedling was recorded from covering for all time followed by covering from 11.0 am to sun set and covering for all time with opening at both end of the seedbed cover. Fresh weight of seedling was significantly higher in covering for all time with opening at both end than all other treatments. However, highest seedling strength was recorded from seedbed having polythene covering for 24 hrs during cold wave only from19 to 23 December 2020 followed by covering for whole night and covering for all time with opening at both end. The lest seedling mortality after transplanting in the main field was recorded from covering for 24 hrs during cold wave and covering for whole night which was statistically similar to control. Seedling mortality after transplanting was comparable between covering from 11.0 am to sun set and covering for all time with opening at both end although it was slightly higher than the control treatment. Polythene covering for all time at seedbed had lower seedling strength but higher seedling mortality.

Reduction of growth duration through accumulation of degree days at seedling stage. An experiment was conducted to measure growth duration reduction of Boro rice variety (BRRI dhan81) through accumulation of degree days at seedling stage. Seeds of BRRI dhan81 were sown in seed beds on 13 December 2020. For accumulation of degree days at seedling stage seedbeds were covered by transparent polythene sheet. Five different types of polythene covering treatment at seedbed (covering for all time, covering for 24 hrs during cold wave, covering from 11.0 am to sun set, covering for whole night and covering for all time with opening at both end of the seedbed cover) along with control were used. Forty three day old seedlings were transplanted in the main field. Days required to panicle initiation, flowering and maturity of BRRI dhan81 were recorded. A growing degree day (GDD) of a particular day was calculated by adding the daily high and low temperature then dividing by 2 which provides a type of average temperature for the day and then subtracting 50 from that number. Growing degree day required in different treatments was calculated for whole growing period. Results showed that GDD differed significantly in different treatments but days required for panicle initiation (P)I and flowering as well as growth duration remain statistically similar (Table 7). It indicating that growth duration of Boro rice variety could not be reduced through accumulation of degree day at seedling stage. Accumulation of degree day at seedling stage become useless for reducing growth duration of rice as it did not translate into new tillers. After transplanting in main field rice seedlings started tillering and new tillers received same amount of light energy in all the treatments which ultimately provide rice development at same time.

Table 7. Total growing degree day (GDD) required in different treatments (sowing date: 13 December 2020).

Treatment	Day to PI	Day to flower	Growth duration (day)	GDD for whole growing period
Polythene covering for all time	87	113	138	4139.28
Polythene covering for 24 hrs during cold wave	88	112	138	3772.08
Polythene covering from 11.0 am to sun set	88	113	138	4032.15
Polythene covering for whole night	87	113	138	3787.00
Polythene covering for all time with opening at both end of the seedbed cover	87	112	138	3906.18
Control (uncovering)	87	113	138	3697.00
LSD @5%	1.72	1.52	1.28	41.86

Effect of vernalization on Boro rice. An experiment was conducted to determine seed vernalization effect on growth duration and yield of Boro rice. Seeds of BRRI dhan96, Dharial-DA14 and Dharial were vernalized with 5 and 35 °C for 25 days. Vernalized and unvernalized seed of those three varieties were sown in seedbed on 31 December 2020. Forty day old seedlings were transplanted in the main field. Data on date of panicle initiation (PI), flowering, grain yield and yield components were recorded. Days to PI, flowering and maturity differed significantly among different variety but it did not altered due to seed vernalization treatment. Likewise, grain yield also differed significantly among different varieties but it remain unaffected due to vernalization (Table 8).

GROWTH STUDIES

Determination of growth stages of some rice varieties as affected by sowing time during Aman season. Due to inevitable circumstances, farmers of some regions of Bangladesh have to cultivate rice out of season and affect rice's phenological development. We experiment to determine the duration of different growth phases at various planting times.

The experiment was carried out in the research field of the Plant Physiology Division located at BRRI HQ Gazipur, during T. Aman 2020. Five different seed sowing times, including 15 June, 30, 16 July, 30 July, and 16 August, were considered five sets of sowing and designated as 1st set, 2nd set, and 3rd, 4th and 5th set, respectively.

For panicle initiation (PI), significant variation was observed among the five sets of sowing. For all variety advance of sowing time days to PI decreased gradually with few exceptions for BRRI hybrid dhan4 and BRRI hybrid dhan6. Both BRRI hybrid dhan4 and BRRI hybrid dhan6 took similar days to PI for the first two sets. In the 5th set, Both BRRI hybrid dhan4 and BRRI hybrid dhan6 took relatively more time for PI than the 3rd and 4th sets. Like PI, significant variation was observed for days to flowering. For all variety advance of sowing time decreased in days to flowering. But the reduction in days to flowering was comparatively higher in BRRI dhan95, BRRI dhan94 and BRRI dhan93 and lower in BRRI hybrid dhan4 and BRRI hybrid dhan6. For BRRI dhan87 days to flowering for the last three sets was the same (Table 9).

Similarly, days to maturity varied significantly at various sowing dates. Days to maturity of BRRI dhan95 were dramatically reduced from 157 days in the 1st set to 95 days in the 5th set. Similarly, in BRRI dhan94, it was 135 days to 92 days (Table 9). Too early planting of BRRI hybrid dhan4 and BRRI hybrid dhan6 may be detrimental because they may face terminal drought, high-temperature stress, and late planting. It may be hazardous due to cold stress sterility. BRRI dhan95 and BRRI dhan94 were relatively safe both the early and late planting because it matures closely in both cases.

Table 8. Growth duration and yield of different rice varieties vernalized at 5°C and 35°C (sowing date: 31 December 2020).

Variety	Vernalization	Day to PI	Day to flowering	Growth duration (day)	Yield (t/ha)
BRRI dhan96	at 5°C	81	107	130	6.24
	at 35°C	81	106	130	6.32
	Unvernalized	82	107	130	6.27
Dharial-DA14	at 5°C	74	99	123	2.96
	at 35°C	74	99	122	3.11
	Unvernalized	74	99	124	2.89
Dharial	at 5°C	73	99	124	2.82
	at 35°C	73	99	123	2.78
	Unvernalized	74	100	124	2.91
LSD @5%		1.44	1.60	1.65	0.35

Table 9. Flowering trait of tested rice varieties based on five different sets of planting.

Trait	Set	Rice variety							
		BRRI dhan87	BRRI dhan90	BRRI dhan91	BRRI dhan93	BRRI dhan94	BRRI dhan95	BRRI hybrid dhan4	BRRI hybrid dhan6
Days to panicle initiation (day)	1	85a	76a	96a	91a	92a	94a	68a	67a
	2	77b	73b	89b	83b	87b	83b	67a	67a
	3	70c	67c	81c	79c	77c	70c	62b	60c
	4	68d	67c	74d	74d	76c	63d	56c	56d
	5	67d	61d	66e	73d	72d	60e	62b	61b
Days to flowering (day)	1	108a	96a	123a	120a	122a	118a	95a	94a
	2	98b	94b	112b	111b	110b	107b	84b	82b
	3	95c	83c	108c	100c	105c	93c	80d	80c
	4	95c	82c	103d	100c	101d	84d	83c	82b
	5	95c	80d	94e	95d	97e	79e	81d	78d
Days to maturity (day)	1	130a	122a	140a	139a	135a	157a	116a	111a
	2	126b	117b	126c	126b	125b	129b	107b	104b
	3	123c	103c	124cd	122c	119c	113c	104c	104b
	4	119c	100d	123d	118d	119c	104d	103c	104b
	5	123b	98e	133b	121c	92d	95e	101d	102c

Photosensitivity test of advanced breeding lines. Forty advanced breeding lines along with check Nazirsail were tested to measure the level of Photosensitivity at net house of plant physiology division. Out of 40 advanced breeding lines, fourteen advanced breeding lines were found strongly photosensitive (Table 10). Four advanced lines were found moderately photosensitive, 18 were found weakly photosensitive and four were found non photosensitive (Table 10).

Response to photoperiod of some promising advanced breeding lines under control condition. A study was conducted to find out the photoperiod sensitivity of some promising breeding lines. Thirty-one advanced breeding line**s** were tested along with BR22, Nizersail (strong photoperiod sensitive) and BR11 (moderate photoperiod sensitive) as standard check. Seeds of all the tested and check varieties were directly sown to the well prepared trays during 26 June 2020.Ten-hour photoperiodic treatment (7.00 AM to 5.00PM) was started from seed sowing by using black cover. One set were grown at natural day length. Observations were made on date of seeding and date of heading to determine the basic vegetative phase (BVP), photoperiod sensitive phase (PSP) and relative photoperiod sensitivity (RPS). On the basis of relative photoperiod sensitivity, two genotypes (BR11919-4R-26 and BR11921-4R-124) out of 31 breeding lines showed RPS about 55-66% classified as moderately photoperiod sensitive. However, 10 and 19 lines showed insensitive and weakly sensitive to photoperiod, respectively (Table 11).

YIELD POTENTIAL

Investigation of anatomical differences in the leaves of C3 and C4 species. Leaf structure strongly controls leaf photosynthesis and plays a key role in every step starting from light interception up to the biochemical fixation of carbon dioxide. However, there has been growing interest in the characterization of rice leaf anatomical differences between C3 (rice) and C4 species such as maize, sorghum, green foxtail millets etc. Engineering the leaf structure of cultivated rice could, therefore, be of direct interest to current research efforts that aimed to increase photosynthetic efficiency and thereby achieve improve yields. Considering the above

Table 10. BVP, PSP and RPS ofsome advance breeding lines, Plant Physiology BRRI, 2020.

Variety no.	BVP (day)	PSP (day)	RPS (%)	Comment
BR9571-13-1-9-1-1	38	66	43	Weakly photosensitive
BR9571-28-4-1-2-1	39	44	29	Weakly photosensitive
BR9573-31-1-2-5-1	34	87	57	Moderately photosensitive
BR9573-36-1-3-2-1	22	77	51	Moderately photosensitive
BR9574-15-3-4-2-1	36	52	34	Weakly photosensitive
BR9574-3-3-1-1-1	25	63	41	Weakly photosensitive
BR9574-9-5-3-1-1	37	24	16	Weakly photosensitive
BR9571-2-2-5-2-1	26	68	45	Weakly photosensitive
BR9571-28-2-1-2-1	40	33	22	Weakly photosensitive
BR9571-4-1-2-2-1	29	60	39	Weakly photosensitive
BR9571-4-2-6-1-1	19	39	26	Weakly photosensitive
BR9573-28-1-1-1-1	30	28	18	Weakly photosensitive
BR9573-28-2-4-1-1	27	33	22	Weakly photosensitive
BR9573-28-2-5-1-1	28	62	41	Weakly photosensitive
IR118194-B-6-3-HR1	31	24	16	Weakly photosensitive
IR118194-B-6-3-HR2	36	22	14	Non photosensitive
IR118194-B-3-3-HR2	32	24	16	Weakly photosensitive
IR118194-B-3-3-HR3	33	22	14	Non photosensitive
IR118194-B-6-4-HR1	34	46	30	Weakly photosensitive
BR10190-3-7-3-2-2-1-8	17	169	111	Strongly Photosensitive
BR10190-3-7-3-2-8-1-12	17	172	113	StronglyPhotosensitive
BR10190-3-7-14-7-1-2-1-16	17	172	113	StronglyPhotosensitive
IR118194-B-6-4-HR2	37	26	17	Non photosensitive
BR10190-3-7-3-2-8-1-7	17	168	111	StronglyPhotosensitive
BR10190-3-1-19-5-5-1-11	20	165	109	StronglyPhotosensitive
IR118194-B-6-2-	34	80	53	Moderately photosensitive
BR10190-3-7-3-2-10-1-14	16	165	109	StronglyPhotosensitive
IR118194-B-51-1	36	78	51	Moderatelyphotosensitive
IR118194-B-12-1	36	37	24	Weakly photosensitive
BR10190-3-1-19-5-5-1-15	14	175	115	StronglyPhotosensitive
IR118194-B-17-3	31	68	45	Weakly photosensitive
BR10190-3-1-19-5-1-1-7	14	171	113	StronglyPhotosensitive
IR118194-B-10-1	28	45	30	Weakly photosensitive
BR10190-3-1-19-5-1-1-13	16	171	113	StronglyPhotosensitive
BR10190-3-7-3-2-3-1-6	15	176	116	StronglyPhotosensitive
BR10190-3-7-3-2-8-1-6	16	174	114	StronglyPhotosensitive
IR118194-B-26-3	29	24	16	Non photosensitive
BR10190-3-7-14-7-7-1-7	16	169	111	StronglyPhotosensitive
BR10190-3-7-14-7-7-1-3	16	174	114	StronglyPhotosensitive
BR10190-3-1-19-5-1-1-2	15	164	108	StronglyPhotosensitive
N. SAIL	40	152	100	Check
BRRI dhan87	35	29	19	Non photosensitive

points, the current research aimed to study anatomical differences of cultivated high yielding rice varieties and related C4 species. The stomata in the leaves of C3 and C4 species were counted of representative samples of leaves in both surfaces. The highest density of stomata was observed in Uri dhan leaves (233.82 in abaxial and 206.93 in adaxial surface) but the lowest in Maize (71.45 in abaxial and 93.92 in adaxial surface) (Table 12). However, Rice and Shayma showed intermediate number of stomatal density in both the surfaces of leaves. Kaoun and Shayma showed an equal distribution in the number of stomata in both the surfaces of leaves (Fig. 5-11). Stomatal density depends on leaf area of each species, Uri dhan showed higher density because of narrow leaf and less leaf area, Maize has low density because of larger leaf area compared to Uri dhan. However, in general stomatal density is higher in C4 compared to C3 species.

Table 11. Photoperiod sensitivity of promising advanced breeding lines during T. Aman 2020. Each value is the mean of five plants data (sowing date: 27 June 2020).

Variet/Line	BVP	PSP	Relative photo-sensitivity (%)	Photo-sensitivity class	Remarks
Nizersail	23	74	100.00	Strong sensitive	
BR11	33	42	56.76	Moderately sensitive	
BR22	11	86	116.22	Strong sensitive	
BR11905-4R-87	34	23	31.08	Weakly sensitive	
BR11905-4R-268	31	25	33.78	Weakly sensitive	
BR11905-4R-270	34	24	32.43	Weakly sensitive	Segregating line
BR11910-4R-71	34	24	32.43	Weakly sensitive	Segregating line
BR11910-4R-127	35	20	27.03	Weakly sensitive	
BR11919-4R-26	18	49	66.22	Moderately sensitive	
BR11920-4R-80	32	6	8.11	Insensitive	
BR11920-4R-92	34	4	5.41	Insensitive	
BR11920-4R-121	30	2	2.70	Insensitive	
BR11920-4R-122	19	18	24.32	Weakly sensitive	
BR11920-4R-153	34	4	5.41	Insensitive	
BR11920-4R-157	33	8	10.81	Insensitive	
BR11920-4R-163	34	6	8.11	Insensitive	
BR11920-4R-168	31	2	2.70	Insensitive	
BR11920-4R-180	32	9	12.16	Insensitive	
BR11920-4R-183	23	16	21.62	Weakly sensitive	
BR11920-4R-184	33	7	9.46	Insensitive	
BR11920-4R-188	18	26	35.14	Weakly sensitive	Segregating line
BR11920-4R-350	36	4	5.41	Insensitive	
BR11921-4R-124	20	41	55.41	Moderately sensitive	
BR11925-4R-9	21	18	24.32	Weakly sensitive	
BR11925-4R-32	24	19	25.68	Weakly sensitive	
BR11925-4R-53	19	19	25.68	Weakly sensitive	
BR11925-4R-99	19	20	27.03	Weakly sensitive	
BR11925-4R-120	21	20	27.03	Weakly sensitive	
BR11925-4R-126	21	15	20.27	Weakly sensitive	
BR11933-4R-537	22	21	28.38	Weakly sensitive	
BR11940-4R-101	29	12	16.22	Weakly sensitive	
BR11940-4R-127	21	17	22.97	Weakly sensitive	
BR11940-4R-171	18	19	25.68	Weakly sensitive	
BR11940-4R-210	24	20	27.03	Weakly sensitive	

Table 12. Stomata per mm of leaf surface in the mature leaves of C3 and C4 species. Each value is the mean of five samples.

Species	Average stomatal density (no./mm)	
	Adaxial/upper part	Abaxial/lower part
Rice (C3)	106.24	94.21
Uri dhan (C4)	206.93	233.82
Shayma (C4)	107.44	98.67
Kaoun (C4)	133.23	131.63
Sorghum (C4)	112.43	77.15
Maize (C4)	93.92	71.45
Sugarcane (C4)	139.8	131.75

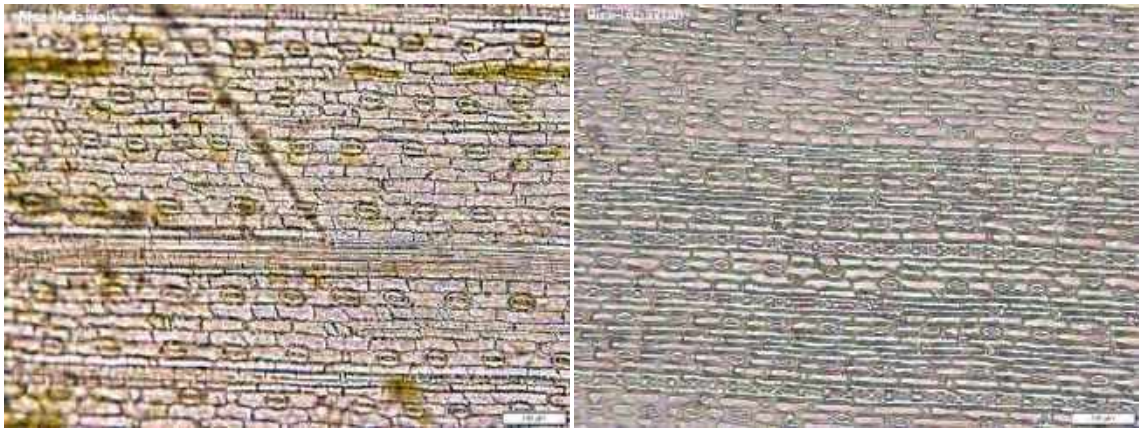

Fig. 5. Stomata of Rice leaf (20x) (left= adaxial surface; right= abaxial surface).

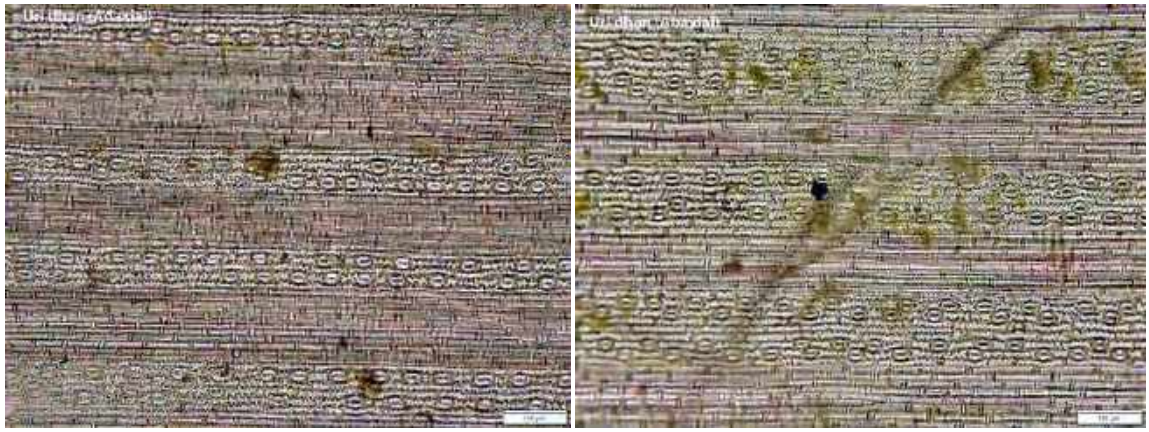

Fig. 6. Stomata of Uri dhan leaf (20x) (left= adaxial surface; right= abaxial surface).

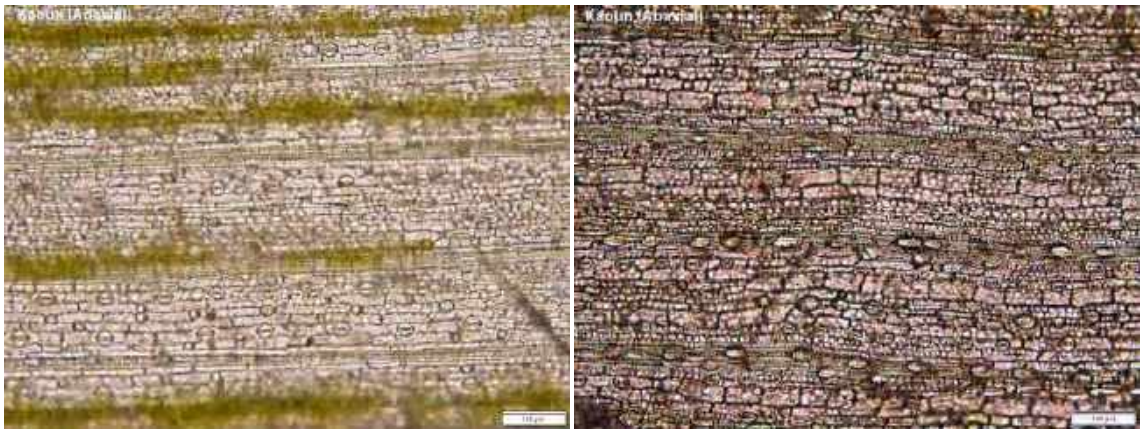

Fig. 7. Stomata of Kaoun leaf (20x) (left= adaxial surface; right= abaxial surface).

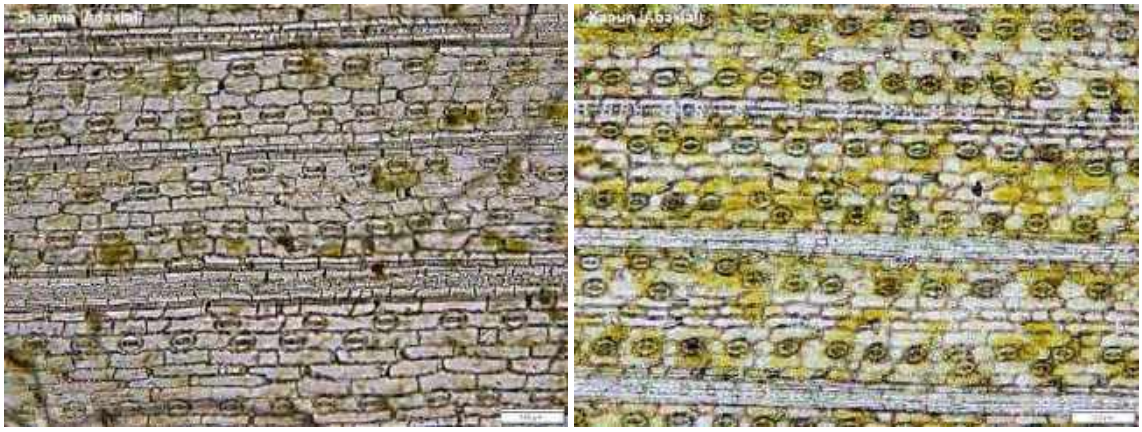

Fig. 8. Stomata of Shyama leaf (20x) (left= adaxial surface; right= abaxial surface).

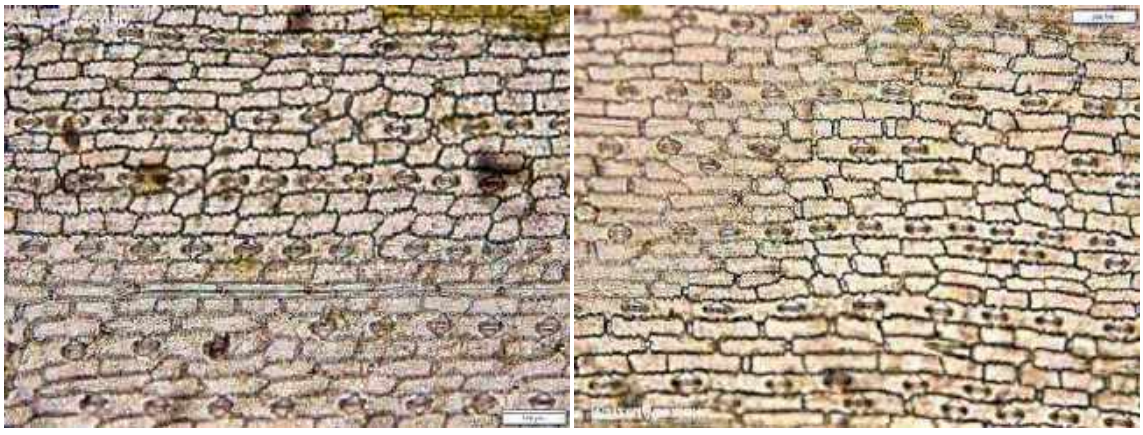

Fig. 9. Stomata of Maize leaf (20x) (left= adaxial surface; right= abaxial surface).

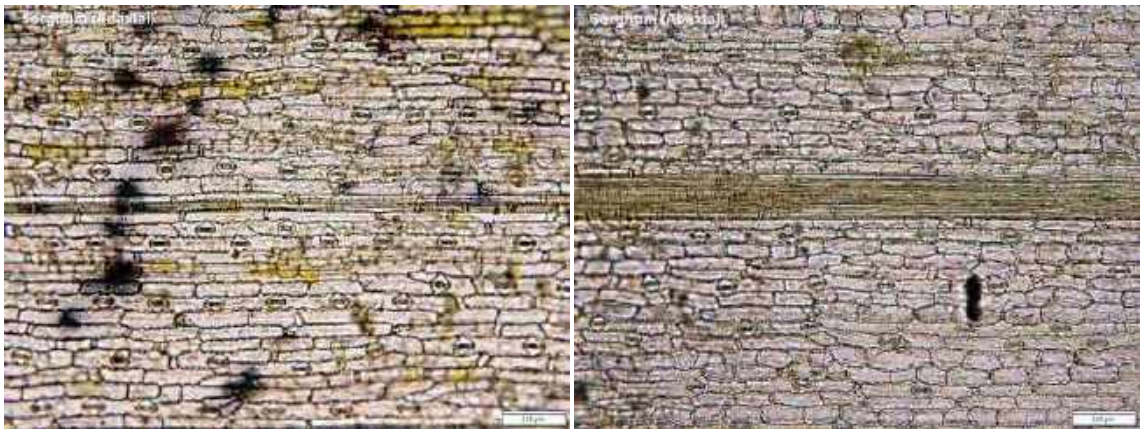

Fig. 10. Stomata of Sorghum leaf (20x) (left= adaxial surface; right= abaxial surface).

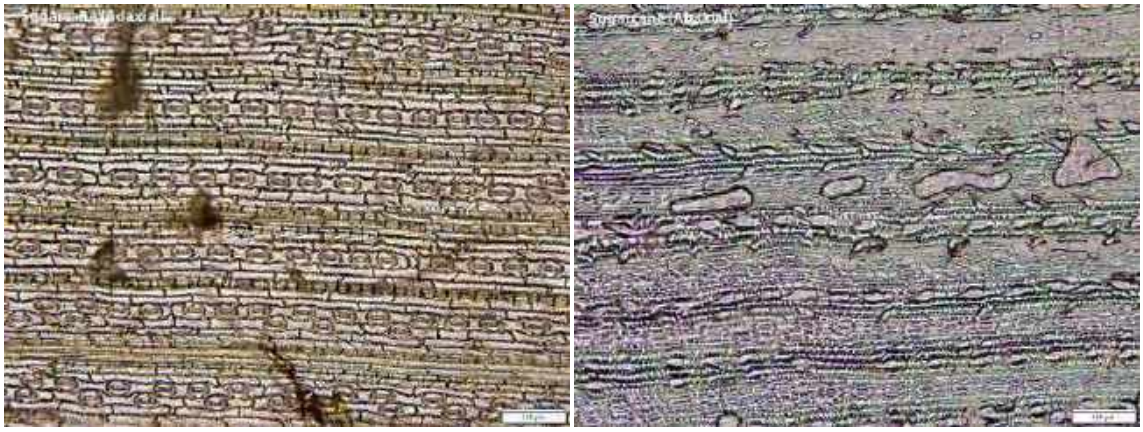

Fig. 11. Stomata of Sugarcane leaf (20x) (left= adaxial surface; right= abaxial surface).

Rooting dynamics of BRRI rice varieties against different nitrogen concentrations

Nitrogen is the essential nutrient for plant growth and is commonly deficient in soils. There are two forms of plant-available inorganic nitrogen NO_3^- and NH_4^+ in the soil. Genetic variations in root length have been clearly detected in rice seedlings in response to different forms of nitrogen (Noma and Hirose 2005; Ogawa et al. 2014) and different NH_4^+ concentrations (Tanaka et al.2003). An experiment was conducted in the net house of the plant physiology division. A total of 84 BRRI rice cultivars/varieties were evaluated for the determination of the different levels of genetic variations of three root traits TRL (Total root length), MRL (Maximum root length), RN (Root number). Seedlings were grown hydroponically and evaluated in both nitrogen-deficient and sufficient conditions. In the study, five μM represents the nitrogen-deficient condition and 500 μM represents nitrogen sufficient condition. Despite this, we also used the control condition to evaluate the nature of root growth where nitrogen was completely absent. Data were measured 14 days after sowing in the nutrient solution.

Distribution of TRL. A large variation was observed among 84 rice varieties in the trait TRL. For five μM NH_4Cl, TRL ranged from 264 mm to 1155.33 mm (mean = 563.04 mm), also for 500 μM NH_4Cl it ranged from 129.67 mm to 776.50 mm (mean = 440.52 mm). In case of KNO_3, the TRL ranged from 267.67 mm to 996.33 (mean = 593.51 mm) for 5 μM KNO_3 and 238 mm to 1125.33 mm (mean = 680.23) for 500 μM KNO3. The TRL varied from 327.67 mm to 866.67 mm (mean = 552.46 mm) (Fig. 12). The TRL was significantly higher in 500 μM KNO_3 compared to other treatments.

Distribution of MRL. Significant variations were also observed in the MRL trait. The variation ranged from 56.67 mm to 157.33 mm (mean = 104.85) for 5 μM NH_4Cl, 40 mm to 112.67 mm (mean= 75.74) for 500 μM NH_4Cl, 63.33 mm to 148.33 mm (mean = 106.27 mm) for 5 μM KNO_3 and 40 mm to 141.67 mm (mean = 98.62 mm) for 500 μM KNO_3. In control it was between 55 mm to 165 mm (mean = 105.74 mm) (Fig. 12). The MRL was significantly higher in 5 μM KNO_3 and control conditions in comparison with other nitrogen treatments.

Distribution of RN. Distribution of RN grown under different concentration also showed a large variation ranging from 5.67 to 13.67 (mean = 8.79) for 5 μM NH_4Cl, 5.67 to 13.67 (mean = 9.45) 500 μM NH_4Cl, 6 to 12.67 (Mean = 9.48) for 5 μM KNO_3 and 6.33 to 15 (mean = 10.64) for 500 μM KNO_3. The RN in control condition ranged 6.67 to 13.33 (mean = 9.66). Like TRL, RN was also higher in 500 μM KNO_3 condition in comparison with other nitrogen forms and conditions.

Varieties under different cluster

Among 84 varieties, 36 in cluster Ia, 26 in Ib, and 22 in II. Varieties under cluster II had higher MRL, TRL, and RN than other varieties of Ia and Ib. (Table13)

Generation of male sterile rice line for two-line hybrid system by editing *TMS5* gene using CRISPR/Cas9 system

The two-line hybrid rice system is an important innovation for the better exploitation of hybrid vigour (heterosis). Thermo-sensitive genic male sterile (TGMS) line has been shown to be an ideal replacement for cytoplasmic male sterility (CMS) and explored in two-line hybrid systems; particularly in rice. TGMS lines are sensitive to the temperature for the expression of male sterility or fertility. To design a CRISPR/Cas9 targeting the *TMS5* gene in rice, a 19bp guide sequences (5′-ACCGTCGAGGGCTACCCCG-3′) have a protospacer adjacent motif lying within the *TMS5* coding sequence (*LOC_Os02g12290.1*). The guide sequences were properly cloned into the binary vector pC1300-Cas9 (Fig. 13). The binary vector pC1300-Cas9 harboring *Cas9/TMS5* sgRNA was mobilized into *Agrobacterium tumefaciens* LBA4404 by freeze-thaw method and confirmed through PCR-gel electrophoresis (Fig. 14).

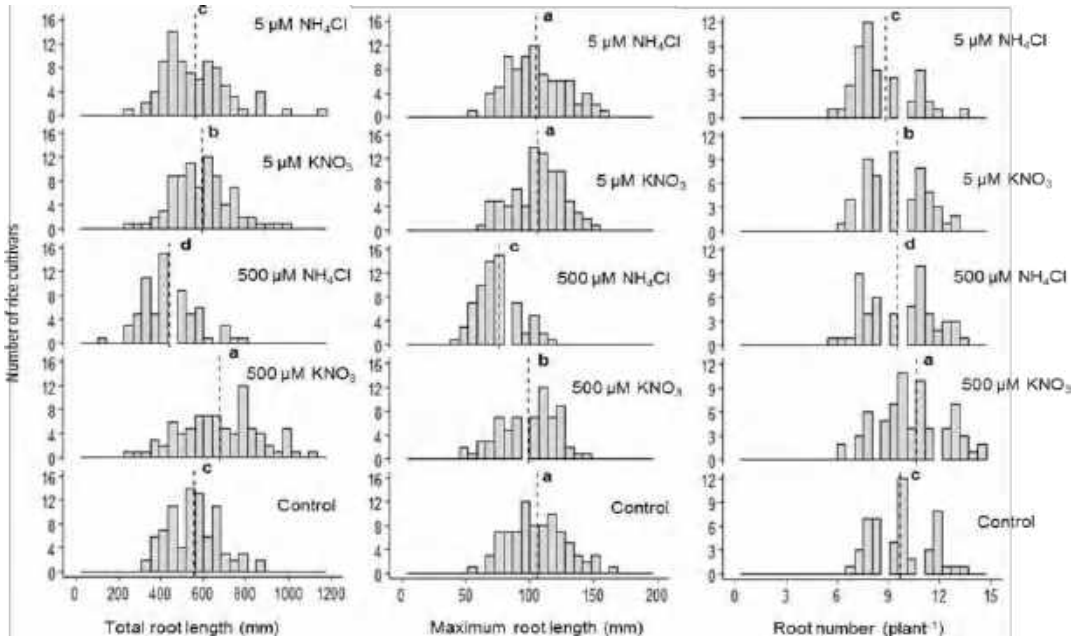

Fig.12. Distribution of root traits under different nitrogen forms and conditions.

Table 13. Number of varieties under different clusters.

Cluster	Variety list
Ia (36)	BRRI hybrid dhan1, BRRI hybrid dhan2, BRRI hybrid dhan6, BR12, BR14, BR16, BR18, BR19, BR2, BR25, BR3, BRRI dhan32, BRRI dhan36, BRRI dhan45, BRRI dhan48, BR5, BRRI dhan51, BRRI dhan52, BRRI dhan54, BRRI dhan55, BRRI dhan56, BRRI dhan59, BRRI dhan63, BRRI dhan64, BRRI dhan69, BRRI dhan77, BRRI dhan79, BR8, BRRI dhan87, BRRI dhan89, BR9, BRRI dhan90, BRRI dhan91, BRRI dhan92, BRRI dhan97, BRRI dhan98
Ib (26)	BRRI hybrid dhan4, BRRI hybrid dhan5, BR1, BR10, BR15, BR17, BR22, BR23, BRRI dhan27, BRRI dhan28, BRRI dhan35, BRRI dhan39, BR4, BRRI dhan41, BRRI dhan47, BRRI dhan57, BRRI dhan6, BR7, BRRI dhan70, BRRI dhan73, BRRI dhan74, BRRI dhan78, BRRI dhan84, BRRI dhan88, BRRI dhan96, BRRI dhan99
II (22)	BRRI hybrid dhan7, BR11, BR26, BRRI dhan29, BRRI dhan31, BRRI dhan33, BR46, BRRI dhan49, BRRI dhan50, BRRI dhan53, BRRI dhan58, BRRI dhan60, BRRI dhan61, BRRI dhan62, BRRI dhan66, BRRI dhan67, BRRI dhan71, BRRI dhan72, BRRI dhan75, BRRI dhan76, BRRI dhan80, BRRI dhan93

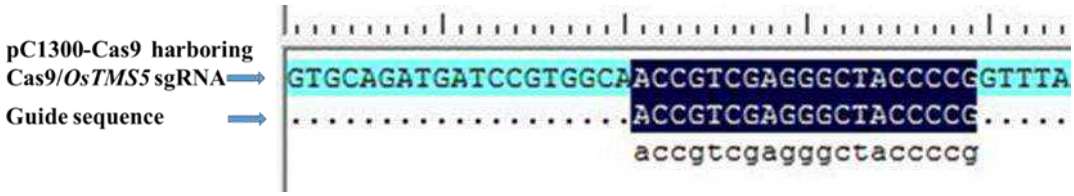

Fig. 13. Confirmation of vector constructs by alignment of sequence of recombinant pC1300-Cas9 harboring Cas9/*OsTMS5* sgRNA with guide sequence.

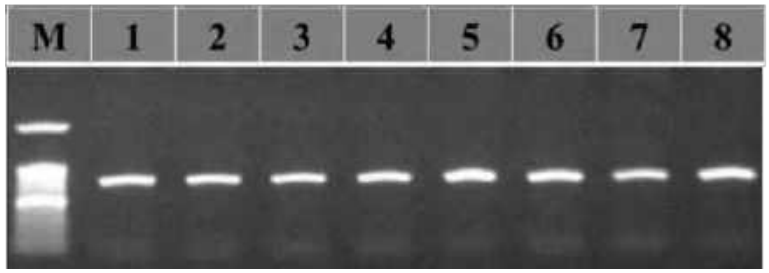

Fig. 14. Confirmation of *Agrobacterium* transformation through PCR-gel electrophoresis. *Agrobacterium tumefaciens* LBA4404 with recombinant pC1300-Cas9 harboring Cas9/*OsTMS5* sgRNA (Lane 1-8). M: marker (50 bp DNA ladder).

Entomology Division

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SUMMERY

Among the six habitats in BRRI research farm, grass fallow harbored higher insect pest population than the other habitats and higher number of natural enemies were observed in seedbed.

The highest number of insect pests were caught in the light trap at Gazipur followed by BRRI RS, Rajshahi, Barishal, Rangpur, Sonagazi and Cumilla. On the other hand, the highest catch of natural enemies in light trap was recorded at Barishal followed by Gazipur, Rajshahi, Rangpur, Cumilla and Sonagazi. Immediate after sunset to first three hours showed the highest number of insects trapped in light and thereafter declined. Only 0.13% yield loss occurred in BRRI dhan89 due to infestation of different insects during Boro season at Fatepur, Pirganj, Rangpur.

Daily average FAW moth count per trap was found the highest (1.8 moth/trap/day) at farmer's field Mithapukur, Rangpur followed by farmers field at Chuadunga (0.74 moth/trap/day).

FAW could survive and complete its life cycle on rice plants. Rice varieties have no significant impact on developmental time of FAW. The mean length of generation (tG) and the doubling (tD) time was significantly longer when fed on rice than that of maize. The reproduction rate (R_0), the intrinsic rate of natural increase (rm) and the finite rate of increase (λ) were higher when fed on maize than that of rice. The rm value of FAW is 0.121 and 0.173 when fed on rice and maize respectively.

Growth and development of rice leafroller (RLR) has shown no significant differences in temperature changes from 30ºC to 35ºC in the growth chamber.

Pathogenicity of entomogenous fungi showed around 63-68% mortality of BPH after seven days of inoculation.

The concentrations of chlorantraniliprole and thiamethoxam were 0.0046 to 0.0243 and 0.0026 to 0.04 mg/kg respectively in the polished rice grain of different treatments. However, the detected amount of both chlorantraniliprole and thiamethoxam in the samples were below the Maximum Residue Limit (MRL: 0.4 mg kg-1 for chlorantraniliprole and 0.6 mg kg-1 for thiamethoxam, EU).

A total of 107, 28, 07 and 06 commercial formulations of insecticides were evaluated against brown plant hopper, yellow stem borer, rice hispa and rice weevil respectively. Among them 100, 10, 07 and 06 insecticides were found effective respectively.

Abamectin followed by chlorantraniliprole and fipronil showed comparatively safe for natural enemies of rice field. Sex pheromone trap showed effective result to monitor as well control the yellow stem borer and leaffolder in rice field.

A total of 1,300 advanced breeding lines and INGER IRBPHN materials were evaluated at green house of Entomology division. Among them three lines were found moderately susceptible (score 5) to BPH, WBPH and GLH respectively, 18 favourable lines and 31 IRR line also showed moderately susceptible reaction against BPH.

Tiller and panicle number hill^{-1} was found the highest in IR107736-5-2-1-1 (10.72 and 9.67/hill respectively). More tiller hill^{-1} also observed IR101840-1-1-11-2 (10.36/hill) and IR107736-7-1-2-1(9.67/hill) but more panicle was found in IR107736-7-1-2-1(8.97/hill).

CRISPR cas9 genome editing tool was used to clone the target 20 bp fragment of CYP71A1 gene into VK005-01 vector for developing insect resistance rice variety. The recombinant vector harboring Cas9/CYP71A1 sgRNA was transformed into Agrobacterium tumefaciens LBA4404 cells. After co-cultivation, putative transformed calli were kept in resting medium for plant regeneration.

Live traps (single capture) were more effective than handmade bamboo traps and bucket trap to catch rice field rats.

SURVEY AND MONITORING OF RICE ARTHROPODS

Pest and natural enemy incidence at BRRI farm, Gazipur

Rice insect pests, natural enemies and crop damage intensities in six habitats (seedbed, rice ratoon, grass fallow, irrigated rice, rice bund and upland rice) were monitored at BRRI research farm, Gazipur at every week throughout the year. Data

were collected using 100 complete sweeps from each habitat. The overall insect pest incidence was low in the reporting year. Green leafhopper (GLH), white leafhopper (WLH) and grasshoppers (GH) were the most abundant pests and found in all habitats. highest number of GH was found in grass fallow followed by rice bund, seedbed and transplanted rice (T. rice) (Fig. 1). Higher numbers of natural enemies were found in the seedbed. Spider (SPD), damsel fly (Dam. fly), ladybird beetle (LBB) and carabid beetle (CDB) were the dominant predators in all the habitats of the reporting year (Fig. 1).

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Incidence of insect pest and natural enemies in light trap

Rice insect pests and their natural enemies were monitored by Pennsylvanian light trap from dusk to dawn throughout the year at BRRI HQ, Gazipur and six regional stations of BRRI. The highest number of insect pests were found at BRRI HQ, Gazipur followed by BRRI RS, Rajshahi, Barishal, Rangpur, Sonagazi and Cumilla but natural enemies were found the highest in BRRI RS, Barishal followed by BRRI HQ, BRRI RS, Rajshahi, Rangpur, Cumilla, and Sonagazi (Fig. 2). In contrast, incidence of both insect pests and natural enemies was comparatively lower in BRRI RS, Cumilla and Sonagazi.

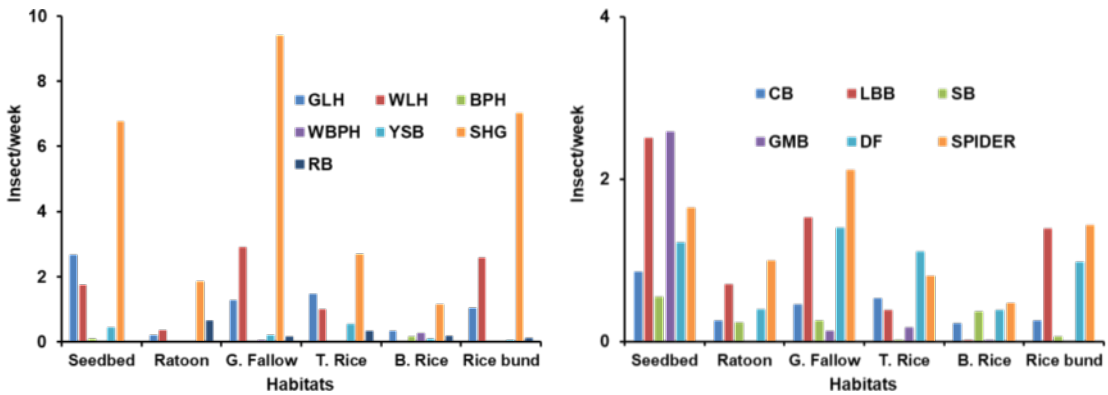

Fig. 1. Incidence of insect pest and natural enemies in different habitats at BRRI farm, Gazipur.

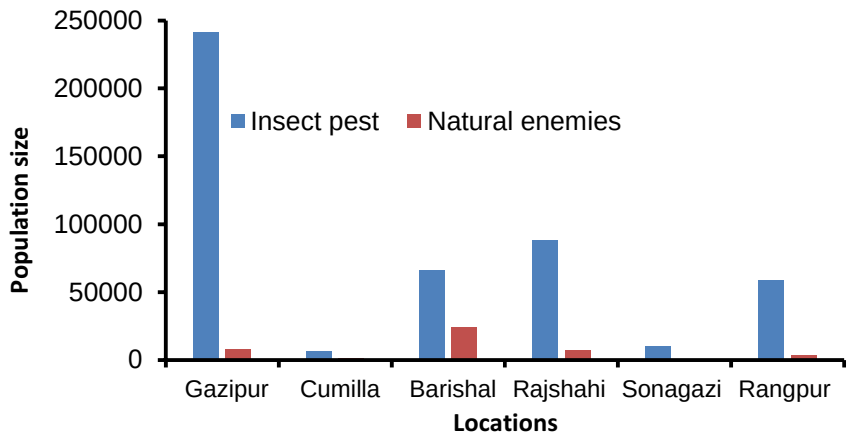

Fig 2. Population of insect pests and natural enemies at BRRI HQ, Gazipur and six regional stations.

The abundance of BPH, WBPH, YSB and GLH was observed almost in all the locations (Fig. 3). The highest number of BPH was observed during the month of November at Gazipur and Rangpur. WBPH has two peaks on October for Gazipur and November for Barishal station. The highest peak of YSB was observed in November and May at Barishal and Rajshahi region respectively. Usually stem borer shows two peaks in a year- one in April-May and the other in October-November. The second peak was observed Rajshahi in May (Fig 3). All locations showed higher populations of GLH in the month of November, 2020 (Fig 3). In conclusion, higher peak of insect pests was found in November across the locations.

Among the natural enemies, the highest catch of natural enemies in light trap was recorded at Barishal, and then followed by Gazipur, Rajshahi, Rangpur, Cumilla, and Sonagazi (Fig 1). GMB population of Rangpur was higher than those of other stations (Gazipur, Barishal and Rangpur). The highest peak was observed in November and December in Rajshahi. Similarly, CDB showed the highest population at Barishal in the same month (Fig. 4). In contrast, two peaks of STPD were observed at Barishal, in October 2020 and March, 2021 (Fig. 4). No other stations showed any peak for STPD incidence. Among natural enemies, highest peak was found in November for GMB and CDB and March for STPD.

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Survey and monitoring of rice arthropods and yield loss assessment in a selected village

Most of the farmers of Fatepur village belongs to small farmer category (36.48%) followed by land less (32.57%) and marginal (18.89%). Boro-Fallow-T. Aman cropping pattern was the highest (60.49%) coverage followed by Potato-Boro-T. Aman (8.06%). On average 70, 60.33 and 66.73% of the farmers cultivated BRRI varieties during Aus, T. Aman and Boro season respectively. But 30.36% farmers used Indian variety especially different types of Swarna varieties during T. Aman season. A total of 78% farmers applied granular insecticide during 1st urea top dressing and 100% farmers used insecticide 2-4 times in a season. Majority of the farmers (80%) used knowledge

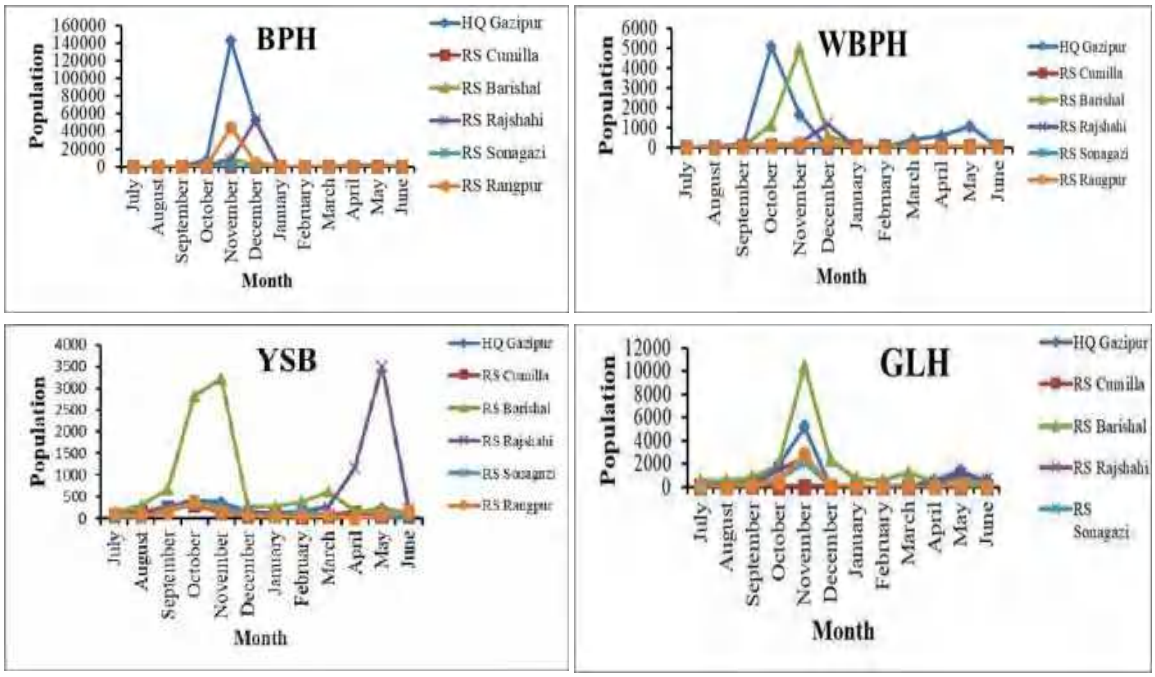

Fig. 3. Incidence pattern of major insect pests in light trap, BRRI HQ Gazipur and regional stations during July 2020-June 2021.

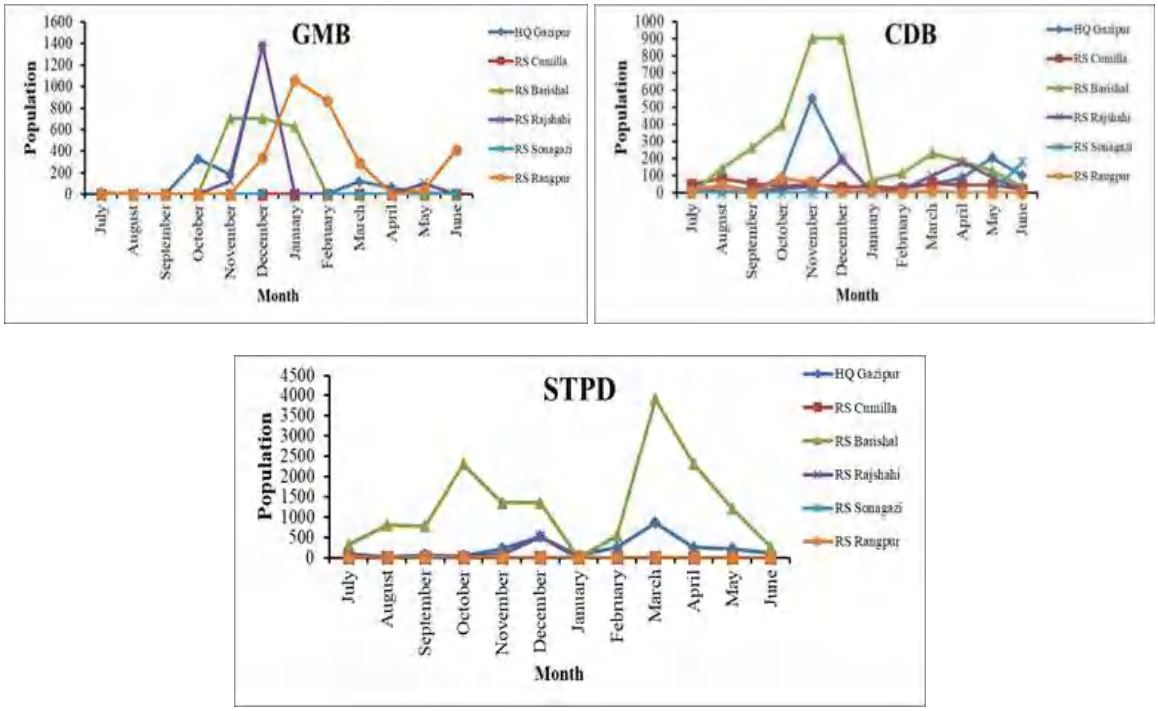

Fig. 4. Incidence pattern of natural enemies of rice insect pest in light trap, BRRI, Gazipur and regional stations, during July 2020-June 2021.

source from pesticide dealer for pest control. Only 0.13% yield loss occurred in BRRI dhan89 due to infestation of different insects during Boro season at Fatepur, Pirganj, Rangpur.

Fall Armyworm (FAW) monitoring through pheromone trap on non-maize crops

Five pheromone traps were set 100 m between traps (in separate fields) in rice from seedbed to ripening stage of rice crops (in separate fields) in five different locations of Bangladesh**.** Every Monday the trap catch and field scouting data were collected using tablets/ smart phones, with data and GPS of field locations automatically uploaded to a centralized database. The highest population of FAW (388 moths) was trapped in farmers field at Chuadunga within 19 weeks followed by farmers field at Mithapukur, Rangpur (381) within six weeks.

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BIO-ECOLOGY OF RICE INSECT PEST AND NATURAL ENEMY

Behaviour and biological parameters of Fall Armyworm when feeding rice

Fig. 3. shows the duration of developmental period from egg to adult at different rice varieties using pot experiment. Results show that rice variety has no significant impact on the development period of FAW from egg to adult (Fig. 5, $F = 1.349$, $df = 69$, $P = 0.208$). It indicates that rice varieties did not significantly differ their developmental period. Therefore, we used only seedling tray method for further studies using rice and maize. Mean immature developmental time (from larva to adult) was significantly differed between rice (31.75 ± 1.65 days) and maize host (26.94 ± 0.72 days, $t = 11.997$, $df = 6$, $P < 0.01$). This result indicates that rice delays 4.81 days for their development from larva to adult when compared to maize.

Development time from egg to adult did not differ significantly between male and female within the same host (Table 1). Host plant has no

significant impact on survival rate of FAW between rice and maize hosts (t = 0.172, df= 6, P = 0.869). Significantly higher larval weight was found in maize than that of rice at two sequential dates of their growth (Fig. 4, df = 31, P < 0.001 for seven days and df = 42, P < 0.001 for 13 days). However, statistically similar pupal weight was observed between two hosts (Fig. 6, F = 2.0385, df = 18, df = 21, p-value = 0.1193). Host has significant impact on pre-oviposition, oviposition, post-oviposition periods and fecundity/female (Table 2). Female developed from maize showed lower pre-oviposition and higher oviposition periods than that of female developed from rice. Likewise, they showed significant higher post-oviposition period and fecundity than that of rice. But daily egg production (eggs/female/day) was not significantly different between maize and rice (Table 2, F = 1.4501, df = 27, p-value = 0.3461).

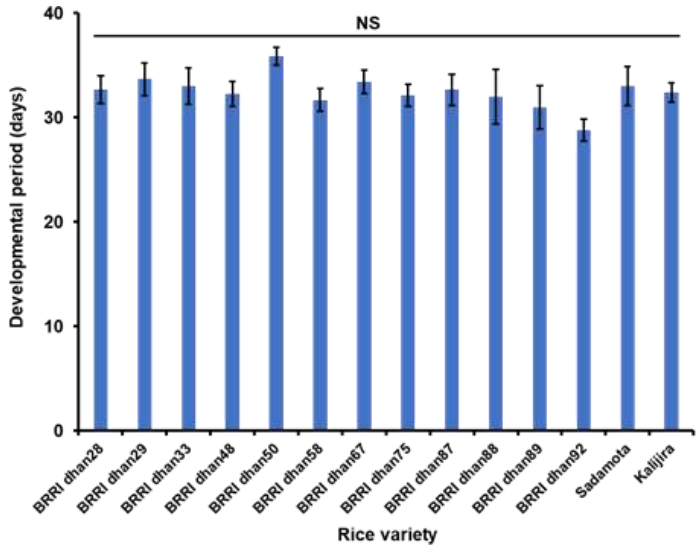

Fig. 5. Developmental time (egg – adult) of Fall Armyworm (FAW) on different rice varieties. The experiment was conducted in earthen pot. NS indicates non-significant difference at the 5% level of significance. Error bar represents the standard error.

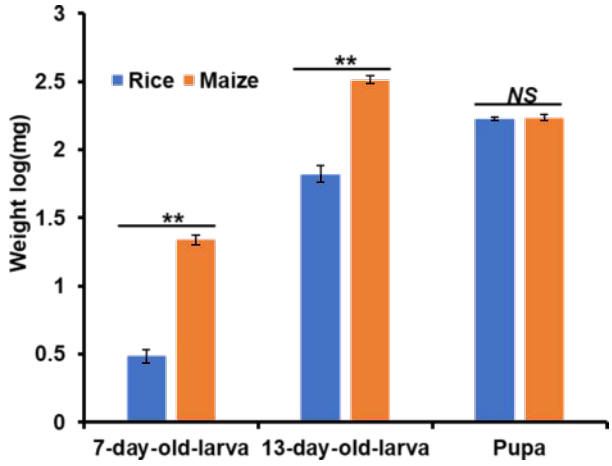

Fig. 6. Effect of host plant on the body weight of Fall Armyworm (FAW) larvae. Weight was measured at 7-day old larva, 13-day old larva and pupal stages using analytical balance (KERN ABJ220-4NM, Germany). N = 20 – 30. Error bars indicate standard error. ** indicates significant differences at P < 0.01. NS represents non-significant at the 5% level of significance.

Table 1. Immature developmental stages (days ± S.E.) (from egg to adult), and adult longevity (mean ± S.E.) of FAW at rice and maize hosts. Experiment was conducted at 27 ± 2°C and 65 ± 5 % RH in a greenhouse room.

Host	Sex	N[a]	Developmental period in days (Egg – adult)	Adult longevity
Rice	Female	32	34.52 ± 0.367	9.71± 0.294
	Male	23	35.88 ± 0.312	8.50 ± 0.301
Maize	Female	26	27.37 ± 0.201	12.46 ± 0.547
	Male	19	30.73 ± 0.395	10.45 ± 0.383
Statistics for female			F = 0.3309, df = 31, p = 0.004581	F = 2.8734, df = 31, p = 0.0086
Statistics for male			F = 1.60, df = 25, p = 0.146	F = 1.33, df = 25, p = 0.5043

[a]Number of insects were tested.

Table 2. Duration adult phases and fecundity (mean ± S.E.) of Fall Armyworm at rice and maize at 27 ± 2ºC and 65 ±5% RH in a greenhouse room.

Host	N[a]	Pre-oviposition period	Oviposition period	Post-oviposition period	Fecundity per female	Eggs laid per day
Rice	28	4.25 ± 0.203	3.89 ± 0.292	1.93 ± 0.192	559.21 ± 61.53	150.59 ± 12.69
Maize	26	4.15 ± 0.362	5.92 ± 0.505	2.46 ± 0.329	1010.62 ± 104.99	186.09 ± 15.85
F-value		2.9509**	2.7693**	2.7317**	2.7037**	1.4501NS

[a] Number of females were tested.

[a] Data were analysed using independent two sample test in SPSS software.
** $P < 0.001$ significant difference at 1% level of significance.
NS – non-significant difference at 5% level of significance.

Table 3. Demographic parameters of Fall Armyworm at rice and maize hosts: the intrinsic rate of natural increase (rm, day-1), net reproductive rate (R_0), generation time (tG, day), the finite rate of increase (λ), and doubling time (tD, day).

Host	N[a]	r_m	R_0	t_G	λ	t_D
Rice	28	0.121 ± 0.007	66.18 ± 2.76	36.07 ± 1.23	1.13 ± 0.006	5.95 ± 0.194
Maize	26	0.173 ± 0.006	256.83 ± 1.10	32.57 ± 0.75	1.19 ± 0.005	4.07 ± 0.091
t value		175.97	156.71	-2.4712	7.7061	-9.0012
p-value		<2.2e-16	<2.2e-16	0.0173	3.778e-10	4.645e-11
Df		52	35	45	52	39

[a]Number of females were tested.

[a] Data were analysed using Welch two sample t-test; two sided with 95% confidence level.
The age-specific survival rate (lx) started to drop at earlier ages in maize than that of rice (Fig. 5). Significant higher immature stage of female was observed when larvae fed on rice than that of maize (Table 2, F = 0.3309, df = 26, p = 0.004581). Female adults started to die on days 39, and 33 at rice and maize respectively (Fig. 7). Oviposition began from 2 to 9 days after adult emergence. However, female developed from rice had shorter oviposition period than maize (Table 2). The age-specific fecundity rate (mx) peaked at 40 days in rice and 33 days in maize (Fig. 5). The intrinsic rate of natural increase (rm), the reproductive rate (R0) and the finite rate of increase (λ) were observed significantly higher when fed on maize than that of rice (Table 3; t = 175.97, df = 52, p-value < 0.001 for rm, t = 156.71, df = 35, p-value < 0.001 for R0 and t = 7.7061, df = 52, p-value < 0.001 for λ). The average length of a generation (tG) time significantly lowered when fed on maize than that of rice (t = -2.4712, df = 45, p-value = 0.0173). Likewise, significant lower tD value observed when fed on maize (Table 3, t = -9.0012, df = 39, p-value < 0.001). This result indicates that FAW required higher days to become doubling population when fed on rice.

FAW larvae consumed significant higher amount of maize leaf than that of all tested rice varieties (Fig. 8, F = 70.989, df = 6, 56, P < 0.01). Result indicates that significant variation was not observed among rice varieties (Fig. 6; F = 0.982; df = 5, 48; P = 0.440).

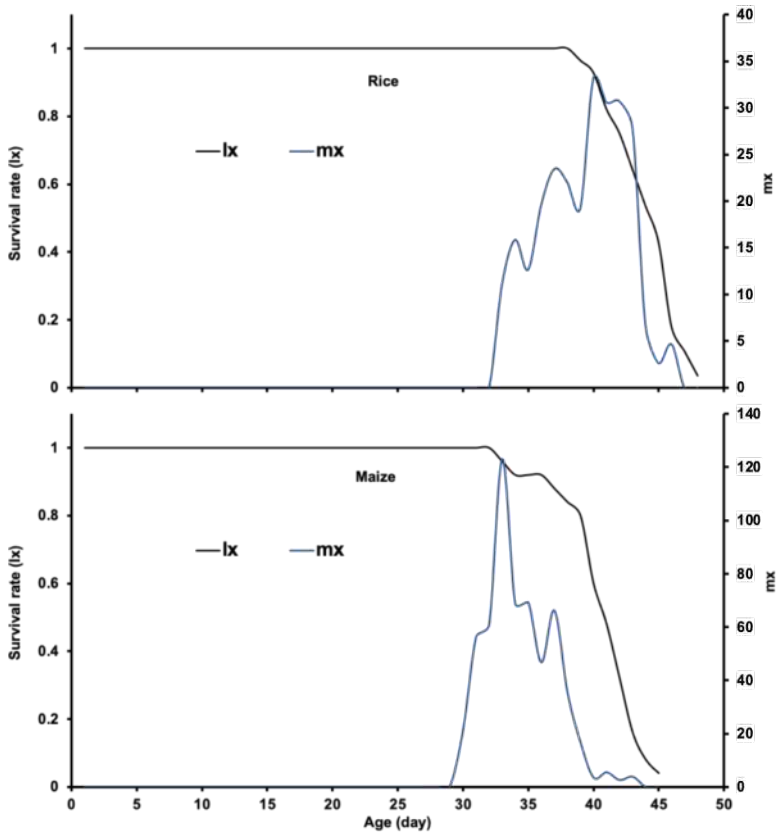

Fig. 7. Age specific survival (lx) and fecundity (mx) rates of female fall armyworm at rice and maize host.

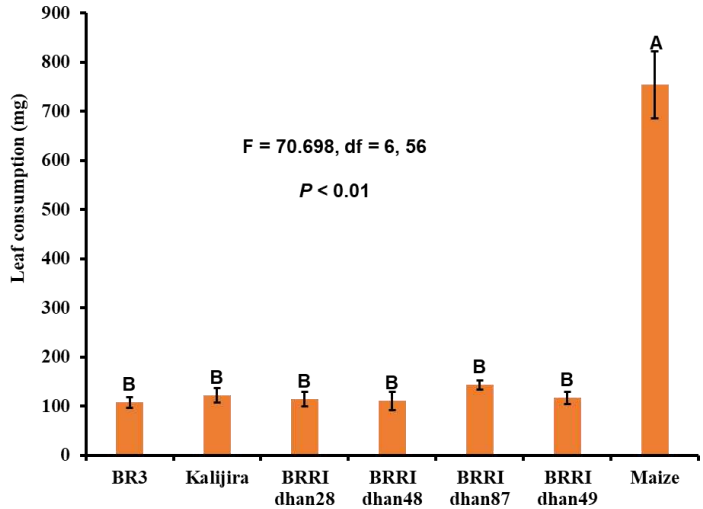

Fig. 8. Leaf consumption of Fall Armyworm larvae against different rice varieties and maize. N = 20-30. Each bar represents the leaf consumption per larva for 24 h. Error bar represents standard error. Tukey's Honest Significant Difference test was performed for mean separation.

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Behavioural adaptation of rice leafroller (RLR) in different temperature

This experiment was conducted at the growth chamber in Entomology laboratory. Potted plants (BR3) grown in outside were used for this experiment. Growth chamber adjusted in different temperature was considered as treatments e.g.; 20ºC, 25ºC, 30ºC, 35ºC and 40ºC.

Rice leafroller (RLR) was introduced in a pair into each pot and kept in the growth chamber set with specific temperature. Relative humidity was kept similar for every temperature setting. Plants were monitored carefully to collect data from larva to adult stage of RLR. After larval hatching, no. of larvae hatched, no. of folded leaves by the larvae and adult emergence by RLR for each temperature were taken and analyzed statistically. Due to some inconvenience in the greenhouse, rice leafroller were not available for testing in each temperature. Therefore, data for 30ºC and 35ºC only collected. The growth and development of RLR has shown slight differences in changing temperature in the growth chamber but these results were not statistically different (Fig. 9). Number of hatched larvae were higher in 35ºCthan 30ºC. However, the number of folded leaves by the RLR larvae were higher in 30ºC. It might be due to higher temperature, leaf folding behaviour was slowed down by the RLR. Adult emergence was counted after 35 days after larva hatched and higher number of adult RLR were found in 35ºC. It indicates that temperature is one of the important factor for RLR growth and development. Any deviation from the optimum temperature during their lifetime can cause changes in their life stages from larva to adult. More research of RLR in different temperature is further needed to understand the mechanism of their behavioural adaptations.

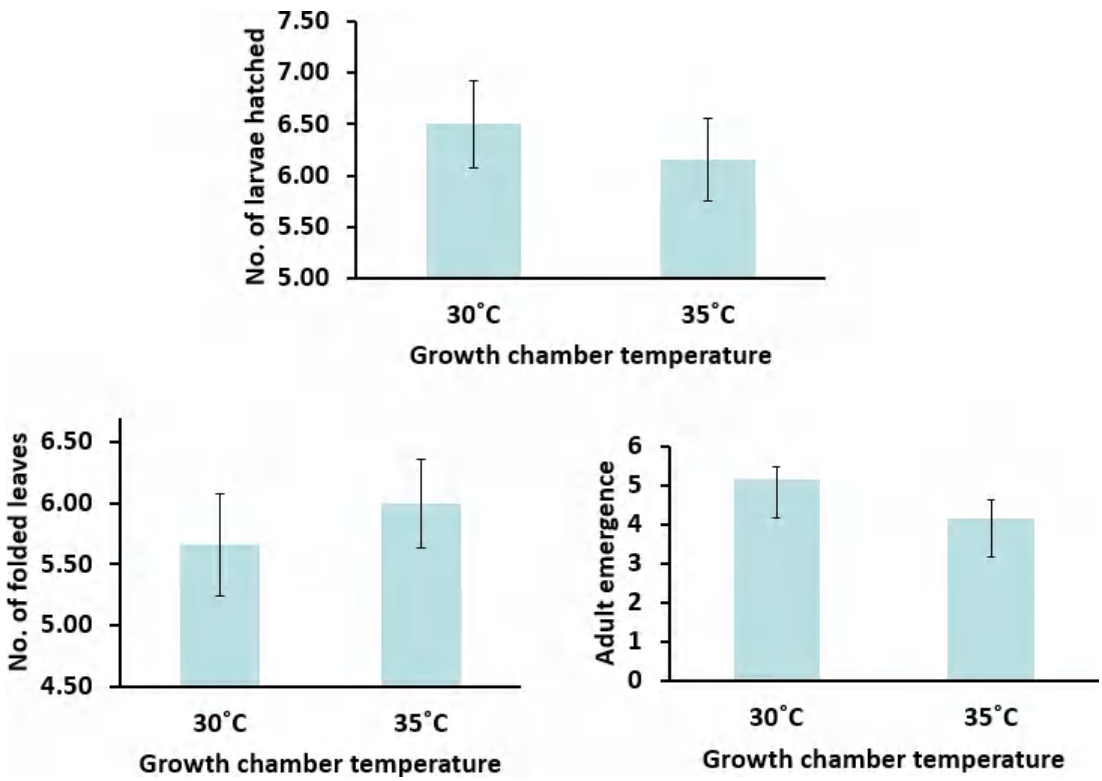

Fig. 9. Effect of temperature on rice leafroller life cycle. Error bar represents standard error.

PI: Farzana Nowrin, **CI:** Md. Panna Ali, PL: Sheikh Shamiul Haque

BIOLOGICAL CONTROL OF RICE INSECT PESTS

Leveraging diversity for ecologically based pest management

Two experiments on leveraging diversity for ecologically based pest management were conducted in BRRI HQ farm, Gazipur during T. Aman and Boro season to conserve natural enemies in rice field and to validate eco-friendly insect pest management technology in farmer's field. Two treatments were used in all locations i.e., T_1=Sesame and cosmos flower were grown on rice bunds, T_2=Farmers practice i.e. prophylactic use of insecticide. Insect pest infestation both in T. Aman and Boro seasons remains below the ETL in both the treatments T_1 and T_2 . The highest natural enemies, % egg parasitism of YSB and larval parasitism of rice leaffolder were observed in rice field with nectar-rich flowering plants on bunds (Eco-engineering). However, least natural enemies and parasitism were found in farmer's practice rice field where four times insecticides were applied. Moreover, there was no yield reduction observed in eco-engineering field compared to farmers practice field (insecticide application). So, farmers should avoid the toxic and hazardous insecticides to control the insect pests by growing nectar-rice flowering plants on the bunds of rice crop.

PI: Md Nazmul Bari, **PL:** Sheikh Shamiul Haque

Study on entomopathogenic fungi to control BPH

The study was conducted at Entomology greenhouse, BRRI to isolate the fungi from naturally infected BPH and to know the pathogenicity of entomopathogenic fungi against BPH. Potted BR3 plants were infested by 10 3rd-4th instar BPH nymphs of greenhouse populations and confined by mylar film cages. Fungus was sprayed at the rate of 1 x 106 conidia/mL per plant. Insecticide treatment was also included in CRD replicated trials in pots in the net house of Entomology Division. Fungus inoculated plants showed around 63-68% death of BPH in compared to 100% mortality with Insecticide treatment.

PI: Farzana Nowrin; **CI**: Quazi Shireen Akhter Jahan, **PL:** Sheikh Shamiul Haque

CROP LOSS ASSESMENT

Effect of dead heart and white head on grain yield of BRRI rice varieties

The experiment was conducted at BRRI research farm, Gazipur to determine the yield loss and recovery abilities of BRRI dhan87 against stem borer damage. Four hills were randomly selected diagonally from each plot and infested with the 1st instar larvae of one egg mass after 35 days after transplanting (DAT). Another four hills from the same plots were also selected as control. On average 1.39% dead heart and 0.83% white head observed when rice plant were infested at 35 DAT. No significant difference was found in tiller and panicle per hill between infested and un-infested hill. But significantly higher filled grain number (924.44/hill) was found in infested hill compared to un-infested hill (851.52/hill). As a result grain weight was found the highest (21.85 g/hill) in infested hill compared to un-infested hill (20.16 g/hill). So, no yield loss was found by the damage of YSB at early crop stage when deadheart and white head remain below 2 and 1% respectively.

PI: Md Nazmul Bari, PL**:** Sheikh Shamiul Haque

INTEGRATED PEST MANAGEMENT

Use of sex pheromone to control yellow stem borer, *Scirpophaga incertulas* and leaffolder, *Cnaphalocrosis medinalis*

Pheromone lures for rice leadfolder were collected from China and used for field evaluation in Gazipur and at the same time pheromone lures for yellow stem borer (YSB) were collected from Ispahani Agro Limited and used for these studies. The test was conducted in BRRI RS, Barishal and BRRI HQ, Gazipur. The optimal blend of used pheromone for leaffolder was Z11-18:Ald, Z13-

18:Ald, Z11-18:OH and Z13-18:OH at a ratio of 3 : 25 : 3 : 3. For YSB, each trap contained one lure tube which was impregnated with a mixture of (Z)-11 hexadecenal + (Z)-9 hexadecenal in 3:1 ratio. Pheromone traps were placed at 30 cm above the crop canopy and maintained a distance 20 m from one trap to another one. Significant number of YSB and leaffolder were caught in each trap both in Gazipur and Barishal (Fig. 10). However, higher number of YSB catches observed in Gazipur than Barishal. This result indicates that pheromone trap can be effective to monitor and control YSB and leaffolder in rice field.

PI: Md Panna Ali, **CI:** Farzana Nowrin, Mir Md Moniruzzaman Kabir and PL: Sheikh Shamiul Haque

EVALUATION OF CHEMICALS AND BOTANICALS AGAINST RICE INSECT PESTS

Residues analysis of chlorantraniliprole and thiamethoxam in rice grain

Sample was collected from insecticide treated field and pesticide residues were detected using a LC-MS2020 fitted with electrospray ionization (ESI) probe operated in the positive ion mode. The following parameters were optimized for chlorantraniliprole and thiamethoxam: capillary voltage, 3500 V; ion source temperature, 150°C; desolvation gas temperature, 500°C; desolvation gas flow rate, 1000 L h-1 of nitrogen. Detection was carried out in multiple reaction monitoring (MRM) mode. The retention time of chlorantraniliprole was 2.3 minute and thiamethoxam 1.9 minute. The concentrations of chlorantraniliprole and thiamethoxam in the tested samples were 0.0046 to 0.0243 and 0.0026 to 0.04 mg/kg in chlorantraniliprole and thiamethoxam respectively in the polished rice grain of different treatments. However, the detected amount of both chlorantraniliprole and thiamethoxam in the samples were below the Maximum Residue Limit (MRL: 0.4 mg kg-1 for chlorantraniliprole) and 0.6 mg kg-1 for thiamethoxam, EU).

PI: Md Nazmul Bari, **CI:** Md Panna Ali, Farzana Nowrin and Sadia Afrin

Test of different insecticides against major insect pests of rice

A total of 107, 28 and seven and six commercial formulations of insecticides were evaluated against BPH, YSB, RH and rice weevil (RW) respectively. Among them 100, 10, seven and six were found effective against BPH, YSB, RH, rice weevil (RW) respectively. All the 10 biopesticides were found effective against BPH and YSB.

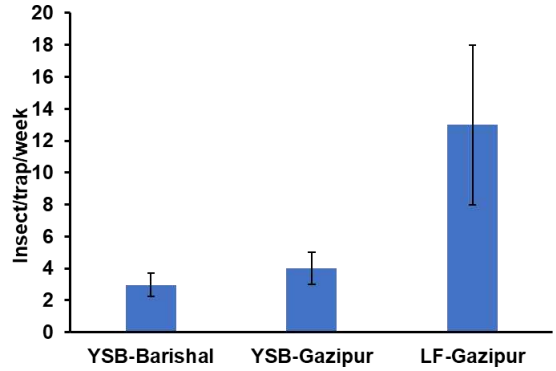

Fig. 10. Weekly catches of yellow stem borer (YSB) and leaffolder (LF) moths in sex pheromone trap. Bar represents the mean of 10 traps per week. Error bar indicates the standard error.

PI: Md Panna Ali, **CI:** Farzana Nowrin; **PL**: Sheikh Shamiul Haque

Effect of insecticides on natural enemies of rice insect pests

Available insecticides of different chemical group were evaluated at BRRI HQ, Gazipur in T. Aman and Boro 2020 to know their effects on natural enemy populations of rice field. The generic name of six insecticides are acetamiprid, spinosad, abamectin, chlorantraniliprole, Fipronil and chlorpyrifos. Sweeping data of natural enemy populations was counted after 48 hours of spraying. Abamectin followed by chlorantraniliprole and fipronil showed comparatively safe for natural enemies of rice field.

PI: Md Mosaddque Hossain, **PL:** Sheikh Shamiul Haque

HOST PLANT RESISTANCE

Screening of advanced breeding lines against major insect pests of rice

A total of 1,300 advanced breeding lines and INGER IRBPHN materials were evaluated at green house of Entomology Division to identify resistance sources against major insect pests of rice. Among them three different lines showed moderately susceptible (score 5) reaction against BPH, WBPH and GLH each. IRBPHN line, SVIN347 showed moderately susceptible reaction to BPH, ZER line, IR101757-46-1 to WBPH and RLR breeding line, BR9857-7-6-5-1 showed to GLH, 18 favourable Boro and 31 IRR line also showed moderately susceptible reaction against BPH.

Susceptible check: BR3 (for all), Resistant check: T27A, IR64 scores were made according to SES. BPH= brown planthopper, WBPH= white-backed planthopper, GLH= green leafhopper, R= resistant (score 0-1), MR= moderately resistant (3), MS= moderately susceptible (5), S=susceptible (>7)

PI: Md Mosaddque Hossain, **PL:** Sheikh Shamiul Haque

Screening of rice genotypes against BPH populations in field condition at BRRI HQ, Gazipur

Fifteen BPH NIL's including one resistant check, T27A and two susceptible checks, IR24 and BR3 (local susceptible) genotypes were evaluated against BPH in the field condition at BRRI HQ, Gazipur, during T. Aman 2020 season. Tiller and panicle number hill^{-1} was found highest in IR107736-5-2-1-1 (10.72 and 9.67/hill respectively). More tiller hill^{-1} was also observed IR101840-1-1-11-2 (10.36/hill) and IR107736-7-1-2-1(9.67/hill) but more panicle was found in IR107736-7-1-2-1(8.97/hill) and BR3 (7.97/hill). The lowest tiller number (6.90 tiller/hill) was found in IR101795-1-5-1-1 but the lowest panicle number (5.95/hill) was observed in T27A.

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Suppression of serotonin synthesis in rice using CRISPR Cas9 for insect control

Serotonin is ubiquitous across all forms of life and in mammals. It is well known as a neurotransmitter and in insects it is thought to be involved in behavior and immunity. Serotonin also is involved in plant growth, development and response to biotic and abiotic stresses. In rice, the gene CYP71A1 encodes a cytochrome P450 monooxygenase, which exhibits tryptamine 5-hydroxylase enzyme activity, catalyzing the conversion of tryptamine to serotonin. In CYP71A1 knockout mutants, prevention of serotonin synthesis increases resistance to brown planthopper (BPH) and stem borer. Furthermore, recent studies on serotonin in rice plants and insect resistance, suggesting a potential role of serotonin in the regulation of insect resistance. Therefore, we have taken this study to develop insect resistant rice variety using clustered regularly interspaced short palindromic repeats (CRISPR) Cas9 genome editing tool.

In the production of CYP71A1 knockout (CYP71A1-KO) rice plant, a 20 bp fragment (TGGTCGCGTTGAGGAGGAGC-F and GCTCCTCCTCAACGCGACCA-R) of CYP71A1 gene was designed as the target and inserted into the vector VK005-01 for CRISPR/Cas9 knockout. The oligonucleotide sequence of target insertion part of CYP71A1 gene was purchased from Macrogen company (Humanizing Genomics, Seoul, Korea) via Biotech Concern (Dhaka, Bangladesh). The Cas9/gRNA (Catalog. No. VK005-01, VIEWSOLID BIOTEC, Beijing, China) was purchased and used in this experiment. Table 4 outlines the component and amount used for this cloning reaction. The recombinant Cas9 vector was selected, and cultured. DNA was extracted from cultured recombinant vector and target part of the genome was amplified using PCR. The amplified part of the DNA was confirmed by gel electrophoresis (Fig. 11). The target amplified DNA band was purified from agarose gel using FavorPrep Gel/PCR purification Mini Kit (Cat No. FAGCK001, FAVORGEN, Biotech CORP, Taiwan) and sent for sequencing in National Institute of Biotechnology (NIB), Ashulia, Savar, Dhaka. The sequencing results confirmed that Cas9 vector contains target sequence of CYP71A1 gene.

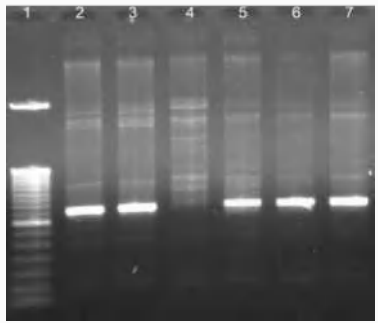

Fig. 11. Electrophoresis of PCR product of recombinant vectors. Lane 1: DNA ladder; lanes 2-7: PCR product derived from 6 recombinant vectors. (b) Alignment of the original target site of CYP71A1 and the sequence of recombinant CYP71A1-SK-gRNA. * indicates the similarity between original target site and recombinant CYP71A1-SK-gRNA.

Table 4. Component and their amount of a restriction system.

Component	Amount (µl)
Cas9/gRNAVector (VK005-01)	1
Mixture of TGGTCGCGTTGAGGAGGAGC-F GCTCCTCCTCAACGCGACCA-R	1
Solution I	1
Solution II	1
dH_2O	6
Total	10

Sequencing result shows 100% similarity with original target sequence and recombinant SK-gRNA – CYP71A1 (indicated by *) (Fig. 12).

```
CYP71A1          ------------------------------------------------------ 0
VK005-01-CYP71A1 ARRRRGWAARGGTTYGCMGGCCCTGTGCAGGTAAGAAGATGGAAATTYGATAGAGGTACG 60

CYP71A1          ------------------------------------------------------ 0
VK005-01-CYP71A1 CTACTATACTTAGAWAWACAACKAAGGGAATGCTTGTATTTATACCCTATMCCCCCTAAK 120

CYP71A1          ------------------------------------------------------ 0
VK005-01-CYP71A1 AACCCCTTATCAATTTAAGAAATAATCCGCATAAGCCCCCGCTTAAAAATTGGTATCAGA 180

CYP71A1          ------------------------------------------------------ 0
VK005-01-CYP71A1 GCCATGAATAGGTCTATGACCAAWRCTCAAGAGGATAAAACCTCACCAAAATACGAAAGA 240

CYP71A1          ------------------------------------------------------ 0
VK005-01-CYP71A1 GTTCTTAACTCTAAAGATAAAAGATCTTTCAAGATCAAAACTAGTAAAAAAAGCACCGAC 300

CYP71A1          ------------------------------------------------------GC 2
VK005-01-CYP71A1 TCGGTGCCACTTTTTCAAGTTGATAACGGACTAGCCTTATTTTAACTTGCTATTTCTAGC 360
                                                  **
CYP71A1          TCCTCCTCAACGCGACCA ------------ 20
VK005-01-CYP71A1 TCCTCCTCAACGCGACCASKAGGA 384
                 ******************
```

Fig. 12. Alignment of the original target site of CYP71A1 and the sequence of recombinant CYP71A1-SK-gRNA. * indicates the similarity between original target site and recombinant CYP71A1-SK-gRNA.

The successful recombinant vector VK005-01 harboring Cas9/CYP71A1 sgRNA was transformed into *Agrobacterium tumefaciens* LBA4404 by freeze-thaw method. Seeds of rice variety BRRI dhan87, BRRI dhan89 and BRRI dhan92 were collected and used for Agrobacterium mediated transformation. Sufficient amount of calli were produced for all the varieties and used for co-cultivation with recombinant Agrobacterium (Fig. 13). After co-cultivation, putative transformed calli were kept in resting medium for a period of 5 days followed by the second round of resting for 10 days. Putative transformants were selected by subjecting the calli to two rounds of selection in a

medium containing 35 mg/L hygromycin. Putative transgenic calli were regenerated in the presence of 1 mg/mL of NAA and 3 mg/mL 6-BA and rooted on half MS media containing 35 mg/L hygromycin. **PI:** Md Panna Ali, **CI:** Juel datta, Md Shah Ashadul Islam; and **PL:** Sheikh Shamiul Haque

Development of BPH resistance breeding lines through marker assisted selection

Crosses were made between donor parent (IR101791-10-1-4-3-2-4) and recipient parent BRRI dhan87 and BRRI dhan 89. F_1 were confirmed using 10 SNP panel and developed F_2 population in RGA nursery. Among F_2 population, performed molecular analysis using SSR marker. RM8072 was used for confirmation of the presence of BPH32 gene. To understand the inheritance of BPH resistance in segregating population of BRRI dhan87, a total of 39 F2:3 lines were infected with BPH at the seedling stage.The results showed that the damage score of F2:3 lines was single peak and partial distribution, suggesting that the BPH resistance was controlled by multiple major and/or minor genes/QTLs.

PI: Sadia Afrin, **PL:** Sheikh Shamiul Haque

INSECT MOLECULAR BIOLOGY

Molecular characterization of *Nilaparvata lugens* population in Bangladesh based on COI analysis

N. lugens populations were collected from nine different geographic locations including Gazipur, Chandpur, Dinajpur, Rajshahi, Barishal, Satkhira, Sirajganj, Cumilla and Cox's Bazar. The exact collection point of each geographic location was demonstrated in Bangladesh map (Fig. 14). DNA was extracted from all collected samples. The universal barcode primer (LCO-1490-5′- GGT CAA CAA ATC ATA AAG ATA TTG G-3′; HCO-2198-5′-TAA ACT TCA GGG TGA CCA AAA AAT CA-3′) was used to amplify the target part of COI gene. PCR products were visualized on 1% TAE-agarose gel electrophoresis (Fig. 10). Single band was purified from all samples using FavorPrep Gel/PCR purification Mini Kit (Cat No. FAGCK001, FAVORGEN, Biotech CORP, Taiwan). The purified DNA was sent to company for sequencing. Sequencing results will be analyzed.

PI: Md Panna Ali, **CI:** Juel Data, and **PL:** Sheikh Shamiul Haque

VERTEBRATE PEST MANAGEMENT

Study on the efficiency of different traps against rice field rats

Efficacy of single capture live trap, hand-made bamboo trap and paint bucket trap were evaluated to capture rat in rice field of BRRI HQ, Gazipur in T. Aman 2020. Live traps (single capture) were more effective than handmade bamboo traps and bucket trap to catch rice field rats.

PI: Md Mosaddque Hossain, **PL:** Sheikh Shamiul Haque

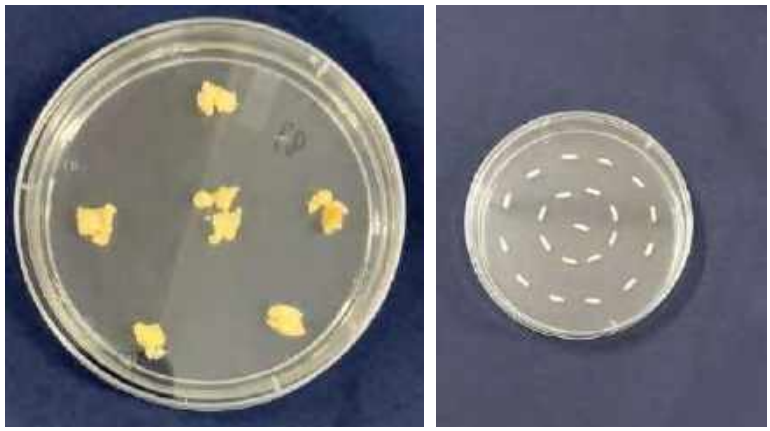

Fig. 13. Culture of calli for co-cultivation with recombinant Agrobacterium (left side) and dehusked seeds were placed in callus induction plate (right side).

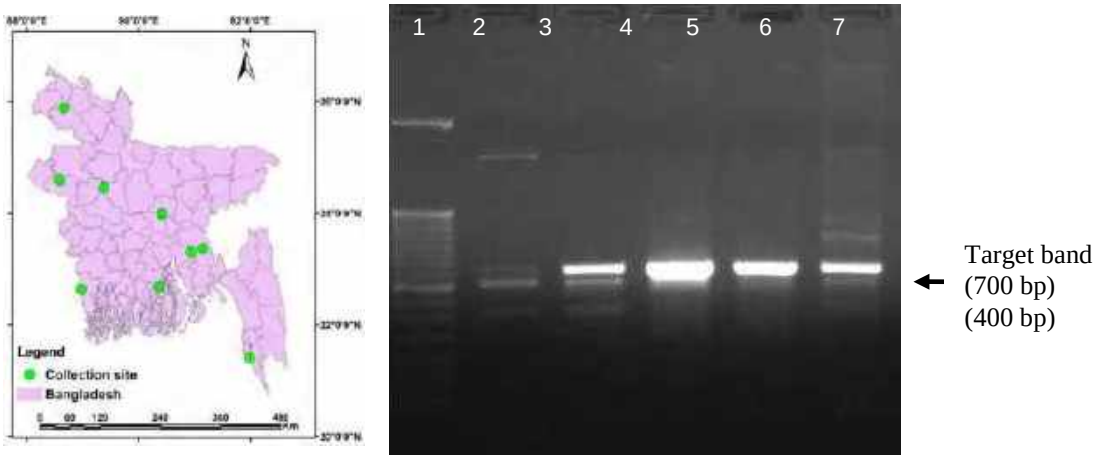

Fig. 14. Collection points of BPH (*Nilaparvata lugens*) sample (left side) and COI gene (PCR amplicon) samples showing 700 bp product in 1% agarose gel (right side). Lane 1: 1 kb DNA ladder, lanes 2-6: Sample of Gazipur, Cumilla, Chandpur, Dinajpur, and Cox's Bazar.

Plant Pathology Division

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SUMMARY

Disease survey was conducted in different rice ecosystems during T. Aman and Boro 2020-21. Incidence pattern and severity of rice diseases over the locations and varieties were assessed. Bacterial blight (BB), sheath blight (ShB) and brown spot were observed predominant irrespective of season. Prevalence of sheath rot was observed in Barisal in T. Aman season. Sheath blight incidence indicates a threat for Boro rice. Blast disease incidence was recorded in aromatic rice during T. Aman while this disease was observed less in Boro except for BRRI dhan29. Severe tungro incidence was found in Cumilla only.

Three blast isolates of grass weed were inoculated in three trays and did not show any symptom on leaves of rice, foxtail millet and wheat. But rice blast isolate developed symptoms of blast disease on leaves of BRRI dhan28 excluding foxtail millet and wheat leaves. In a comparative epidemiology study, the incidence of rice false smut increased progressively with the delay in planting time compared to recommended planting time, while sheath rot disease incidence increased in mid planting (9 August) than early (25 July) or late (24 August) plants. Neither of the six fungicides significantly reduced the incidence of either of the diseases. In another comparative epidemiology study, disease incidence tended to reduce on plants generated from healthy seeds compared to those generated from diseased seeds in both blast and false smut diseases. This was particularly evident in false smut disease, which indicates infected seed might be a source of infection for the disease.

Although in the previous study there was no significant variation of cluster group of reaction pattern of blast pathogen over the region, present study indicates that there was a possibility of the changing of reaction type over the region in Bangladesh. With the help of CIMMYT, a team of BRRI led by Plant Pathology Division is trying to develop Early Warning System (EWS) for rice blast. To determine the actual crop loss due to diseases, a study was undertaken during Boro 2020-21 season with the help of BRRI RS at Cumilla, Satkhira and Rajshahi. On average, frequencies of neck blast disease found the highest followed by bacterial leaf blight, sheath blight and so on. This study will be repeated in the successive seasons also. Causal organism of panicle blight was identified as *Burkholderia glumae* using selective media (King‟s B and CCNT). A total of 900 bacterial blight infected samples were collected from the 40 different districts of Bangladesh. In T. Aman 2020, to identify the physiological races, pathogenicity tests of 300 BB isolates were done on NILs and Pyramid lines of bacterial blight resistance. In total, 13 races were identified according to the reaction patterns of the BB isolates against BB resistant NILs.

Multilocation trials of bacterial blight (BB) and blast resistant lines were evaluated in different locations over the country. Average yields of the genotypes were ranged from 6.1-6.7 t/ha with 141-144 days. The yields were high compared to the susceptible check variety BRRI dhan28 (5.7 t/ha, 145 d). Among the tested genotypes BR(Path)13784-BC3-63-6-4-HR6 produced the highest average yield (6.7 t/ha) with yield range 5.2-8.5 t/ha over the locations. The lowest yield at Gazipur and Rajshahi was due to high temperature and extremely hot weather during flowering. All the lines showed resistant over the locations when BRRI dhan28 was affected 6.7%-85% . The highest infection was recorded in Rangpur (85%) followed by Gazipur (75%) and Dinajpur (53.3%) in BRRI dhan28. No or very low BB incidence was recorded. Ten blast and BB resistant fixed lines along with two checks (BRRI dhan29 and BRRI dhan58) were evaluated by Observational trial (OT) during the Boro 2020-21 season. Fourteen BB and blast resistant fixed lines along with a check BRRI dhan28 were evaluated during the T. Aman 2021 season. The highest yield hactor^{-1} (6.615 ton) was recorded from the genotype BR (Path)13784-BC_3-63-6-4-HR_6 while the lowest (3. 390 ton) was recorded for BR (Path)13784-BC_3-4-8-9-HR_8. Advanced generation (BC2F2, BC3F2, BC4F2, BC3F3) of the crosses of BRRI dhan28, BRRI dhan29 and BRRI dhan58 and Pi9 (US)* Pb1 (US2), *Pi9* (IR64), IRBB58, ST3 were developed for blast and bacterial blight diseases resistance using marker assisted backcross breeding. Blast and

bacterial blight resistant genes were introgressed in the background of BRRI dhan58 and six advanced lines were evaluated along with two checks (BRRI dhan28 and BRRI dhan58). To develop gene pyramided lines for blast and bacterial blight crosses were made between BRRI dhan49, BRRI dhn63, BRRI dhan81 and IRBB58, IRBB60, US-Pi9, US-Pb1 and developed BC_2F_2, BC2F3, BC_3F_2, BC3F3. To develop bacterial blight gene pyramided lines BRRI dhan28, BRRI dhan29, CN6 and BRRI dhan58 were used as recipient parents. IRBB57, IRBB58, IRBB60, IR64 (*Pi9*), US2 (*Pb1*), STRASA3 and STRASA 4 were used as donor parents. Phenotyping and genotyping were applied for suitable plant selection. Pathogenicity results shown that a good number of progenies of BC_4F_2, BC_3F_2 and BC_3F_4 developed from the crosses were resistant to the most virulent BB isolate *BXo93*. A total of 74 rice germplasm was evaluated for the confirmation of resistant genes of bacterial blight resistance through gene base SSR markers and pathogenicity test against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen in T. Aman 2020 and Boro 2020-21. Six gene specific SSR markers were used for confirmation of *Xa4, xa5, Xa7, xa13, Xa21* and *Xa23* gene among the germplasm. Out of 74 germplasm (according to molecular data), 41 germplasm carried *Xa4* gene, 15 carried *xa5* gene, 62 carried *Xa7* gene, 33 carried *xa13* gene, and 19 carried *Xa23* gene. Only a single germplasm consisted of *Xa21* gene. Interestingly, we found a wide range of gene combinations ranged from 2 to 4 genes among the germplasm resistant to bacterial blight and G3 genotype (Acc. no. 4216; highly resistant) having *Xa4, Xa7, xa13, Xa21* and G43 genotype (Acc. no. 1523; resistant) having *Xa4, xa5, xa13* and *Xa23* gene combination being the most effective against all the *Xoo* strains.

Blast resistant seven fixed lines contains *Pi9* gene were evaluated in multi-location trial. Four lines eg., BR (Path)12452-BC_3-35-21-8-5 BR(Path)12452-BC_3-42-22-11-4, BR(Path)12452-BC_4-77-25-11-8-5 and BR (Path)12452-BC_6-53-21-11 including a pure line Jhum rice, Bekui-HR(Path)-4-3 (ZM-82) were found field resistant while BRRI dhasn28 (check) was highly blast infected. The yield (5.3-6.5 t/ha) and growth durations (144-148 d) of these lines were comparable with the check variety (5.7 t/ha, 145 d). Grain quality are also similar to BRRI dhan28. Thirteen blast resistant lines (long duration) possessing Pi9 gene were also developed which can yield (8.6-10.1 t/ha, 161-166 d) equally or more than BRRI dhan29 (9.0 t/ha, 166 d). Blast resistant lines containing *Pita2* gene were found resistant both in UBN and field with 4.5-5.3 t/ha yield in 144-146 days. While BRRI dhan63 was highly blast infected in the field resulting 2.0 t/ha yield in 154 days. Pyramiding *Pita2* and *Pi9* genes in the same background of BRRI dhan28, BRRI dhan29 and BRRI dhan63 were also done. BC2F1 seeds are advancing for linkage and QTL mapping of blast resistant BR16. Three lines BR (path) 13784-BC3-61-1-6-HR3, BR (path)13784-BC3-62-3-5-HR2 and BR (path)13784-BC3-63-6-4-HR from multi-location trial and 38 lines were confirmed and selected for blast resistant lines during Boro 2020-21 in blast hot spot area in Debidwar, Cumilla. To develop blast resistant variety by targeted mutagenesis of *OsERF922* gene by CRISPR/Cas9 method, final vector pc1300-Cas9 with targeted site was transformed into Agrobacterium for the transformation into rice variety BRRI dhan81. *Agrobacterium*-mediated transformation of the embryogenic calli is now performing in Biotechnology Division to get the mutant lines.

A total of 61 lines were selected as blast resistance with different agronomic characteristics. Seeds of these lines are now multiplying in T. Aman 2021 season and the MLT will be conducted at four blast hot spots of Bangladesh in Boro 2021-22. Subsequently, artificial screening using differential blast isolates will be done at the laboratory of Plant Pathology Division under controlled conditions. To know the genetic mechanism of blast and gall midge resistance of BRRI dhan33, a programme was undertaken on blast and gall midge resistant gene estimation using differential system and QTL analysis using segregating population (BC1F2 family lines). A total of 625 markers were surveyed for polymorphism studies between BRRI dhan33 and US2 and 184 markers showed polymorphic. The phenotyping against blast disease has completed. A QTL mapping approach were conducted to identify

the tungro resistance QTL in Kumragoir. Five significant ($p < 0.05$; 0.01) QTLs that is *qRTVR3.1, qRTVR4.2, qRTVR9.3, qRTVR10.4* and *qRTVR11.5*, were found in chromosomes 3, 4, 9, 10 and 11, respectively. Out of these four major QTLs (*qRTVR3.1, qRTVR4.2, qRTVR10.4* and *qRTVR11.5)* explained 12.2, 10.8, 12.2 and 10.8 % phenotypic variations and one minor QTL *qRTVR9.3* explained 3.8% phenotypic variation. Moreover, markers RM5548, RM6487, RM242, RM5806, RM536 was found linked with the QTL *qRTVR3.1, qRTVR4.2, qRTVR9.3, qRTVR10.4* and *qRTVR11.5*, respectively. These linked markers could be used in marker assisted selection for the development of tungro resistant variety. To develop tungro resistance pre-breeding materials, hybridization was done to produce advanced generation between tungro resistant (IR69705-1-1-1-3-2, IR71605-2-1-5-3-4, IR71605-3-1-1-2-6, TW-16, Kumragoir and Sonahidmota) and tungro susceptible variety (BRRI dhan48, BRRI dhan71 and BRRI dhan87). Advanced population of the respective crosses were developed by marker assisted selection and rapid generation advance method. Besides, for the validation of identified tungro resistant QTL in landrace Kumragoir, BC_2F_4 and BC_2F_5 population were developed in Aman,2020 and Boro,2020-21, respectively. A total 96 INGER materials were tested against rice blast disease and out of them 12 entries such as SVIN682, SVIN683, SVIN684, SVIN690, SVIN271, SVIN272, SVIN509, SVIN332, SVIN446, SVIN352, SVIN457 and SVIN458 showed resistance. Screening of BRRI T. Aman varieties and Patnai germplasm against blast disease resulted 13 resistant varieties/lines need to be tested further. BR16 and BR33 identified repeatedly as blast resistant. A total of 100 germplasm was screened against bakanae disease and out of them five were found resistant. A total of 5,190 advanced breeding lines were screened against bacterial blight (BB) and 2,138 materials were found as resistant. These materials will be screened again for confirmation. In Boro 2020-21, among 135 genotypes ten advanced breeding lines are found as resistant materials and 17 as moderately resistant against bacterial blight disease. Diversity of upland rice varieties were assessed and 86 alleles were detected by the 28 polymorphic SSR markers. The number of alleles per locus varied from 2 to 5, with a mean of 3.07 alleles per locus. The polymorphic information content (PIC) value for each marker was used to assess the polymorphic level. The mean PIC value of the SSR markers was 0.46 with a range of 0.74-0.08. The germplasms were classified based on the polymorphism data into nine cluster groups, cluster I- cluster IX. Most of the germplasm from Philippines, Malaysia, Bangladesh and India are under the same cluster respectively. To implement GWAS we need phenotypic data as well as the genotypic data of the genotypes under study. Phenotypic data was obtained through field experiment. Genotypic data have downloaded the "404k CoreSNP Dataset" for each of the 12 different chromosomes of rice from the data repository of 3K Rice Genome Project and OryzaSNP Project, hosted by IRRI.

About 80 bacteria were determined from soil collected from west byde, BRRI. Among them two bacteria have shown strong antagonistic activity against *R. solani.* The lowest bakanae disease and the highest yield were found in tricho-compost treated plot and the highest disease and lowest yield was found from untreated disease control plot. Four types of nano particles (silver, copper oxide, zinc oxide and silica) were green synthesized using different plant extracts to control rice diseases. Besides this, silver (Ag NP), zinc oxide (ZnO NP) and copper oxide (CuO NP) nano-particles (NPs) were prepared synthesized following microwave assisted starch stabilization technique where D-glucose was used as reducing agent and boric acid for creating congenial environment. Antipathogenic activities of these particles are going on. Seven fungicides (mostly Tricyclazole group fungicide) controlled more than 80% of blast disease. These chemicals were evaluated consecutively two years at BRRI HQ, Gazipur. Among 19, six fungicides such as Mukti 32.5 SC (Azoxystrobin 20% + Difeconazole 12.5%), Newtec 300 SC (Hexaconazole + Tricyclazol), Opec 32.5 SC (Azoxystrobin 20%+ Difeconazole 12.5%), Clean 75W (Tebuconazole 50%+ Trifloxystrobin 25% WDG) and Famous 60WG (Pyraclostrobin 5%+ Metiram) and Farmbin 32.5EC (Azoxystrobin

20%+ Difeconazole 12.5%) controlled sheath blight disease successfully (equal or above 80%) in both BRRI HQ, Gazipur and BRRS RS, Cumilla Farm.

TRANSFERABLE TECHNOLOGY

Management of Sheath blight disease utilizing *Trichoderma harzianum*

Compost was prepared in the net house of Plant Pathology Division, BRRI, Gazipur. After preparing compost, it was applied in T. Aus 2020 field of Irrigation and Water Management Division, BRRI. As that variety BRRI dhan48 was used variety to find out the efficacy of this compost in reducing sheath blight disease. A total of seven treatments including control were applied with replications in RCB design. Data were collected on **r**elative lesion height (RLH%) and yield (t/ha) in treated plots versus in farmers practice plots. Tricho-compost application T1 (2 t/ha) and Trichoderma formulation T2 (1000L/ha) reduced %RLH and increase increase increased yield compare compare compared to chemical treatment T5 (Nativo 2 spray) and healthy control (T7). Yield was increased and % RLH was reduced when Tricho-compost and Trichoderma formulation were applied compared to diseased control (Table 1). Among the treatments, T3 (Compost + Nativo -1 spray) reduced the disease severity and resulted in yield increasing.

Q S A Zahan and M A Latif

Table 1. Effect of Tricho-compost on sheath blight disease minimization and yield of BRRI dhan48 during T. Aus 2020.

Treatment	RLH (%)	Flag Leaf Leng(cm)	Flag Leaf Wid (cm)	Yield (t/ha)
T1 Compost (2t/h)	36.3	35.4	1.31	5.96
T2 (*Trichoderma* formulation 1000L/ha)	17.0	35.0	1.21	5.21
T3 (Compost + Nativo -1 spray)	17.4	36.4	1.38	6.04
T4 (Formulation + Nativo -1 spray)	40.8	32.5	1.31	5.72
T5(Nativo -2 spray)	31.6	35.5	1.26	5.83
T6 (Diseased control)	58.3	32.7	1.21	4.16
T7 (Healthy control)	8.8	34.6	1.16	5.89

EPIDEMIOLOGY OF RICE DISEASE

Survey and monitoring of rice diseases

Disease survey was conducted in different rice ecosystems during T. Aman and Boro 2020-21. Incidence pattern and severity of rice diseases over the locations and varieties were assessed. Bacterial blight (BB), sheath blight (ShB) and brown spot were observed predominant irrespective of season. Severe tungro incidence was found in high disease prone region, Cumilla only during T. Aman. False smut incidence was less in Cumilla and to some extent more in Shirajganj district (Char land ecosystem). Sheath rot (ShR) incidence was recorded the highest in surveyed upazilas in Barishal during T. Aman. A considerable percentage of sheath blight incidence was recorded in Boro season which indicates the threat for rice production in this season. Blast disease incidence was recorded in scented rice during T. Aman while this disease was observed less in Boro season over the locations except for BRRI dhan29 in Gazipur and Habiganj regions (Haor ecosystem). Blast was recorded in all the upazilas in Dinajpur.

TH Ansari, Q S A Jahan, M Hossain, S Mia, M A I Khan, S Akter, M M Rashid, A Ara, M Ahmed, S A I Nihad, R Akter, H A Dilzahan, H R Hira and M A Latif

Development of early warning system of rice blast disease

Blast is the most important disease of concern for rice production in Bangladesh. The incidence and severity of the disease is largely characterized by its unpredictable regional and seasonal variability, which makes it difficult for effective management of the disease in space and time. This is because the epidemiology of rice blast is driven by weather in the background of the pathogen density and varietal tolerance. Development of an effective weather-based early warning system (EWS) will be a smart avenue to deal with the disease. To develop such an EWS, BRRI Plant Pathology Division, together with scientists from Agricultural Statistics, Entomology and Irrigation and Water Management Divisions, is collaborating with CIMMYT-Bangladesh and Embrapa-Brazil. The Rice Blast

EWS is being developed based on the already developed Wheat Blast EWS. The BRRI team, in the last year, has been providing an enormous amount of data to the CIMMYT team towards the EWS development and validation.

M A I Khan, M S student, B Nessa, M R Bhuiwan, M M Rashid, S A I Nihad, Bellal Hossain, Moin-US-Salam and M A Latif

Studies on host ranges of the blast pathogen

An experiment was conducted to investigate the host specificity among the rice, foxtail millet (*Setaria italic*) and wheat under control condition following completely randomized block design. Three samples of torpedo grass weed (*Panicum repens*) infected with blast fungi were collected from Wheat Research Centre, Dinajpur and infected rice plants were also collected from BRRI farm, Gazipur. Three blast isolates from grass weed and one from rice (single conidia) were used in the experiment. Rice (BRRI dhan28), foxtail millet (Local variety) and wheat (Pradip) were used in this study. Germinated seeds of three different test entries were sown in separate four plastic trays containing sandy loam soil. Each plastic tray contains seedlings of three test entries and three lines of each entry. Spores of each fungus were harvested from 14- day– old colonies growing on oatmeal agar petri plates by gentle rubbing with a paintbrush after flooding with sterilized water. The conidial suspension was adjusted to a concentration of 1 X 10^5 spores per ml. The spore suspension of each isolate was sprayed by hand sprayer on 20-day-old seedling of each test entry in a plastic tray. After inoculation, plants were incubated in a humid chamber at 25°C. Plants were examined for symptoms seven days after inoculation. Three blast isolates from grass weed inoculated in three trays and did not show any symptom on leaves of rice, foxtail millet and wheat. But rice blast isolate developed symptoms of blast disease on leaves of BRRI dhan28 excluding foxtail millet and wheat leaves. More isolates from torpedo grass and foxtail millet need to test further for confirmation.

M S Mian, M Ahmed, T H Ansari, M A Latif

Identification of the source of infection of major rice diseases

To find out the source of infection of major rice diseases, four rice varieties (BR11, BRRI dhan34, BRRI dhan49 and BRRI dhan51) were transplanted on three times of transplanting (25 July, 9 August and 24 August) using two seed sources (healthy and disease infected). Data on total tiller (TT), disease incidence on blast and false smut disease were recorded. For both disease (blast and false smut) the disease incidence tended to reduce on plants generated from healthy seeds compared to those generated from diseased seeds (Fig. 1). This was particularly evident in false smut disease, which indicates infected seed might be a source of infection for the disease.

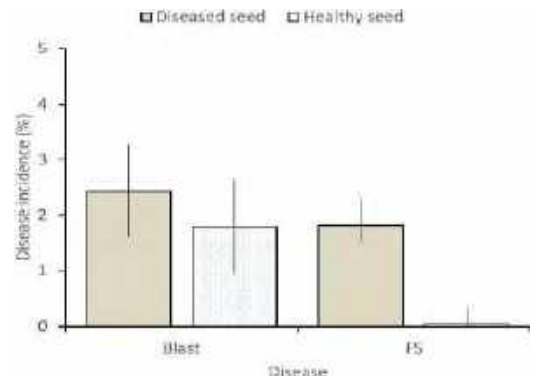

Fig. 1. Status of blast and false smut disease on two seed sources

B Nessa

PATHOGEN POPULATION STRUCTURES AND BIOLOGY

Improvement of differential system for rice blast disease in Bangladesh

To improve the existing differential system for rice blast disease resistance, a total of 102 blast infected samples were collected from different rice growing regions of Bangladesh during Boro season 2019-20 and 2020-21. The isolates were collected from the severely blast infected plots of BRRI dhan28, BRRI dhan29, BRRI dhan63, BRRI dhan64 and BRRI dhan81. Among them 80 isolates were purified as single spore isolation those used for pathogenicity tests. The reaction pattern of single spore isolates to

25 differential varieties harboring 23 blast resistance genes showed the distinct variation of reaction type over the region (Fig. 2), although in our previous study we did not find significant variation of cluster group of reaction pattern over the region. It indicates that there was a possibility of the changing of reaction type over the region in Bangladesh. Five isolates were selected for the details study (pathogenicity and molecular) in laboratory.

M A I Khan, M R Bhuiyan, S A I Nihad, M M Rashid, M A Latif and Y. Fukuta

Identification and validation of physiological races of bacterial blight and its distribution patterns in Bangladesh (NATP-2)

A total of 900 bacterial blight infected samples were collected from the 40 different districts of Bangladesh. From the collected samples 300 bacterial blight isolates were isolated, purified and preserved. During T. Aman 2020, to identify the physiological races, pathogenicity tests of 300 BB isolates were done on NILs and Pyramid lines of bacterial blight resistance. In total, 13 races were identified according to the reaction pattern of the BB isolates against BB resistant NILs. Again in Boro 2020-21, pathogenicity tests of 52 representative BB isolates from 13 races were done on NILs and Pyramid lines for validation. From this study *Xa27*, *Xa21*, *xa13* and *xa5* were identified as effective gene for the development of bacterial blight resistance in Bangladesh.

M A Latif, M A I Hasan, S Das, M M Rashid and M A I Khan

Etiology, epidemiology and management of bacterial panicle blight (BPB). An emerging and climate sensitive rice disease in Bangladesh

Identification of causal organism and details studies on bacterial panicle blight (BPB), an emerging and climate sensitive rice disease in Bangladesh, was started at Plant Pathology Division, BRRI. A total of 25 infected panicles were collected from different regions of Bangladesh by DAE and BRRI regional stations. From these samples, 14 isolates were isolated as single colony culture. Physical properties of these pure cultures were evaluated using selective media of King‟s B and CCNT. Among these isolates, only three were found as *Burkholderia glumae* causal organism of BPB. These isolates are further evaluating molecularly using 16-29S rRNA for translating ITS region. A perspective survey was conducted in T. Aman 2020 season with the help of DAE and BRRI regional station and found that mostly BRRI dhan52 and BRRI dhan87 were comparatively more vulnerable to this disease. The infected seeds of these varieties were cultivated at T. Aus 2021 and found the same symptoms on the panicle. Moreover, the isolated pathogen showed the same characteristics of *B. glumae* on selective media. The experiment will be repeated in next year for the confirmation.

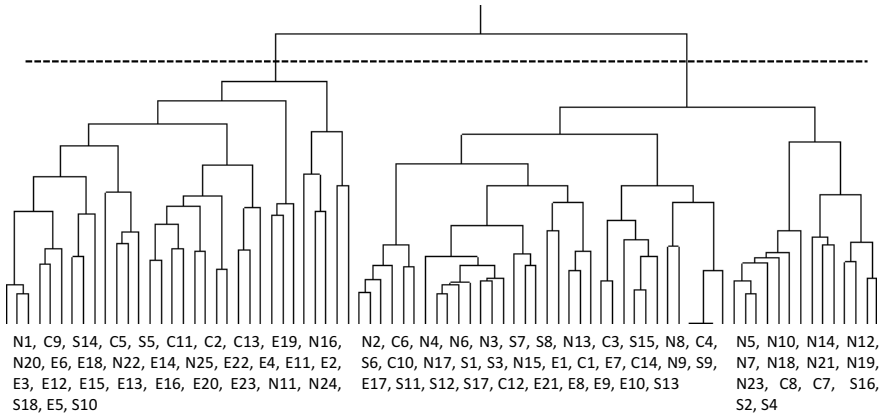

Fig. 2. Virulence frequencies of blast isolates from each cluster group on differential varieties (DVs). Cluster analysis using Ward‟s hierarchical clustering method was used to classify 80 blast isolates on the basis of the reaction pattern of 25 DVs and susceptible check LTH.

M A I Khan, M S Student, R Akhter, M M Rashid, M R Bhuiyan, S Das and M A Latif

Crop Loss Assessment of rice due to major diseases in Bangladesh

To determine the actual crop loss due to diseases, a study was undertaken during Boro 2020-21 season with the help of BRRI Regional Station at Cumilla, Satkhira and Rajshahi. Three villages namely Jorpukuria, Debnagar and Kukhondi, respectively were selected as study area (Figs. 3, 4 and 5). Fifty plots were selected randomly across the village and two crop-cut from each plot done during data collection. Details cultivation information and disease data of incidence and severity were collected. In addition, yield and yield contributing characters were also collected from the plot. Data were collected digitally using open data kit (ODK). On average, frequencies of neck blast disease found highest followed by bacterial leaf blight, sheath blight and so on.

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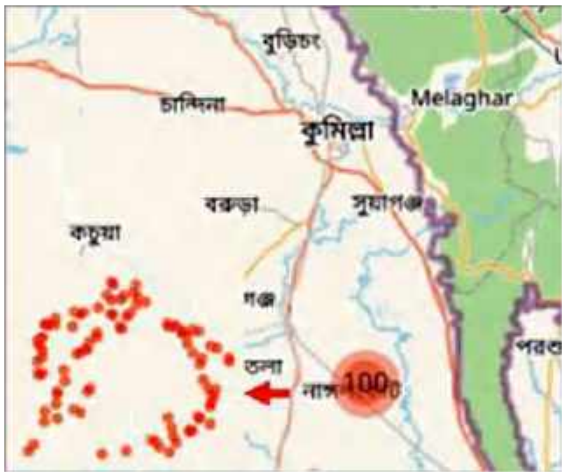

Fig. 3. ODK survey and crop loss data area map in Jorpukuria village, Nangalkot, Cumilla during Boro 2020-21.

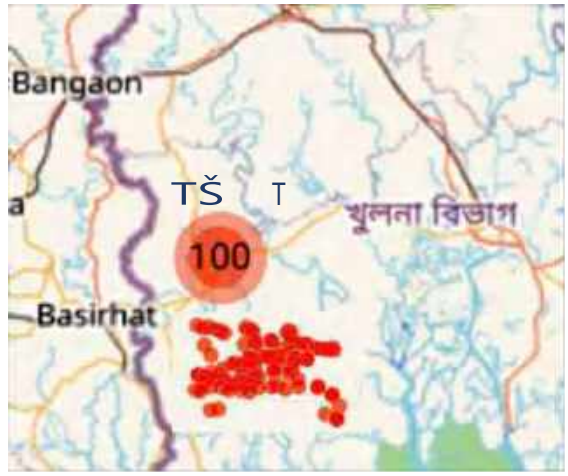

Fig. 4. ODK survey and crop loss data area map in Debnagar village, Satkhira sadar, Satkhira during Boro 2020-21.

Fig. 5. ODK survey and crop loss data area map in Kukhondi village, Paba, Rajshahi during Boro 2020-21.

DISEASE RESISTANCE AND MARKER ASSISTED SELECTION STUDIES

Development of blast and bacterial blight resistant variety

Multilocation trials of four advanced lines having blast (*Pi9, Pb1*) and bacterial blight (*Xa4, Xa21*) resistant genes were evaluated in different locations over the country. Average yield of the geneotypes were ranged from 6.1-6.7 t/ha with 141-144 days (Table 2, Table3). The yields were comparable to the susceptible check variety BRRI dhan28 (5.7 t/ha, 145 d). Among the tested genotypes BR

(Path)13784-BC3-63-6-4-HR6 produced the highest average yield (6.7 t/ha) with yield range 5.2-8.5 t/ha over the locations. The lowest yield at Gazipur and Rajshahi was due to high temperature and extremely hot weather during flowering. All the lines showed resistant over the locations when BRRI dhan28 was affected 6.7%-85% (Table 4). The highest infection was recorded in Rangpur (85%) followed by Gazipur (75%) and Dinajpur (53.3%) in BRRI dhan28. No or very low BB incidence was recorded.

Table 2. Yield of BB and blast resistant advanced lines at different locations in Boro 2020-21.

Genotype	Cumilla	Gazipur[1]	Habigonj	Kustia	Mymensingh	Rajshahi[1]	Rangpur	Satkhira	Barishal	Dinajpur	Average
	Yield (t/ha)										
BR (Path)13784-BC_3-5-3-8-HR4	5.48	4.94	6.93	6.65	6.66	5.24	6.68	6.15	ND	ND	6.1
BR (Path)13784-BC_3-61-1-6-HR3	6.06	5.09	6.32	6.82	7.15	5.69	7.90	5.77	6.27	7.46	6.5
BR (Path)13784-BC_3-62-3-5-HR2	6.10	5.67	6.07	7.50	6.59	5.42	8.10	6.16	6.40	8.53	6.7
BR (Path)13784-BC_3-63-6-4-HR6	6.66	5.19	7.03	7.61	7.25	5.52	8.49	6.24	ND	ND	6.7
BRRI dhan28 (S. Check)	4.48	4.6	6.74	6.53	7.35	5.50	3.43	6.18	5.78	6.06	5.7
CV(%)	8.07								4.49		
LSD	0.82								0.57		

[1]Genotypes were affected due to high temperature and extremely hot weather during flowering.

Table 3. Growth duration of BB and blast resistant lines at different locations in Boro 2020-21.

Genotype	Rangpur	Dinajpur	Satkhira	Cumilla	Gazipur	Mymensingh	Kushtia	Rajshahi	Habiganj	Barishal	Average
	Growth duration (days)										
BR (Path)13784-BC_3-5-3-8-HR4	146.0	ND	133.7	142.7	140.8	143.0	140.8	140.0	141.0	ND	141.0
BR (Path)13784-BC_3-61-1-6-HR3	146.0	152.0	136.0	145.0	142.3	145.7	142.3	142.0	144.0	140.0	143.7
BR (Path)13784-BC_3-62-3-5-HR2	146.0	155.0	135.0	144.7	144.4	145.7	144.4	141.0	141.3	140.0	143.9
BR (Path)13784-BC_3-63-6-4-HR6	146.0	ND	135.3	145.3	145.4	146.3	145.4	143.0	141.7	ND	143.2
BRRI dhan28 (S. Check)	146.0	153.0	135.7	144.0	144.7	146.7	144.7	145.0	145.3	139.0	145.0

Table 4. Neck blast incidence in the genotypes at different locations during Boro 2020-21.

Genotype	Rangpur	Dinajpur	Satkhira	Cumilla	Gazipur	Mymensingh	Kushtia	Rajshahi	Habiganj	Barishal
	[a]Neck/panicle blast infection (%)									
BR (Path)13784-BC_3-5-3-8-HR4	0.0	ND	10.7	1.0	0.0	0.0	0.0	0.0	0.0	ND
BR (Path)13784-BC_3-61-1-6-HR3	2.3	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BR (Path)13784-BC_3-62-3-5-HR2	1.7	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BR (Path)13784-BC_3-63-6-4-HR6	2.0	ND	3.3	0.0	0.0	0.0	0.0	0.0	0.0	ND
BRRI dhan28 (S. Check)	85.0	53.3	6.7	18.3	75.0	0.0	0.0	0.0	0.0	0.0

[a]Per cent panicle infection based on SES, IRRI 2014 as resistant ≠10% neck/panicle infection.

Development of multiple disease resistant (blast and bacteria blight) rice varieties in the background of BRRI dhan29 using gene pyramiding approach

Seven advanced lines having blast (*Pi9* and *Pb1*) and BB (*Xa21*) resistant fixed lines along with two checks (BRRI dhan29 and BRRI dhan58) were evaluated during the Boro 2020-21 season. Thirty-five days old seedlings were transplanted following RCB design with three replications with a spacing of 20cm × 20cm during. Single seedling was used for transplanting. Fertilizers @120 (261 kg Urea): 19 (95 kg TSP): 60 (120 kg MP): 20 (111 kg Gypsum): 4 (11 kg $ZnSO_4$) kg/ha NPKSZn were applied to the field. Crop managements practice such as weeding, irrigation etc were done in time. Insects and other pests were controlled properly. Yield and yield attributing characters such as, plant height (cm), number of tiller hill^{-1}, number of effective tiller hill^{-1}, panicle length, yield hector^{-1}, growth duration (days) were documented with three replications (Table 5).

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Development of multiple disease resistant (blast and bacteria blight) rice varieties in the background of BRRI dhan58 using gene pyramiding approach

Six advanced lines having blast (*Pb1*) and BB (*Xa21*) resistant genes along with two checks (BRRI dhan28 and BRRI dhan58) were evaluated during the Boro 2020-21 season. Thirty-five-day old seedlings were transplanted following RCB design with three replications with a spacing of 20cm × 20cm during. Single seedling was used for transplanting. Fertilizers @120 (261 kg Urea): 19 (95 kg TSP): 60 (120 kg MP): 20 (111 kg Gypsum): 4 (11 kg $ZnSO_4$) kg/ha NPKSZn were applied to the field. Crop managements such as weeding, irrigation etc were done in time. Insects and other pests were controlled properly. Yield and yield attributing characters such as, plant height (cm), number of tiller hill^{-1}, number of effective tiller hill^{-1}, panicle length, yield hector^{-1}, growth duration was documented with three replications (Table 6). Genotypes from BR(Path)13801-BC_3-58-4 had lowest plant height (101 cm) while genotypes from BR(Path)13800-BC_3-118-37 had height plant height (110 cm). Number of tiller hill^{-1} ranged from 15 to 18 while number of effective tiller hill^{-1} ranged from 13 to 16. Panicle length ranged from 21.1 cm to 23.7 cm. The highest yield ha^{-1} (7.756 ton) was recorded from the genotypes BR (Path)13801-BC_3-45-1 while lowest (7.351 ton) was recorded for BRRI dhan28. On the other hand, growth duration ranged from 137 to 160 days.

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Table 5. Yield and yield attributing characters of blast and BB resistant advance lines.

Line	PtH (cm)	NTH	NETH	PL (cm)	YH (ton)	GD (day)	Disease score	
							Blast	BB
BR(Path)13800-BC_3-109-181	106	17	15	20.1	8.856	148	1	1
BR(Path)13800-BC_3-118-37	102	20	15	23.4	8.206	157	0	0
BR(Path)13800-BC_3-124-133	102	17	17	23.2	8.678	150	1	1
BR(Path)13800-BC_3-126-166	101	16	15	24.4	8.896	160	1	0
BR(Path)13800-BC_3-134-96	109	17	16	21.5	8.927	150	0	1
BR(Path)13800-BC_3-237-266	110	16	15	21.6	8.654	149	1	1
BR(Path)13800-BC_3-125-143	103	18	16	22.4	8.986	160	0	0
BRRI dhan29 (check)	109	14	12	20.5	8.747	160	5	5
BRRI dhan58 (check)	110	14	13	21.5	7.151	152	5	7

PtH- plant height; NTH- number of tiller hill^{-1}; NETH^{-1}- number of effective tiller hill^{-1}; PL- panicle length; YH-yield hactor^{-1}; GD-growth duration

Table 6. Yield and yield attributing characters of blast and BB resistant advance lines

Line name	PtH (cm)	NTH	NETH	PL (cm)	YH (ton)	GD (day)	Disease score	
							Blast	BB
BR (Path)13801-BC_3-45-1	104	17	14	21.1	7.756	155	0	0
BR (Path)13801-BC_3-45-2	105	18	14	22.4	7.406	151	1	1
BR (Path)13801-BC_3-58-3	102	18	16	23.7	7.578	152	1	1
BR (Path)13801-BC_3-58-4	101	15	15	23.4	7.396	159	1	0
BR (Path)13801-BC_3-58-5	105	16	16	22.5	7.427	153	0	1
BR (Path)13800-BC_3-118-37	110	16	15	22.4	7.654	148	1	1
BRRI dhan58 (check)	109	15	13	21.5	7.747	155	5	5
BRRI dhan28 (check)	108	15	14	22.5	7.351	145	5	7

PtH- plant height; NTH- number of tiller hill^{-1}; NETH^{-1}- number of effective tiller hill^{-1}; PL- panicle length; YH-yield ha^{-1}; GD-growth duration

Development of multiple disease resistant (blast and bacteria blight) short duration rice varieties for T. Aman

Fourteen BB and blast resistant fixed lines along with a check BRRI dhan28 were evaluated during the T. Aman 2020 season. Twenty-two day old seedlings were transplanted following RCB design with three replications with a spacing of 25cm × 15cm during. Single seedling was used for transplanting. Fertilizers @120 (261 kg Urea): 19 (95 kg TSP): 60 (120 kg MP): 20 (111 kg Gypsum): 4 (11 kg $ZnSO_4$) kg/ha NPKSZn were applied to the field. Crop managements such as weeding, irrigation etc. were done in time. Insects and other pests were controlled properly. Yield and yield attributing characters such as, plant height (cm), number of tiller hill^{-1}, number of effective tiller hill^{-1}, panicle length, yield ha^{-1}(ton), growth duration (days) were documented with three replications (Table 7). Genotypes BR (Path)13784-BC_3-6-8-9-HR_{16} had lowest plant height (106 cm) while check variety BRRI dhan28 had height plant height (128 cm). Number of tiller hill^{-1} ranged from 11 to 19 while number of effective tiller hill^{-1} ranged from 10 to 15. Panicle length ranged from 18 cm to 25 cm. The highest yield ha^{-1} (6.615 ton) was recorded from the genotype BR (Path)13784-BC_3-63-6-4-HR_6 while the lowest (3.a390 ton) was recorded for BR (Path)13784-BC_3-4-8-9-HR_8. On the other hand, growth duration ranged from 101 days to 96 days.

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Table 7. Yield and yield attributing characters of BB and blast resistant advance lines.

Line	PtH (cm)	NTH	NETH	PL (cm)	YH (ton)	GD (day)	Disease score	
							Blast	BB
BR (Path)13784-BC_3-5-3-8-HR_4	111	15	13	25	5.277	96	0	1
BR (Path)13784-BC_3-61-1-6-HR_3	108	12	11	22	5.810	96	0	1
BR (Path)13784-BC_3-62-3-5-HR_2	109	13	11	22	6.610	96	0	1
BR (Path)13784-BC_3-63-6-4-HR_6	110	15	14	25	6.615	95	0	0
BR (Path)13784-BC_3-1-5-10-HR_7	108	14	13	22	4.100	103	0	0
BR (Path)13784-BC_3-4-8-9-HR_8	107	15	13	25	3.390	98	0	1
BR (Path)13784-BC_3-34-9-10-HR_9	106	13	12	22	5.390	96	0	1
BR (Path)13784-BC_3-240-6-9-HR_{10}	114	19	15	25	4.120	98	0	0
BR (Path)13784-BC_3-1(1)-6-8-HR_{12}	109	13	12	23	3.800	102	0	1
BR (Path)13784-BC_3-340-5-10-HR_1	110	11	10	23	4.380	97	0	0
BR (Path)13784-BC_3-3-8-7-HR_{13}	112	12	11	23	4.580	96	0	1
BR (Path)13784-BC_3-5-3-4-HR_{15}	111	15	11	23	5.990	97	0	0
BR (Path)13784-BC_3-6-8-9-HR_{16}	106	12	11	23	5.980	105	0	1
BR (Path)PR-5-3-HP5	109	13	12	22	3.903	104	0	0
BRRI dhan28 (check)	98	13	11	18	5.250	110	0	5

PtH- plant height; NTH- number of tiller hill^{-1}; NETH^{-1}- number of effective tiller hill^{-1}; PL- panicle length; YH-yield hactor^{-1}; GD-growth duration

Improvement of BRRI dhan28, BRRI dhan29 and BRRI dhan58 for resistance to blast and bacterial blight diseases using marker assisted backcross breeding

To introgress bacterial blight (BB) and blast resistant genes in high yielding variety; parent materials were grown during T. Aman 2020 and Boro 2020-21. Four sets of parents were grown with seven days interval for the synchronization of flowering among the parents. Seeding was started from 17 July 2020 in Aman season and for Boro season it was started from 17 December, 2020. In Aman‟20 and Boro 20-21, selfing were done to obtain seeds from advanced generation of BB and blast resistant advance lines (Tables 8 and 9). Heterozygosity of the populations was confirmed through respective molecular marker.

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Gene pyramiding of blast and bacterial blight resistance genes into the genetic background of BRRI dhan49, BRRI dhan63 and BRRI dhan81 (NATP-2)

To introgress blast and bacterial blight (BB) resistant genes in high yielding variety, parent materials were grown during T. Aman 2019 and Boro 2019-20. Four set of parents with were grown seven days interval for the synchronization of flowering among the parents. Seeding was started from 16 July 2020 in Aman season and for Boro season it was started from 21st December, 2020. In Aman20 and Boro20-21, selfing was done to obtain seeds from advanced generations (Tables 10 and 11). Heterozygosity of the populations was confirmed through respective molecular marker. After confirmation, crossing was advanced to make next generation.

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Table 8. List of backcrosses and number of seeds for respective cross, T. Aman 2020.

Generation	Cross	No. of seeds
BC_3F_2	BRRI dhan28*IRBB58/ BRRI dhan28**Pi9* (US)	55
BC_3F_2	BRRI dhan28*IRBB60	69
BC_2F_2	BRRI dhan28**Pb1*/BRRI dhan28**Pi9*(IR64)//BRRI dhan28*IRBB58	35
BC_4F_2	BRRI dhan28*ST3/ BRRI dhan28**Pi9* (IR64)	75
BC_3F_3	BRRI dhan29*IRBB58	65
BC_3F_3	BRRI dhan29*Pi9 (IR64)	60
BC_3F_3	[BRRI dhan29*Pi9 (US)* Pb1 (US2)]	52
BC_3F_3	[BRRI dhan29*IRBB58*{BRRI dhan29*Pi9(US)*Pb1 (US2)}]	50
BC_4F_2	BRRI dhan58**Pb1*/ BRRI dhan58**Pi9*(IR64)// BRRI dhan58	120
BC_4F_2	BRRI dhan58**Pi9*(IR64)	100
BC_4F_2	BRRI dhan58**Pb1*	90
BC_2F_2	BRRI dhan58**Pb1*/BRRI dhan58**Pi9*(IR64)// BRRI dhan58*ST3	120

Table 9. List of backcrosses and number of seeds for respective cross, Boro 2020-21.

Generation	Cross	No. of seeds
BC_3F_3	BRRI dhan28*IRBB58/ BRRI dhan28**Pi9* (US)	50
BC_3F_3	BRRI dhan28*IRBB60	75
BC_2F_3	BRRI dhan28**Pb1*/BRRI dhan28**Pi9*(IR64)//BRRI dhan28*IRBB58	55
BC_4F_3	BRRI dhan28*ST3/ BRRI dhan28**Pi9* (IR64)	65
BC_3F_4	BRRI dhan29*IRBB58	70
BC_3F_4	BRRI dhan29*Pi9 (IR64)	80
BC_3F_4	[BRRI dhan29*Pi9 (US)* Pb1 (US2)]	59
BC_3F_4	[BRRI dhan29*IRBB58*{BRRI dhan29*Pi9(US)*Pb1 (US2)}]	60
BC_4F_3	BRRI dhan58**Pb1*/ BRRI dhan58**Pi9*(IR64)// BRRI dhan58	90
BC_4F_3	BRRI dhan58**Pi9*(IR64)	80
BC_4F_3	BRRI dhan58**Pb1*	70
BC_2F_3	BRRI dhan58**Pb1*/BRRI dhan58**Pi9*(IR64)// BRRI dhan58*ST3	80

Table 10. List of crosses and number of seeds for respective cross combinations. (T. Aman, 2020).

Generation	Cross combination	No. of seeds
BC_3F_2	BRRI dhan49*IRBB60	50
BC_3F_2	BRRI dhan63-*Pb1**IRBB58	35
BC_2F_2	BRRI dhan81*IRBB60/ BRRI dhan81-*Pb1*	40
BC_2F_2	BRRI dhan81*IRBB58/ BRRI dhan81-*Pi9*	65
BC_2F_2	BRRI dhan63-*Pb1**IRBB60/ BRRI dhan63-*Pi9*	40
BC_2F_2	BRRI dhan49*IRBB58	30

Table 11. List of backcrosses and number of seeds for respective cross. (Boro 2020-21).

Generation	Cross combination	No. of seeds
BC_3F_3	BRRI dhan49*IRBB60	30
BC_3F_3	BRRI dhan63-*Pb1**IRBB58	20
BC_2F_3	BRRI dhan81*IRBB60/ BRRI dhan81-*Pb1*	25
BC_2F_3	BRRI dhan81*IRBB58/ BRRI dhan81-*Pi9*	50
BC_2F_3	BRRI dhan63-*Pb1**IRBB60/ BRRI dhan63-*Pi9*	60
BC_2F_3	BRRI dhan49*IRBB58	40

Gene pyramiding for bacterial blight (BB) resistance

In this study, BRRI dhan28, BRRI dhan29, CN6 and BRRI dhan58 were used as recipient parents. IRBB57, IRBB58, IRBB60, IR64 (*Pi9*), US2 (*Pb1*), STRASA3 and STRASA 4 were used as donor parents. Phenotyping and genotyping were applied for suitable plant selection. The results Tables 12 and 13 present. Pathogenicity results showed that a good number of progenies of BC_4F_2, BC_3F_2 and BC_3F_4 developed from the crosses were resistant to the most virulent BB isolate *BXo93*.

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Table 12. Development of BB resistant materials from the crosses of BRRI varieties and bacterial blight resistant pyramid lines of IR24 (T. Aman 2020).

Recipient/Recurrent	Donor		Present status
	Designation	Target *R* gene	
BRRI dhan29	IRBB58	*Xa4, xa13, Xa21*	40 seeds of BC_4F_2
CN6	IRBB60	*Xa4, xa5, xa13, Xa21*	60 seeds of BC_3F_4
BRRI dhan28	IRBB57	*Xa4, xa5, Xa21*	90 seeds of BC_3F_2
BRRI dhan28	IRBB60	*Xa4, xa5, xa13, Xa21*	60 seeds of BC_4F_2
BRRI dhan28	IRBB58	*Xa4, xa13, Xa21*	30 seeds of BC_3F_2
BRRI dhan28	ST3	*xa13, Xa2, Xa23*	60 seeds of BC_3F_2
BRRI dhan29	ST4	*xa13, Xa2, Xa23*	90 seeds of BC_3F_2
BRRI dhan58	ST3	*xa13, Xa2, Xa23*	80 seeds of BC_3F_2

Table 13. Development of BB resistant materials from the crosses of BRRI varieties and bacterial blight resistant pyramid lines of IR24 (Boro 2020-21).

Recipient/Recurrent	Donor		Present status
	Designation	Target *R* gene	
BRRI dhan29	IRBB58	*Xa4, xa13, Xa21*	50 seeds of BC_4F_3
CN6	IRBB60	*Xa4, xa5, xa13, Xa21*	450 seeds of BC_3F_5
BRRI dhan28	IRBB57	*Xa4, xa5, Xa21*	80 seeds of BC_3F_3
BRRI dhan28	IRBB60	*Xa4, xa5, xa13, Xa21*	50 seeds of BC_4F_3
BRRI dhan28	IRBB58	*Xa4, xa13, Xa21*	39 seeds of BC_3F_3
BRRI dhan28	ST3	*xa13, Xa2, Xa23*	55 seeds of BC_3F_3
BRRI dhan29	ST4	*xa13, Xa2, Xa23*	85 seeds of BC_3F_3
BRRI dhan58	ST3	*xa13, Xa2, Xa23*	65 seeds of BC_3F_3

Phenotyping and genotyping of rice varieties for blast resistance

The experiment was conducted to know the resistance level of BRRI developed T. Aman varieties against blast disease and the blast resistance gene (s) exist in these varieties. T. Aman varieties along with susceptible varieties and four blast resistan monogenic lines (for *Pb1, Pi9, Pi40* and *Pita2*) were evaluated in uniform blast nursery (UBN). Genotyping of those varieties with gene-based markers were conducted. Out of 43 varieties 10 varieties were identified as resistant in uniform blast nursery. BR16, BR33, BRRI dhan62, BRRI dhan70, BRRI dhan71, BRRI dhan75, BRRI dhan78, BRRI dhan80, BRRI dhan82 and BRRI dhan83 were found pathotypic resistant. BR16 and BR33 consistently have shown resistance against blast. Marker assisted surveys have shown the absence of *Pi9* and *Pita2* genes in BR16 (Table 14). While BR21 was identified as pathotypic susceptible variety which also amplified *Pi9* and *Pita2* genes with the gene-based 9-pro and Pita2 marker, respectively. *Pi9* gene has identified in BRRI dhan41, a saline tolerant variety, but it showed pathotypic susceptibility. Therefore, only marker assisted selection/identification even with gene-based markers do not indicates the resistance to blast rather the pathotypic reaction with variable differential isolates.

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Development of blast resistant variety (short duration).

Blast resistant *Pi9* (IRBL-9W) gene was introgressed into BRRI dhan28 and fixed lines were developed (Table 15). Preliminary yield trial (PYT) was conducted in BRRI HQ, Gazipur and these lines were also evaluated at hot spots in 2019-20 (Tables 15 and 16). Considering yield, resistant lines were selected for multi-location trials (Table 16). The experiments were conducted with seven fixed lines (one line selected from Jhum rice) and susceptible BRRI dhan28 at ten different locations in blast disease prone hot spots. Tabls 17, 18 and 19 mention the yield, growth durations and disease incidence (neck blast) respectively. Average yield over the location and variety were found significantly different. BR (Path) 12452-BC6-53-21-11 produced the highest yield. Other advanced lines produced similar yield (average 5.66-6.33 t/ha) with growth duration as like the check variety BRRI dhan28 (average 5.66 t/ha). The lower yield at Gazipur and Rajshahi was due to extremely high temperature and hot weather during flowering. BR (Path)12452-BC3-35-21-8-5 received no disease over the locations while BR (Path) 12452-BC3-42-22-11-4 received 1.3% at Satkhira and BR (Path) 12452-BC4-77-25-11-8-5 received 3-6% infections in two locations (Table 19). BR(Path)12452-BC6-53-21-11 which produced highest yield over the location showed 13.3% infection in Rangpur only. On the other hand, the susceptible check BRRI dhan28 showed 85%, 53.3%, 6.7%, 18.7% and 75% infection respectively at Rangpur, Dinajpur, Satkhira, Cumilla and Gazipur locations. None of the lines including susceptible check produced neck blast infections in any other locations. Bekui-HR(Path)-4-3 (ZM-82), a pure line selected from Jhum rice showed field resistant to blast and yielded average 6.05 t/ha. Therefore, considering neck blast disease incidence and yield performance, the above-mentioned lines could be selected for ALART/PVT.

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Table 14. Distribution of *Pi9* gene in selected BRRI varieties.

Variety	Markers					
	NMSMPi9-1	9 Pro (*Pi9*)	RM 8225	Pb8	Pb14	9 Pro (*Pi2/piz*)
BR3	-	-	-	-	-	-
BR12	-	-	-	-	-	-
BR14	-	-	-	+	-	-
BR16	-	-	-	-	-	-
BR17	-	-	+	-	-	-
BR19	-	+	+	-	-	-
BR21	-	+	+	-	-	-
BR41	-	+	+	+	-	-

Table 15. Preliminary yield trial (PYT) of blast resistant advanced lines (short duration) in Gazipur.

Genotype	T. Aman 2019-20		Boro 2019-20	
	Growth duration (day)	Yield (t/ha)	Growth duration (day)	Yield (t/ha)
BR (Path)12452-BC_3-35-21-8-5	106	3.58 bc	144	5.07 ab
BR (Path)12452-BC_3-42-22-11-4	104	4.46 ab	138	6.00 a
BR (Path)12452-BC3-38-26-2-4	106	3.48 bc	144	4.17 b
BR (Path)12452-BC3-67-35-9-3	105	3.02 c	147	3.94 b
BR (Path)12452-BC3-30-6-5-1	104	3.62 bc	144	4.11 b
BR (Path)12452-BC_4-77-25-11-8-5	-	-	144	5.1 ab
BR (Path)12452-BC_6-36-11-5	-	-	142	4.9 ab
BR (Path)12452-BC_6-53-21-11	-	-	143	5.4 a
BR (Path)12452-BC_6-48-18-7	-	-	142	4.4 b
Shilli-HR(Path)-10-7 (ZM81)	-	-	148	5.44 a
Bekui-HR(Path)-4-3 (ZM-82)	-	-	144	5.62 a
BRRI dhan28 (S. Check)	108	4.94 a	145	5.77 a
CV (%)		8.26		13.02

Means with the same letter are not significantly different at the 5% level of significance.
Boro: DS: 1-Dec-2019, DT: 12-Jan-2020

Table 16. Neck blast (%) incidence in the genotypes in UBN and at different blast hot spots.

Advanced	leaf blast (UBN)		% Panicle infection in blast hotspots, 2020[a]					[1]Resis-tance
	2019	2020	Gazipur	Cumilla	Dumuria	Rangpur	Dinajpur	
BR (Path)12452-BC3-52-17-1-8	0	0	0	10.3	0	5.7	1.7	R
BR (Path)12452-BC3-35-21-8-5	0	0	0	6.7	0	7.7	0.0	R
BR (Path)12452-BC3-42-22-11-4	1	0	0	6.7	0	8.3	0.0	R
BR (Path)12452-BC3-38-26-2-4	3	0	0	8.3	0	4.3	0.0	S
BR (Path)12452-BC3-70-34-2-1*	3	0	0	23.3	0	7.3	1.7	S
BR (Path)12452-BC3-67-35-9-3	1	-	0	8.3	0	3.0	0.7	R
BR (Path)12452-BC3-23-5-3-2	0	0	0	33.3	0	10.7	2.3	S
BR (Path)12452-BC3-30-6-5-1	0	0	0	8.3	0	7.7	0.0	R
BR (Path)12452-BC4-77-25-11-8-5	0	1	0	-	-	-	-	R
BR (Path)12452-BC6-36-11-5	0	0	0	-	-	-	-	R
BR (Path)12452-BC6-53-21-11	1	0	0	-	-	-	-	R
BR (Path)12452-BC6-48-18-7	2	1	1	-	-	-	-	R
Shilli-HR-10-7 (ZM81)	-	0	0	2.7	0	10.0	0.0	R
Bekui-HR(Path)-4-3 (ZM-82)	-	0	0	0.0	0	5.0	0.0	R
BRRI dhan28 (S. ck.)	0	5	2	83.3	0	15.3	4.0	S
BRRI dhan58[a]	-	-	-	48.3	-	-	-	S
BRRI dhan29[a]	-	-	-	85.0	-	-	-	S
IRBL9-W (R. ck.)	1	0	-		0	-	-	R
US2	5	5	-	-	-	-	-	S

*Line without *Pi9* gene. UBN: Uniform blast nursery, UBN-D/S: 22/12/19, [a]D/S: 11/12/19, D/T: 21/1/20,
Leaf blast severity score following 0-5 scale (Hyashi et al 2009). [1]Resistance based on leaf and neck blast,
R- Resistant, S- Susceptible, [a]Per cent panicle infection based on SES, IRRI 2014 as resistant ≠10% neck/panicle infection, -: Not done

Table 17. Yield of blast resistant advanced lines at different locations in Boro 2020-21.

Genotype	Rangpur	Dinajpur	Satkhira	Cumilla	Gazipur[1]	Mymensingh	Kushtia	Rajshahi[1]	Habiganj	Barishal	Average
	Yield (t/ha)										
BR (Path)12452-BC_3-35-21-8-5	6.28	5.60	5.01	5.74	4.10	5.83	5.87	4.00	5.59	5.07	5.31
BR (Path)12452-BC_3-42-22-11-4	7.18	6.85	5.65	5.46	5.31	6.14	7.13	5.29	6.53	5.51	6.11
BR (Path)12452-BC_4-77-25-11-8-5	6.82	7.59	5.97	5.81	5.12	6.86	7.38	4.74	5.93	5.56	6.18
BR (Path)12452-BC_6-36-11-5	5.84	7.42	5.91	6.26	5.56	6.67	7.46	5.53	6.95	5.69	6.33
BR (Path)12452-BC_6-53-21-11	8.40	8.23	5.78	4.86	5.62	7.26	6.84	5.64	6.37	6.41	6.54
BR (Path)12452-BC_6-48-18-7	6.50	6.70	5.48	5.73	2.97	6.27	6.76	4.91	6.93	4.98	5.72
Bekui-HR(Path)-4-3 (ZM-82)	7.75	6.68	4.99	6.33	5.10	6.55	6.33	4.98	6.05	5.71	6.05
BRRI dhan28 (S. Check)	3.43	6.06	6.18	4.48	4.61	7.35	6.53	5.50	6.74	5.78	5.66
CV(%)	7.2										
LSD	0.699										
Heritability (%)	74.0										

[1]Genotypes were affected due to high temperature and extremely hot weather during flowering.

Table 18. Growth duration of blast resistant genotypes at different locations in Boro 2020-21.

Genotype	Rangpur	Dinajpur	Satkhira	Cumilla	Gazipur	Mymensingh	Kushtia	Rajshahi	Habiganj	Barishal	Average
	Growth duration (days)										
BR (Path)12452-BC_3-35-21-8-5	148.7	153.0	133.3	146.3	146.4	145.0	153.0	145.7	146.0	139.0	145.6
BR (Path)12452-BC_3-42-22-11-4	148.0	153.0	134.7	142.0	144.4	145.0	147.3	140.7	143.0	139.0	143.7
BR (Path)12452-BC_4-77-25-11-8-5	148.0	157.0	137.3	146.3	147.2	146.3	147.3	145.7	144.0	143.0	146.2
BR (Path)12452-BC_6-36-11-5	148.0	153.0	135.3	146.0	145.6	144.0	148.3	145.3	144.0	139.0	144.9
BR (Path)12452-BC_6-53-21-11	150.3	153.0	136.3	146.7	146.6	148.0	150.7	145.3	142.3	140.0	145.9
BR (Path)12452-BC_6-48-18-7	147.0	154.0	136.0	144.3	145.3	148.0	148.0	145.3	143.0	141.0	145.2
Bekui-HR(Path)-4-3 (ZM-82)	150.3	156.0	143.3	147.0	151.7	148.0	152.3	146.3	143.0	143.0	148.1
BRRI dhan28 (S. check)	146.0	153.0	135.7	144.0	144.7	146.7	145.7	145.3	145.3	139.0	144.5

Table 19. Neck blast incidence in the genotypes at different blast hot spots in Boro 2020-21.

Genotype	Rangpur	Dinajpur	Satkhira	Cumilla	Gazipur	Mymensingh	Kushtia	Rajshahi	Habiganj	Barishal
	[a]Neck/panicle blast infection (%)									
BR (Path)12452-BC_3-35-21-8-5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BR (Path)12452-BC_3-42-22-11-4	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BR (Path)12452-BC_4-77-25-11-8-5	0.0	0.0	6.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
BR (Path)12452-BC_6-36-11-5	45.0	0.0	9.7	6.3	0.0	0.0	0.0	0.0	0.0	0.0
BR (Path)12452-BC_6-53-21-11	13.3	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BR (Path)12452-BC_6-48-18-7	18.3	15.0	6.0	5.0	70.0	0.0	0.0	0.0	0.0	0.0
Bekui-HR(Path)-4-3 (ZM-82)	6.7	0.0	3.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0
BRRI dhan28 (S. check)	85.0	53.3	6.7	18.3	75.0	0.0	0.0	0.0	0.0	0.0

[a]Per cent panicle infection based on SES, IRRI 2014 as resistant ≠10% neck/panicle infection.

Development of blast resistant variety (long duration).

Blast resistant gene *Pi9* (IRBL-9W) was introgressed into BRRI dhan29 to develop a vertical resistant high yielding variety. Observational trial (280 lines) was conducted in Boro 2019-20 and selected 15 lines (Table 20). Preliminary yield trial (PYT) of these lines was conducted in Boro2020-21. Total 20 mentions growth duration and yield of the tested lines. Three lines produced 9.6-10.1 t/ha yield which was promising in compared with BRRI dhan29. The growth duration of these lines were 3-5 days earlier than BRRI dhan29. Five lines produced similar yield with 3-4 days early as compared to BRRI dhan29. PCR amplifications and gel documentation confirmed the presence of *Pi9* gene in these developed lines with gene/allele-based markers.

T H Ansari, M Ahmed, M S Rahman and M A Rahman

Introgression of *Pita2* gene in BRRI dhan63

This study was conducted to develop blast resistant pre-breeding lines containing *Pita2* gene. Donor Parent IRBLta2-Pi was crossed with BRRI dhan63 and then three backcrossed. Eighty-six advanced lines were developed and grown in T. Aman 2020. Out of these, 15 fixed lines were grown in Boro 2020-21. Among those, five lines were identified as resistant against rice blast disease both in UBN and field condition at Gazipur (Table 21). Introgression of *Pita2* gene in these lines were confirmed with PCR amplification using gene-based marker YL155/YL87. The yield ranged from 4.5-5.3 t/ha with the growth duration 144-146 days. The growth durations were 8-10 days earlier than BRRI dhan63. The lowest yield was recorded in BRRI dhan63 due to severe incidence of both leaf blast (score 4-5) and neck blast (85%). These resistant lines have minimum sterility with non-shattering characters. However, the plant type, grain shape and size of these lines were different from BRRI dhan63. These lines can be used as pre-breeding materials for the development of blast resistant varieties.

T H Ansari, M Ahmed, M S Rahman and M A Rahman

Table 20. Preliminary yield trial of blast resistant advanced lines (long duration) in Boro 2020-21.

Line designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)*	[1]Leaf blast	UBN
BR12454-BC2-87-24-32-1-29	97.7	162	9.2	2	R
BR12454-BC2-55-2-20-36-22	97.0	163	8.8	0	R
BR12454- BC2-56-81-27-3-30	95.0	163	10.1	0	R
BR12454- BC2-68-43-4-41-25	93.7	163	8.8	2	R
BR12454- BC2-69-97-39-5-44	93.3	164	8.7	0	R
BR12454- BC2-71-91-6-23-26	96.3	166	8.9	0	R
BR12454- BC2-75-32-31-39-7	95.3	161	9.6	2	R
BR12454- BC2-48-10-88-81-32	94.3	163	9.2	2	R
BR12454- BC2-76-11-65-96-42	91.7	163	6.7	0	R
BR12454- BC2-59-72-12-28-36	-	163	8.0	5	S
BR12454- BC2-13-81-88-87-HR	94.7	163	9.7	2	R
BR12454- BC2-14-66-56-46-HR	98.3	166	7.9	-	-
BR12454- BC2-99-85-15-72-25	98.3	163	8.9	0	R
BRRI dhan29 (S. Check)	95.0	166	9.0	4	S
US2 (S. check)				5	S
CV(%)			9.1		
LSD			0.575		

D/S: 20 Nov 2020, D/T: 31 Dec 2020, Spacing: 20X20 cm, -: missing, UBN: Uniform blast nursery, [1]Leaf blast severity score following 0-5 scale (Hyashi et al 2009). R- Resistant, S- Susceptible, *Yield was calculated from 4m^2 plot and adjusted at 14.0% moisture.

Pyramiding blast resistant *Pita2* and *Pi9* genes.
Both *Pita2* and *Pi9* genes were introgressed in the same background of BRRI dhan28, BRRI dhan29 and BRRI dhan63. Seeds at different generations were harvested for further advancement (Table 22).

M Ahmed, T H Ansari, M S Rahman and M A Rahman

Development of durable blast resistant high yielding rice
BRRI dhan89, BRRI dhan92, BRRI dhan96 and BRRI dhan98 were selected as recurrent parent. Recently developed blast resistant line BR28-*Pi9*/BR29-*Pi9*/BR63-*Pita2* was used as donor parents for introgression and seeds from different crosses were harvested (Table 23). Incorporation of both *Pi9* and *Pita2* genes will be done through hybridization between F1s of same background to make durable blast resistance progenies.

T H Ansari and M Ahmed

Linkage and QTL mapping of blast resistant variety BR16.
BR16, a blast resistant T. Aman rice variety was crossed with universal susceptible variety US2 to produce F1 seeds. F1s were further backcrossed with the susceptible US2. Finally, BC2F1 seeds were produced in Boro, 2020-21. BC2F2 generations will be produced during T. Aman 2021.

T H Ansari and M Ahmed

Table 21. Yield, growth duration and blast disease resistance of *Pita2* lines in Boro 2020-21.

Line designation	Growth duration (day)	Yield* (t/ha)	[1]Leaf blast score (UBN)	[1, 2]Leaf blast score	[2]Neck blast (%)
BR12457-BC3-11-20-13-10-3-3	145	5.3	0	0	0
BR12457-BC3-25-31-26-14-9-10	144	4.5	0	0	0
BR12457-BC3-49-25-10-19-11-9	146	4.7	0	0	0
BR12457-BC3-67-30-15-7-15-3	146	4.9	0	0	0
BR12457-BC3-69-17-11-8-12-7	145	5.0	0	0	0
BRRI dhan63 (Recurrent parent)	154	2.0	4-5	4-5	85

*Yield area: 9 m^2, [1]Leaf blast severity score (Hyashi et al. 2009), UBN: uniform blast nursery
[2]Leaf blast score and neck blast incidence at BRRI rice field, Gazipur during Boro 2020-21.

Table 22. Number of seed produced at different generations in different cross combinations.

Cross combinations	Season	Generation	No. of seed
BRRI dhan28**Pi9*Pita2*	Boro 2020-21	BC2F3	450
BRRI dhan29**Pi9*Pita2*		BC1F3, BC2F2	400, 600
BRRI dhan63**Pi9*Pita2*		BC1F3	450
BRRI dhan81**Pi9*Pita2*		BC1F1	200

Table 23. Generation advancement and seeds produced in different crosses.

Cross combination	Season	Generation	No of seed
BRRI dhan89*BR28-*Pi9*	Boro 2020-21	F3	200
		BC2F1	150
		BC1F2	430
BRRI dhan89*BR63-*Pita2*		F2	500
		BC1F1	26
BRRI dhan89*BR29-*Pi9*		BC1F2	800
BRRI dhan92*BR28-*Pi9*		F1	310
BRRI dhan92*BR63-*Pita2*		F1	275
BRRI dhan96*BR28-*Pi9*		F1	124
BRRI dhan96*BR29-Pi9		F1	133
BRRI dhan96*BR63-*Pita2*		F1	159
BRRI dhan98*BR28-*Pi9*		F1	25

Phenotypic and molecular screening of local germplasm against rice blast disease

Phenotypic reaction and molecular screening of major blast resistance gene(s) possessed in germplasm were studied in this experiment. Forty-four rice local germplasm were collected from BRRI gene bank and phenotypically screened twice at uniformed blast nursery (UBN), BRRI. Genomic DNA were harvested from each germplasm following standard protocol and PCR were done with specific gene-based markers. Rice germplasm were screened twice at UBN. In 1st screening, 39 germplasm were susceptible and five were found resistant. In 2nd screening, 41 germplasm were found susceptible and 3 found resistant. Considering the highest score of both screening, 41 germplasm were found susceptible and three germplasm were found resistant. Among the germplasm, 26 germplasm have *Pit* gene, 21 germplasm have *Pi40* gene and other 19, 17, 13, 11, 7 and 1 germplasm contain *Pib*, *Pita-2*, *Pita/Pita2*, *Pi9*, *Piz* & *Pi5* respectively. Though most of the germplasm 1 to 26 number of blast resistance genes, however they found susceptible.

M Ahmed, T H Ansari and F M Aminuzzaman

Field evaluation of blast resistant lines in blast hot spot area in Debidwar, Cumilla during Boro 2020-21

Thirty-eight highly leaf and neck blast resistant lines were selected out of 3,988 during Boro 2019-20. These 38 lines along with four susceptible/parent checks were used for blast disease resistant confirmation during Boro 2020-21 in blast hot spot area in Debidwar, Cumilla. All 38 genotypes showed neck blast resistantce whereas, susceptible checks showed 10-30 % neck blast with severity score 9.

M M Rashid, M Hossain, A Islam, M Khatun, S S Dipti, M A Hasan, T H Ansari, M A I Khan, M A Latif and Y Fukuta

Development of blast resistant varieties using differential system and molecular markers

To improve the genetic background of popular rice variety BRRI dhan28, BRRI dhan29, BRRI dhan63 and BRRI dhan64 against blast disease, a maker assisted backcross breeding followed by pathogenicity tests were started in collaboration with JIRCAS, Japan in 2014. Different sources of *Pi9*, *Piz-t*, *Pish*, *pi21* and *Pb1* were used as donor. Around 400 plants from each combination of BCnF2 population were selected by foreground selection using linked markers. The selected materials were advanced from BC2F2 to BC2F5 in BRRI field by modified field RGA system. The advanced materials were cultivated for line stage testing (LST) during Boro 2019-20 at BRRI HQ, Gazipur for yield performance and blast hot spot Cumilla for neck blast screening. Among the tested 3982 lines, 38 lines were selected as neck blast resistant from Cumilla. And 379 lines were selected from BRRI HQ, Gazipur with the help of Plant Breeding Division, BRRI mostly based on the yield performance. All of these selected lines were cultivated in T. Aman 2020 season at BRRI HQ and then evaluated for neck blast resistance at blast hot spot of Gazipur and Cumilla during Boro 2020-21 season. A total of 61 lines were selected as blast resistant with different agronomic characteristics (Table 24). Seeds of these lines are now multiplying in T. Aman 2021 season at BRRI HQ and the multilocation trial will be conducted at four blast hot spots of Bangladesh in Boro 2021-22. Subsequently, artificial screening using differential blast isolates will be done at the laboratory of Plant Pathology Division under controlled conditions.

M A I Khan, M R Bhuiwan, M M Rashid, Emam Hossain, Mahmuda Khatun, Y Fukuta and M A Latif

Studies on the genetic mechanism of rice blast and gall midge resistance in BRRI dhan33

BRRI dhan33, a short duration popular variety using as blast resistant check in Plant Pathology Division and gall midge resistant check in Entomology Division BRRI from a long time. To know the genetic mechanism of blast and gall midge resistance of this variety, a programme was undertaken on blast and gall midge resistant gene estimation using differential system and QTL analysis using segregating population (BC1F2 family lines). The mapping population of BC1F2 family lines (US2/BRRI dhan33//US2) were developed in Plant Pathology Division, BRRI. A total of 625 markers were surveyed for polymorphism

Table 24. Some selected neck blast resistant promising lines Boro 2020-21, BRRI, Bangladesh.

BRRI code	Cross combination	Generation	Comments
HAI 72***	BRRI dhan29 x *Pish*/2*BRRI dhan29	BC2F8	High yielding and best blast resistance
HAI 84***	BRRI dhan29 x *Pish*/2*BRRI dhan29	BC2F8	High yielding and best blast resistance
HAI 95***	BRRI dhan29 x *Pish*/2*BRRI dhan29	BC2F8	High yielding and best blast resistance
HAM 111***	Piz-t x BRRI dhan63/2*BRRI dhan63	BC2F8	High yielding and best blast resistance
HAN 9-1***	Pi9 x BRRI dhan63/2*BRRI dhan63	BC2F8	High yielding and best blast resistance
HAN 9-2***	*Pi9* x BRRI dhan63/2*BRRI dhan63	BC2F8	High yielding and best blast resistance
HAN 80***	*Pi9* x BRRI dhan63/2*BRRI dhan63	BC2F8	High yielding and best blast resistance
HCP 144***	*pi21* x BRRI dhan64/2*BRRI dhan64	BC2F8	High yielding and best blast resistance
HCP 292**	*pi21* x BRRI dhan64/2*BRRI dhan64	BC2F8	High yielding and better blast resistance
HGB 21***	*pi21* x BRRI dhan28//BRRI dhan28	BC1F8	High yielding and best blast resistance
HGG 128***	BRRI dhan29 x *pi21*/2*BRRI dhan29	BC2F8	High yielding and best blast resistance
HGG 205***	BRRI dhan29 x *pi21*/2*BRRI dhan29	BC2F8	High yielding and best blast resistance
GI 21**	BRRI dhan29 x *Pish*/2*BRRI dhan29	BC2F8	High yielding and better blast resistance
HGK 236**	BRRI dhan63 x *pi21*/2*BRRI dhan63	BC2F8	High yielding and better blast resistance
HGL 25***	BRRI dhan63 x *Pb-1*/2*BRRI dhan63	BC2F8	High yielding and best blast resistance
HGL 269**	BRRI dhan63 x *Pb-1*/2*BRRI dhan63	BC2F8	High yielding and better blast resistance
HGL 297**	BRRI dhan63 x *Pb-1*/2*BRRI dhan63	BC2F8	High yielding and better blast resistance
HGP 42**	*pi21* x BRRI dhan64/2*BRRI dhan64	BC2F8	High yielding and better blast resistance

studies between BRRI dhan33 and US2, a universal blast susceptible variety. Among 625 markers, 184 markers showed polymorphic. The phenotyping against neck blast disease at two blast hot spots and against leaf blast under artificial inoculation system have already completed. Phenotyping against gall midge is going on at Entomology Division. For the genotyping of segregating population, polymorphic markers have already collected. DNA data using PCR and gel documentation are going on at the molecular laboratory of Plant Pathology Division.

M A I Khan, M R Bhuiwan, M A I Hasan, S A I Nihad, Mofazzel Hossain, Y Fukuta and M A Latif

Detection of novel loci underlying rice blast and BB resistance by integrating a genome-wide association study and evaluation of resistant genes in the background of 186 local germplasm in Bangladesh

To implement GWAS we need phenotypic data as well as the genotypic data of the genotypes under study. Phenotypic data was obtained through field experiment. 76 entries from 186 genotypes were grown in the Boro 2020-21 season under the supervision of Plant Pathology Division, BRRI. Entries were screened against bacterial blight disease infection through artificial inoculation. We have found bacterial blight (BB) resistant 21 entries. Rest of the entries showed susceptible reaction.

We have downloaded the "404k CoreSNP Dataset" for each of the 12 different chromosomes of rice from the data repository of 3K Rice Genome Project and OryzaSNP Project, hosted by IRRI. But the downloaded genotype data is not in ready to use format. Data processing is almost complete. Hopefully data analysis will be completed soon.

M A I Khan, Md Ruhul Quddus, Md Rejwan Bhuiwan, M Rafiqul Islam, M Sazzadur Rahman, A Ara, S A I Nihad, M Ahemd, M M Rashid and M A Latif

Screening of advanced breeding lines against bacterial blight and blast (TRB)

A total of 5,190 advanced breeding lines including OYT, AYT and RYT were inoculated with most virulent bacterial blight (BB) isolate during T. Aman 2020 and Boro 2020-21 season. The plants were inoculated by leaf clipping method at maximum tillering stage. Data of leaf damage area (%) were collected 21 days after inoculation. The collected data were then converted to disease severity scale (0 to 9) following SES 2013, IRRI Philippines. Among the tested entries, 2,138 materials were found resistant against BB. These

materials are needed to evaluate further form confirmation. Due to the renovation of greenhouse, screening against blast not yet done. All these materials will be screened now at the new greenhouse renovated by TRB project.

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Development of blast resistance rice by CRISPR/Cas9-targeted mutagenesis of the *OsERF922* gene

Rice blast, caused by the filamentous ascomycete fungus *Magnaporthe oryzae*, is one of the most destructive diseases affecting rice in all rice-growing countries and often causes serious damage to global rice production. Enhancing the resistance of rice to *M. oryzae* has been shown to be the most economical and effective approach for controlling rice blast. To design a CRISPR/Cas9 targeting the *OsERF922* gene in rice, a 19bp nucleotide sequence (5′-TCTCCTTGGGGTTTAGCGC-3′) was a protospacer adjacent motif lying within the *OsERF922* coding sequence (*LOC_Os01g54890*). The guide sequence was properly cloned into the binary vector pC1300-Cas9 (Fig. 6). The binary vector pC1300-Cas9 harboring Cas9/*OsERF922* sgRNA was mobilized into *Agrobacterium tumefaciens* LBA4404 by freeze-thaw method and confirmed through PCR-gel electrophoresis (Figure 7). *Agrobacterium*-mediated transformation of the embryogenic calli will be performed to get the mutant lines.

M A I Khan, Hirendronath Barmon, S A I Nihad, M R Bhuiyan and M A Latif

Confirmation of resistant genes of BB through gene base SSR markers and pathogenicity test

A total of 74 rice germplasm was evaluated for the confirmation of resistant genes of against bacterial blight through gene base SSR markers and pathogenicity test against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen in T. Aman 2020 and Boro 2020-21. Pathogenicity test was conducted under field conditions using artificial inoculation and confirmation of resistant genes were conducted in molecular laboratory, Plant Pathology Division, BRRI. Six gene specific SSR markers were used for confirmation of *Xa4*, *xa5*, *Xa7*, *xa13*, *Xa21* and *Xa23* gene among the germplasm. A total of 74 materials were resistant to BB. Out of 74 germplasm (according to molecular data), 41 germplasm carried *Xa4* gene, 15 carried *xa5* gene, 62 carried *Xa7* gene, 33 carried *xa13* gene, and 19 carried *Xa23* gene. Only a single germplasm consisted of *Xa21* gene. Interestingly, we found a wide range of gene combinations ranged from 2 to 4 genes among the germplasm resistant to bacterial blight and G3 genotype (Acc. no. 4216; highly resistant) having *Xa4*, *Xa7*, *xa13*, *Xa21* and G43 genotype (Acc. no. 1523; resistant) having *Xa4*, *xa5*, *xa13* and *Xa23* gene combination being the most effective against all the *Xoo* strains.

M A Latif, M A I Hasan, A Kabir, A Hossain and M A I Khan

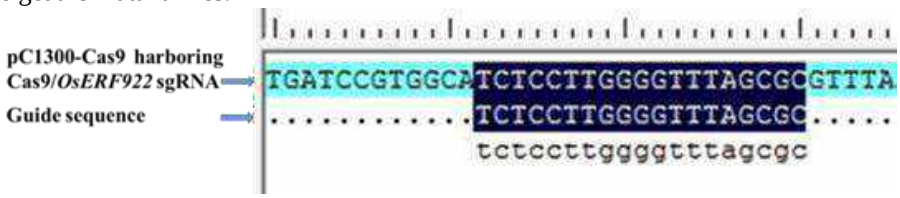

Fig. 6. Confirmation of vector constructs by alignment of sequence of recombinant pC1300-Cas9 harboring Cas9/*OsERF922* sgRNA with guide sequence.

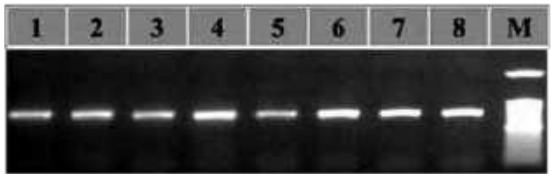

Fig. 7. Confirmation of Agrobacterium transformation through PCR-gel electrophoresis. *Agrobacterium tumefaciens* LBA4404 with recombinant pC1300-Cas9 harboring Cas9/*OsERF922* sgRNA (Lane 1-8). M: marker (50 bp DNA ladder).

Detection of blast and bacterial blight resistant genes in BRRI released Boro varieties through phenotyping and genotyping

The experiment was conducted to know the resistance level of BRRI developed Boro varieties against blast and bacterial blight disease. The presence resistance gene(s) for both diseases exist in these varieties. Boro varieties along with susceptible varieties were evaluated for bacterial blight disease through leaf clipping method using virulent isolates of BB. Genotyping of those varieties with gene-based markers were conducted. Out of 40, varieties no varieties were identified as resistant. While identified as pathotypic susceptible, twenty-eight varieties having *Xa4* gene, single variety consists of *xa5* gene and no varieties having *xa13* and *Xa21* gene (Table 25). Phenotyping for blast resistant will be conducted in the next season. But in marker assisted detection for blast resistant, no varieties were detected having *Pi9* gene, while *Pb1* gene was

Table 25. Detection of blast and bacterial blight resistant genes in BRRI released Boro varieties through genotyping.

Variety	Bacterial blight resistant genes				Blast resistant genes		
	Xa4	*Xa5*	*Xa13*	*Xa21*	*Pi9*	*Pb1*	*Pita2*
BR 1	P	X	X	X	X	X	X
BR 2	P	X	X	X	X	X	X
BR 3	X	X	X	X	X	X	X
BR 6	X	X	X	X	X	X	X
BR 7	X	X	X	X	X	X	P
BR 8	X	X	X	X	X	X	X
BR 9	P	X	X	X	X	X	X
BR 12	P	X	X	X	X	X	X
BR 14	X	X	X	X	X	X	P
BR 15	X	X	X	X	X	X	X
BR 16	P	X	X	X	X	P	P
BR 17	P	X	X	X	X	X	X
BR 18	X	X	X	X	X	X	X
BR 19	P	X	X	X	X	X	X
BR 26	P	X	X	X	X	P	P
BRRI dhan27	P	X	X	X	X	X	X
BRRI dhan28	P	X	X	X	X	X	X
BRRI dhan29	P	X	X	X	X	X	X
BRRI dhan35	P	X	X	X	X	X	X
BRRI dhan36	X	X	X	X	X	X	P
BRRI dhan45	X	X	X	X	X	X	X
BRRI dhan47	P	X	X	X	X	X	P
BRRI dhan50	X	X	X	X	X	P	P
BRRI dhan55	P	X	X	X	X	X	X
BRRI dhan58	P	X	X	X	X	X	X
BRRI dhan59	P	X	X	X	X	P	P
BRRI dhan60	P	X	X	X	X	P	P
BRRI dhan61	P	X	X	X	X	P	P
BRRI dhan63	X	X	X	X	X	X	X
BRRI dhan64	P	X	X	X	X	P	X
BRRI dhan67	X	P	X	X	X	X	X
BRRI dhan68	P	X	X	X	X	P	X
BRRI dhan69	P	X	X	X	X	X	P
BRRI dhan74	P	X	X	X	X	X	X
BRRI dhan81	P	X	X	X	X	X	X
BRRI dhan84	P	X	X	X	X	X	X
BRRI dhan86	P	X	X	X	X	X	P
BRRI dhan88	P	X	X	X	X	X	X
BRRI dhan89	P	X	X	X	X	X	X
BRRI dhan92	P	X	X	X	X	X	X

present in eight varieties and *Pita2* was in 12 varieties (Table 25). Therefore, only marker assisted selection/identification even with gene-based markers do not indicate than the resistance rather the pathotypic reaction with variable differential isolates.

M B Halim, T R Anik, M A I Hasan, M A Latif

Linkage and QTL mapping of tungro resistance in rice

Tungro is one of the major diseases of rice and in severe condition it may cause 100% yield loss of rice. To date, there is no tungro resistant modern rice variety in Bangladesh. However, there are few low-yielding landraces such as Sonahidemota, Kumragoir, Nakuchimota, Khaiyamota, Khairymota and Kachamota which are highly resistant against tungro disease. To identify the resistance QTL in Kumragoir landrace a linkage and QTL mapping study was conducted in Plant Pathology Division, BRRI. A cross was made between Kumragoir and BRRI dhan48 and developed F1, BC1F1, BC2F1 and BC2F2 population. Four hundred seventy-five SSRs markers were used for polymorphic survey between Kumragoir and BRRI dhan48 and out of them 96 polymorphic markers were used for genotyping of 384 plants of BC2F2 population (Fig 8). Additionally, 384 plants were screened against rice tungro disease (phenotyping). Based on phenotyping and genotyping data of BC2F2 population, twelve QTLs (LOD value >3) i.*e. qRTVR3, qRTVR3.1, qRTVR4.2, qRTVR9, qRTVR9.3, qRTVR10, qRTVR10, qRTVR10.4, qRTVR10, qRTVR11, qRTVR11.5, qRTVR11* were identified by Qgene software. Among these, five significant ($p < 0.05$; 0.01) QTLs that is *qRTVR3.1, qRTVR4.2, qRTVR9.3, qRTVR10.4* and *qRTVR11.5,* were found in chromosomes 3, 4, 9, 10 and 11, respectively (Table 26). Out of these four major QTLs (*qRTVR3.1, qRTVR4.2, qRTVR10.4* and *qRTVR11.5)* explained 12.2, 10.8, 12.2 and 10.8 % phenotypic variations and one minor QTL *qRTVR9.3* explained 3.8% phenotypic variation. Moreover, markers RM5548, RM6487, RM242, RM5806, RM536 was found linked with the QTL *qRTVR3.1, qRTVR4.2, qRTVR9.3, qRTVR10.4* and *qRTVR11.5*, respectively. These linked markers could be used in marker assisted selection for the development of tungro resistant variety.

M A Latif, S A I Nihad, M A Rahman

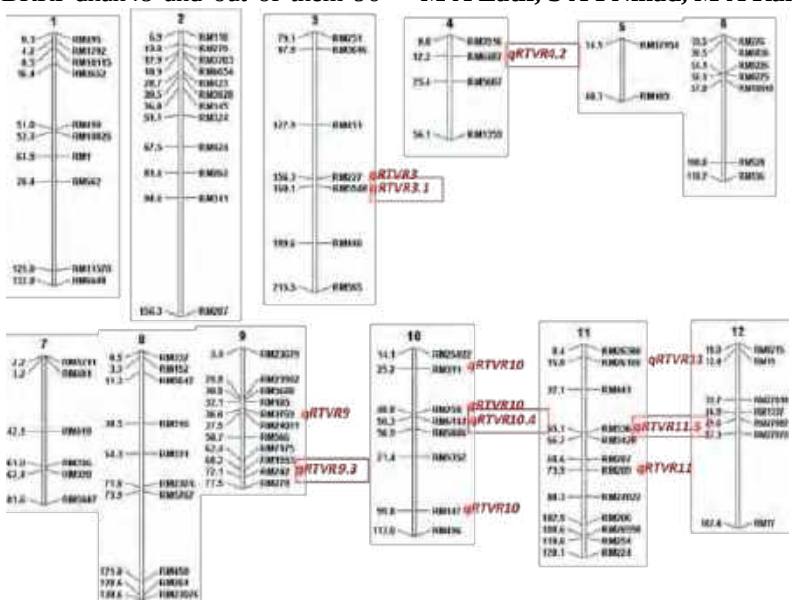

Fig. 8. A genetic linkage map of the 12 chromosomes of rice constructed based on selected individuals of an BC2F2 population of a cross between Kumragoir and BRRI dhan48. The map was constructed using 96 SSR markers. The number at the top of each linkage group indicates the chromosome number. The names of the markers are listed at the right and the map distances between them (cM) are shown on the left of the chromosomes. The markers enclosed in red boxes indicate the approximate locations of the QTL detected for tungro resistance.

Development of pre-breeding materials of tungro resistance

To introgress tungro resistant gene in high yielding variety, parent materials were grown during Aman 2020 and Boro 2020-21. Five sets of parents with seven days interval were grown for the synchronization of flowering among the parents. Seeding was started from 14 July 2020 in Aman season and for Boro season it was started from 6 December 2020-21. In Aman 2020 five crosses (Table 27) and in Boro 2020-21 five crosses (Table 28) were made among the parents. Heterozygosity of the population was confirmed by using the respective marker. After confirmation crossing was done to make the next generation.

S A I Nihad, M M Rashid, M S Mian, M A Latif

Development of pre-breeding materials of tungro resistance through RGA method

To advance the tungro resistant fixed lines of following crosses (Tables 29 and 30), advanced lines were grown during Aman 2020 and Boro season of 2020-21 by following rapid generation advance (RGA) method. Seeding was started from 14 July 2020 in Aman season and for Boro 2020-21 season it was started from 6 December 2020-21. Three hundred plants were selected from 600 plants in Aman 2020 and these lines were advanced during Boro 2020-21.

S A I Nihad, M M Rashid, M S Mian, M A Latif

Table 26. QTLs detected for Rice Tungro Virus Resistance (RTVR) based on interval mapping (IM) and composite interval mapping (CIM) in the Kumragoir/BRRI dhan48 BC2F2 population.

Trait	QTL	Chr.	Peak marker	Position (cM)	QTL bordering marker	Additive effect	[a]Direction of phenotypic effect	IM or CIM	LOD	Threshold LOD values at α0.05 and α0.01 after 1000 iterations in permutation analysis	PVE (R^2)
RTVR	*qRTVR3.1*	3	RM5548	159.1	RM227-RM448	-0.93	Kumragoir	IM	10.83	3.41-4.06	12.2
RTVR	*qRTVR4.2*	4	RM6487	12.8	RM3916-RM5687	-0.81	Kumragoir	IM	9.52	3.33-4.09	10.8
RTVR	*qRTVR9.3*	9	RM242	71.4	RM1553-RM218	1.398	BRRI dhan48	CIM	3.21	3.36-4.16	3.8
RTVR	*qRTVR10.4*	10	RM5806	56.1	RM6142-RM5352	-1.079	Kumragoir	CIM	10.87	3.27-4.19	12.2
RTVR	*qRTVR11.5*	11	RM536	50.4	RM441-RM3428	1.287	BRRI dhan48	IM	9.57	3.30-3.91	10.8

[a]QGene calculates both LOD and additive effect and displays the LOD. If we select a signed statistic such as Add effect (additive effect), a second plot is drawn below the main chromosome-map plot (LOD curve). A positive-signed effect represents an increasing allele from parent1, BRRI dhan48; a negative signed effect, an increasing allele from parent 2, Kumragoir (i.e. the favourable allele comes from Kumragoir).

Table 27. List of crosses and the number of seeds for the respective cross (Aman 2020).

Generation	Cross	No. of seeds
BC2F1	BRRI dhan87*TW-16	74
BC2F1	BRRI dhan87* IR71605-3-1-1-2-6	72
BC2F1	BRRI dhan48* IR71605-2-1-5-3-4	68
BC4F1	BRRI dhan48*Kumragoir	76
BC4F1	BRRI dhan71*Sonahidmota	69

Table 28. List of crosses and the number of seeds for the respective cross (Boro 2020-21).

Generation	Cross	No. of seeds
BC3F1	BRRI dhan87*TW-16	74
BC3F1	BRRI dhan87* IR71605-3-1-1-2-6	72
BC3F1	BRRI dhan48* IR71605-2-1-5-3-4	68
BC5F1	BRRI dhan48*Kumragoir	76
BC5F1	BRRI dhan71*Sonahidmota	69

Table 29. List of crosses and the number of seeds for the respective cross (Aman 2020).

Generation	Cross combination	No. of Panicle Selected
BC_5F_5	BRRI dhan71*TW-16	100
BC_5F_5	BRRI dhan48*IR69705-1-1-1-4-2	100
BC_5F_5	BRRI dhan48*Matatag-1	100

Table 30. List of crosses and the number of seeds for the respective cross (Boro 2020-21).

Generation	Cross combination	No. of Panicle Selected
BC_5F_6	BRRI dhan71*TW-16	100
BC_5F_6	BRRI dhan48*IR69705-1-1-1-4-2	100
BC_5F_6	BRRI dhan48*Matatag-1	100

Validation of tungro resistant QTL identified in Landrace Kumragoir

Five tungro resistance QTL with linked markers, RM5548 (qRTVR3.1), RM6487 (qRTVR4.2), RM242 (qRTVR9.3), RM5806 (qRTVR10.4), RM536 (qRTVR11.5) were identified in chromosomes 3, 4, 9, 10 and 11 of landrace Kumragoir. For validation of the identified QTL, developed mapping population were grown in Aman, 2020 and also planted in Boro, 2020-21 for seed multiplication and advancement of population. BC_2F_4 and BC_2F_5 population were developed in Aman 2020 and Boro,2020-21, respectively.

S A I Nihad, M A Rahman, M A Latif

Screening of INGER materials obtained from IRRI against blast disease of rice, Boro 2020-21

A total 96 INGER materials were collected from IRRI. Among them 88 materials were tested against leaf blast disease in blast nursery, BRRI, Gazipur. Seed of eight entries were not germinated in the rice blast nursery. BRRI dhan28 and BRRI dhan33 were used as local susceptible and resistant check in the test nursery. Rice blast nursery protocol was followed for screening.

Among the tested materials, 12 entries such as SVIN682, SVIN683, SVIN684, SVIN690, SVIN271, SVIN272, SVIN509, SVIN332, SVIN446, SVIN352, SVIN457 and SVIN458 showed resistance. But these materials need further test to confirm the resistance.

M S Mian, T H Ansari, M A Latif

Screening of advanced breeding lines against bacterial blight (BB) disease during Boro 20-21

To identify new resistant source(s) against BB, 118 materials including resistant, susceptible and standard checks were screened against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen In Boro 2020-21. The experiment was conducted under field conditions using artificial inoculation during Boro 2020-21 season at BRRI, Gazipur. Plants were inoculated with a virulent isolate of the major race, BXO97 at maximum tillering stage following leaf clipping method (Kauffman *et al.* 1973). The disease severity data were recorded at 21 days after inoculation from 10 leaves in each entry. In Boro 2020-21, among 135 genotypes ten advanced breeding lines are found as resistant materials and seventeen as moderately resistant against bacterial blight disease. Other genotypes were found as susceptible to bacterial blight disease.

A. Ara, M A I Khan and M A Latif

Screening of advanced breeding lines against sheath blight of rice

In T. Aman 2020-21, a total of 86 materials including 16 checks were screened against sheath blight disease to identify resistant genotypes. The experiment was conducted in BRRI HQ farm, Gazipur by artificial inoculation. Plants were inoculated with pathogen at maximum tillering to booting stage using mycelial plug placement in the centre of hill. Three hills were inoculated from each line. The disease severity data were recorded at mature stage of the plants following SES (2013) IRRI. Among the materials two (BR9888-19-4-7

and BR9143-25-7-2-2) showed resistant reaction and rest of them showed moderately resistant to susceptible reaction against the pathogen.

S Akter and M A Latif

Screening of rice germplasms against bakanae disease

A total of 100 germplasm was screened against bakanae disease. Germplasm were collected from GRS Division. The seeds were surface sterilized with 70% ethanol, washed with sterilized distilled water and then soaked overnight in sterilized distilled water. The water drained out and seeds were further soaked in spore suspension (10^6 conidia/mL) of the virulent isolate for 48 h. The seeds were then planted in sterilized soil in trays (2 kg soil/tray) and were arranged in a completely randomized design with three replications (15 seeds/replication). Pre-soaked seeds for the control treatment (susceptible variety BR1 and resistant check variety BR3) were soaked further in sterile distilled water for 48 hour before sowing. All trays were placed in a glasshouse at room temperature, and were watered once daily with a hand sprinkler. Among the tested germplasm, five were found resistant.

Q S A Zahan

S S R marker-based diversity analysis of upland rice (*Oryza sativa L.*) germplasm

To clarify genomic differences of Aus germplasm this study was taken to decipher the divergence through SSR markers. In this study, a total of 28 SSR markers were used across 24 upland Aus rice germplasm from India, Philippines, Thailand, Ivory Coast, Malaysia and Bangladesh for their characterization and discrimination. This 24 germplasm were Biaw Bood Pae, Chirikata 2, Chirikata 2a, IR 5533-14-1-1, IR 5533-55-1-11, IR 5533-56-1-12, IR 5533-56-1-12a, IR 5533-PP854-1, IR 5533-PP856-1, IR 9559-PP871-1, IR 9669-23-12-7, IR 9669-PP823-1, IR 9669-PP830-1, Ja La Shau, Ja Loy, Ja No Naq, C, Padi Beleong (Jenis Padi Beleong), Padi Kalopak, BR16 * Karingam, Lansam, BR 27, BRRI dhan and unknown. To clarify the differentiations of genome chromosomes among the germplasm, 28 SSR markers distributed over the12 rice chromosomes were used. Whole genomic DNA was extracted from a young leaf of germplasm following the CTAB method. To detect polymorphisms, the amplified PCR products were separated by Polyacrylamide Gel Electrophoresis in TBE buffer. Cluster analysis with Software „R" were used to classify marker polymorphisms and reaction data with respect germplasm into groups. A total of 86 alleles were detected by the 28 polymorphic SSR markers. The number of alleles per locus varied from 2 to 5, with a mean of 3.07 alleles per locus. The polymorphic information content (PIC) value for each marker was used to assess the polymorphic level. The mean PIC value of the SSR markers was 0.46 with a range of 0.74-0.08. The germplasms were classified based on the polymorphism data into nine cluster groups, cluster I-cluster IX. (Figure 8). Most of the germplasm from Philippines, Malaysia, Bangladesh and India are under the same cluster respectively.

H A Dilzahan, T Khatun, T R Anik, S A I Nihad, and M A Latif

DISEASE MANAGEMENT

Sustainable management of blast, sheath blight and bacterial blight diseases of rice through nano-particles (NPs) (KGF Projects)

Green synthesis of nano-particles

To control the major rice diseases silver, zinc oxide and silica nano was produced from Neem leaf extracts while Copper oxide nano particle was produced from Tulsi leaf extracts. The absorption spectra of AgNPs obtained from the reaction of Neem leave extract and AgNO3 recorded in the range of 390-500nm at different reaction time. Absorption maximum is observed at 415nm. (Fig. 9). The absorption spectra of CuO NPs obtained from the reaction of leave extract and CuSO4.5H2O recorded in the range of 200-400nm at different reaction time. Absorption maximum is observed at 240nm. (Fig. 10). The absorption spectra of ZnO NPs obtained from the reaction of leave extract and ZnSO4·7H2O recorded in the range of 200-400nm. Absorption maximum is observed at 343nm. (Figure 11). The absorption spectra of silica NPs obtained from the reaction of leave extract and $Na_20_3Si.9H_2O$ recorded in the range of 170-300nm. Absorption maximum was observed at 220nm. (Fig. 12).

M A Latif, S Akter, M A I Khan and R Akter

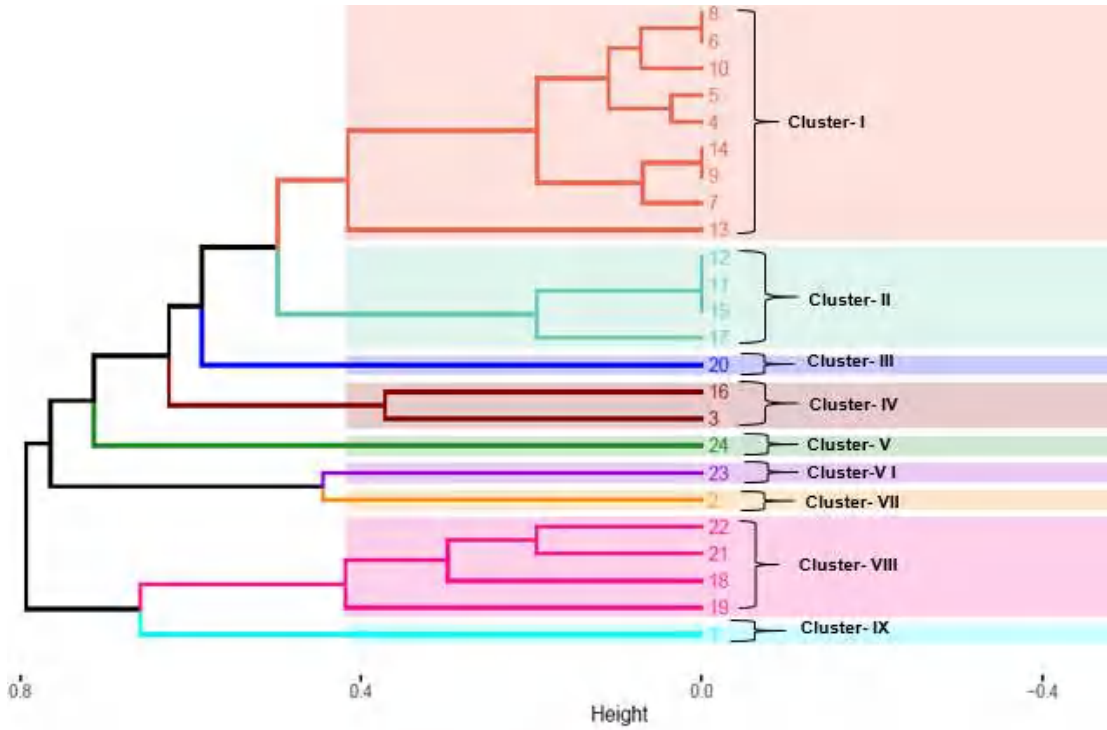

Fig 9. A cluster dendrogram showing the genetic relationships among 24 germplasms based on 28 SSR markers.

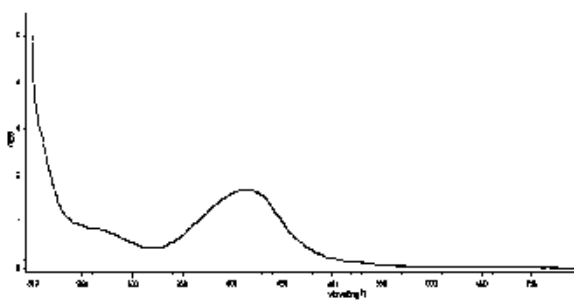

Fig. 10. UV-Vis spectra of silver nanoparticles

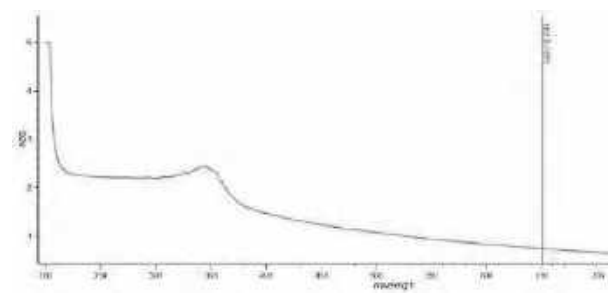

Fig. 11. UV-Vis spectra of zinc oxide nanoparticles

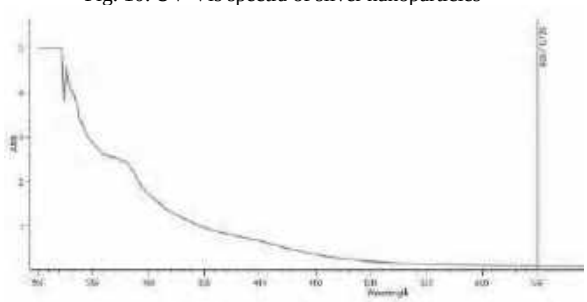

Fig. 12. UV-Vis spectra of copper oxide nanoparticles

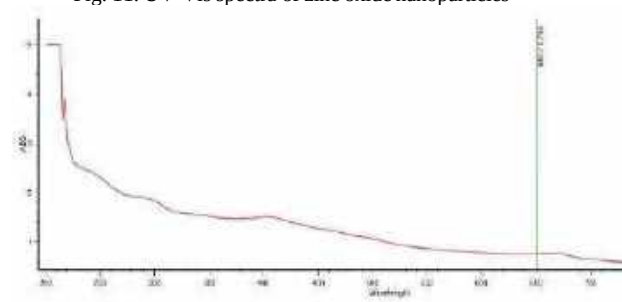

Fig. 13. UV-Vis spectra of silica nanoparticles

Determination of residual effect of trifloxystrobin, tebuconazole and tricyclazole in rice grain under field conditions

Synthetic agrochemicals are commonly using by the farmers to control rice diseases specially for neck blast disease. To determine the level of toxicity in rice grain this experiment was undertaken to find out the pesticide residue in pesticides sprayed rice. An analytical method was developed to determine tricyclazole, trifloxystrobin, tebuconazole group of fungicidal residues in rice grain using high-performance liquid chromatography (HPLC) with ultraviolet absorption detection. An amount of 20 µL of the sample extract was injected in each run. Mobile phases A and B were water/acetonitrile (95:5, v/v) with 0.1% formic acid and MeCN/water (95:5, v/v) with 0.1% formic acid. The chromatographic method held the initial mobile phase composition (10% B) constant for 1 min, followed by a linear gradient to 100% B up to 12 min and kept for 5 min at 100% B. The HPLC system was run using the following operation parameters: PDA detector, pump A flow rate was 0.300 ml/min and max. pressure 300 kgf/cm^2, oven temperature 30 ^{o}C, program time 15 min and reference wavelength 226 nm. Tricyclazole group was standardized with R^2=0.9991 (Fig. 13). Trifloxystrobin and tebuconazole group of fungicide detection process is ongoing.

R akter, M A I Khan, R Bhuiwan, H B shozib and M A Latif

Effectiveness of formulated biopesticides to control bakanae disease of rice in field condition

Two field trials were conducted in Debidwar, Cumilla during Boro 2020-21 season with 3 treatments T1=Trichoderma treated in the seedbed, T2=Root dipping with Trichoderma+Bacteria 1 for 30 min, T3=Control with 3 replications to evaluate field efficiency of formulated biopesticides against bakanae disease of rice in field condition. The experiment was funded by NATP-2 (ID.159). Rice bakanae disease was not found both in the seedbed and in the main field after transplanted. Some bakanae disease was found in both trials during split booting stage which is negligible in yield reduction. No significant differences were found among the treatments of yield parameters.

Q S A Jahan, M Hossain, M M Rashid, A Islam and M A Latif

Biological control of sheath blight disease

Sheath blight is a major disease of rice. Use biological entity is an environment friendly approach to control rice diseases. To control sheath blight disease biologically a study was taken. Rice Soil samples were collected from seven locations of Gazipur at full growing stage of rice. Bacteria from sampled soil ware isolated by serial soil dilution method. Incubated at 25˚C for 72 h. Re-cultured and multiplied on PDA medium. These bacteria were preserved with 20% glycerol for further use. These isolated bacteria were evaluated by dual

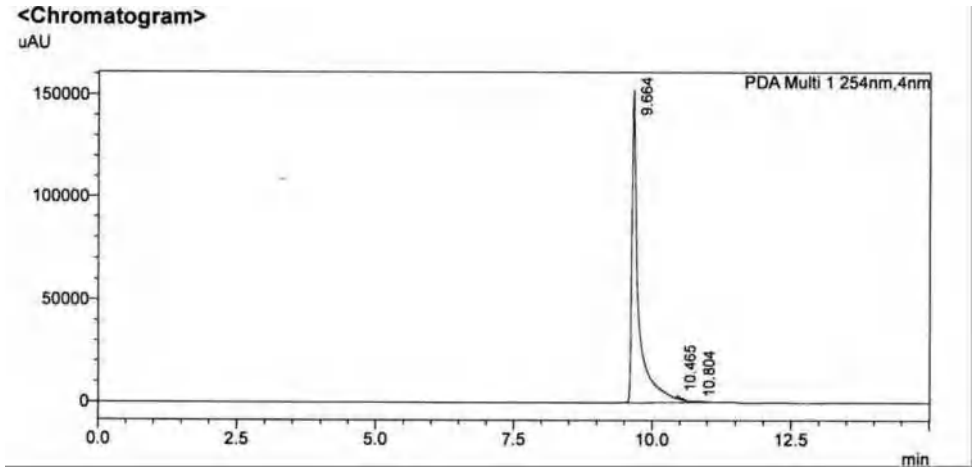

Fig. 14. Chromatogram of standard for tricyclazole by HPLC

culture method *in vitro* against Sheath Blight Disease of rice. About 80 bacteria were obtained from sampled soil. Among them two bacteria have shown strong antagonistic activity against *R. solani.*

H A Dilzahan, S Akter, Q S A Jahan and M A Latif

Evaluation of new chemicals against Blast disease of rice

An experiment was conducted at the Blast Nursery of Plant Pathology Division, BRRI, Gazipur for the evaluation of new chemicals against leaf blast disease of rice. A universal susceptible variety US2 was used as test plant. One of the virulent isolate Hankata28 was used for artificial inoculation. To compare the disease control efficacy of new chemicals against blast, a commonly used blast control fungicide Trooper 75 WP was used as check. In addition, a diseased control plot (blast spore inoculated plot without spraying any fungicides) was also maintained for evaluating the disease development potentiality of artificial inoculation technique. Chemicals were applied 3 days after inoculation and data of leaf damage area by leaf blast infection were collected 14 days after inoculation. Finally, reduction of leaf damage area by spraying tested fungicides was calculated over the untreated diseased plot. A total of 22 chemicals including trooper (check) were evaluated during Boro season, 2020-21. Among them, only seven fungicides (mostly Tricyclazole group fungicide) were controlled more than 80% blast disease. Actually, these chemicals were evaluated consecutively two years at BRRI HQ, Gazipur and now it will be recommended to Plant Protection Wing, DAE for registration.

M A I Khan, M. Tuhina-Khatun, and M A Latif

Development of nano particle mediated fungicide for rice blast disease management in Bangladesh

To prepare silver (Ag), zinc oxide (ZnO) and copper oxide (CuO) nano-particles (NPs), silver nitrate (AgNO3), zinc sulphate (ZnSO4.7H2O) and copper sulphate (CuSO4.5H2O) were used respectively as the precursor of respective nano-particles. Microwave assisted starch stabilization technique was used for NPs syntheses where D-glucose was used as reducing agent and boric acid for creating congenial environment. The UV-Vis spectra of prepared AgNP, ZnONP and CuONP were presented in Figs. 14, 15 and 16 respectively.

M A I Khan, PhD student, M Anik, R Akhter, S Akhter, M R Bhuiwan and M A Latif

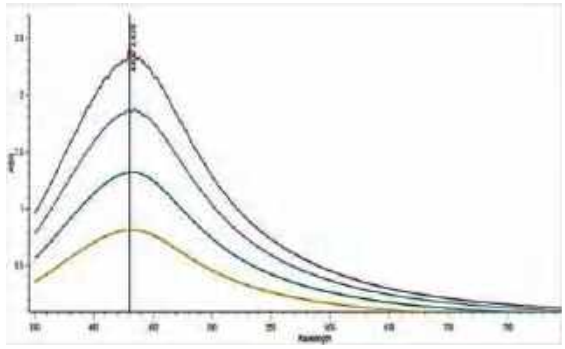

Fig. 15. UV-Vis spectra of silver nano-particles (AgNP) prepared by reacting AgNO3, glucose and starch under microwave irradiation.

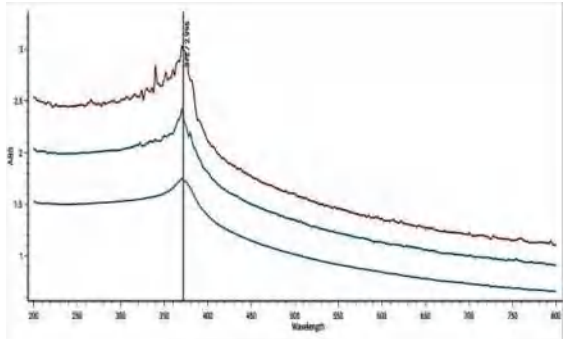

Fig. 16. UV-Vis spectra of Zinc oxide nano-particles (ZnONP) prepared by reacting Zinc sulphate (ZnSO4.7H2O), glucose and starch under microwave irradiation.

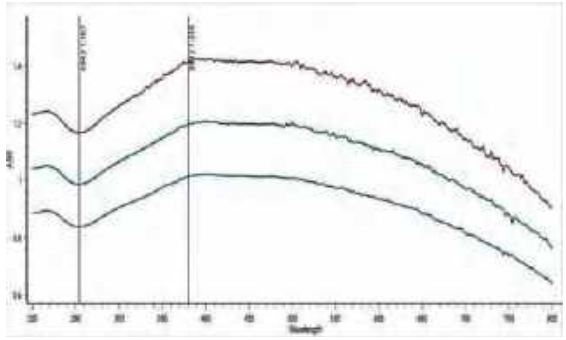

Fig. 17. UV-Vis spectra of Copper oxide nano-particles (CuONP) prepared by reacting Copper sulphete (CuSO4.5H2O).

Evaluation of effective chemical against Sheath Blight disease of rice, T. Aman 2020

To determine the efficacy of new fungicide(s) against sheath blight disease an experiment was conducted at BRRI Gazipur and Cumilla farm under artificial inoculation condition. Nineteen new fungicides with disease control and standard check (Nativo) treatment were tested. Thirty day-old seedlings of BR11 were transplanted with the spacing 20cm X 15cm having 2-3 seedlings/hill during T. Aman 2020. Plot size was 1m X 1m with 3 replications. The plants were inoculated with local *Rhizoctonia solani* culture grown on PDA medium at PI stage. Eight hills were inoculated from central area at random. New fungicides were sprayed at their recommended dose twice, first at five days after inoculation and second at seven days after the first spray. Data on relative lesion height (RLH) was taken at dough stage. Among 19, six fungicides such as Mukti 32.5 SC (Azoxystrobin 20% + Difeconazole 12.5%), Newtec 300 SC (Hexaconazole + Tricyclazol), Opec 32.5 SC (Azoxystrobin 20%+ Difeconazole 12.5%), Clean 75W (Tebuconazole 50%+ Trifloxystrobin 25% WDG) and Famous 60WG (Pyraclostrobin 5%+ Metiram) and Farmbin 32.5EC (Azoxystrobin 20%+ Difeconazole 12.5%) controlled sheath blight disease successfully (equal or above 80%) in both BRRI Gazipur and Cumilla Farm.

A Ara, M M Rashid, H A Dilzahan and M A Latif

Chemical control of sheath rot and false smut disease of rice under different planting time

The objective of this study was to identify most conducive time for sheath rot and false smut disease development and to find out effective fungicide/s against both diseases. Two variety BR11 for sheath rot disease and BRRIdhan49 for false smut disease were selected and transplanted at three different planting time (25 July, 9 August and 24 August) to find out the most conducive time for the development of both diseases. Six chemicals (Kemozole, Winatai, Safa, Armure, Pothic, and Trooper) with one check were sprayed two times to find out the efficacy of the fungicide/s against sheath rot and false smut disease of rice. Data on total tiller (TT), disease incidence (both false smut and sheath rot) were recorded.

Among two varieties sheath rot incidence was higher in BR11, on the other hand false smut incidence was higher in BRRIdhan49 (Fig. 17). The sheath rot incidence increased in the 09 August planting compared to the earliest planting (25 July), but reduced in the late plating (24 August). For false smut, the incidence increased progressively with the delay in planting (Fig. 18). The response of fungicides in controlling both sheath rot and false smut was not evident in this experiment (Table 31).

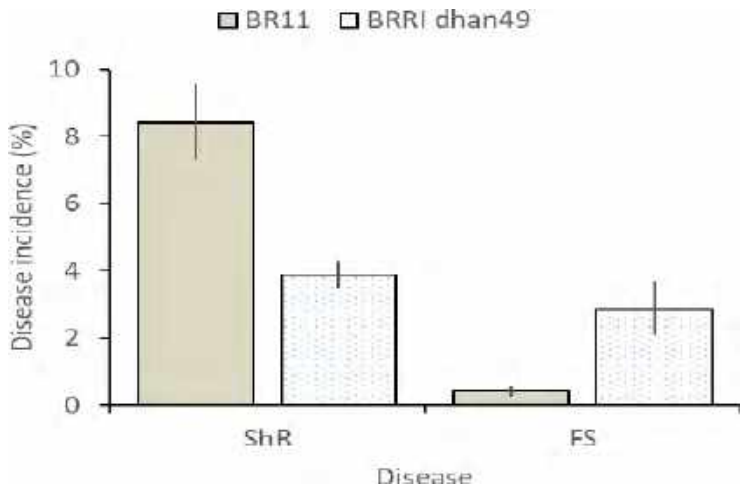

Fig. 18. Status of sheath rot and false smut disease on two varieties.

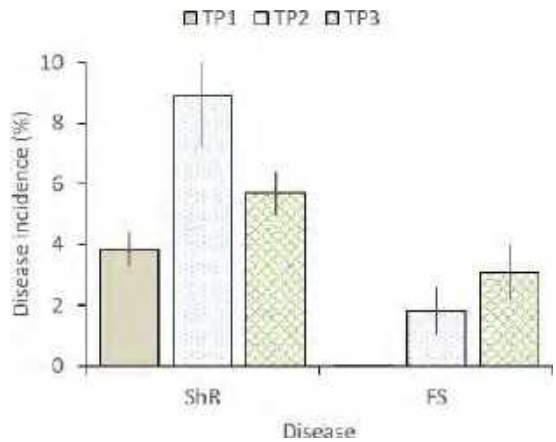

Fig. 19. Status of sheath rot and false smut disease on three transplanting time.

Table 31. Response of fungicide on the incidence of sheath rot and false smut disease

Fungicide	%ShR incidence	%FS incidence
Armure	6.87	1.68
Chemozole	5.66	2.35
Control	6.96	1.56
Pothic	5.61	1.47
Safa	5.69	1.51
Trooper	6.36	1.67
Winatai	5.89	1.29

TECHNOLOGY DISSEMINATION

Farmers training on integrated rice disease management

A total of eight batches of „day-long‟ training program were conducted in Gazipur, Satkhira, Cumilla and Bogra region. Each batches contained 35 farmers. Altogether 280 farmers were trained on rice disease and its management in changing climate of Bangladesh.

Rice Farming Systems Division

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SUMMARY

A long term cropping patterns trial consisting of eight cropping patterns were initiated at BRRI farm in last year 2020-21. In T. Aman season BRRI dhan87 yielded relatively higher (6.16 t ha^{-1}) than BRRI dhan71 and BRRI dhan75. In Rabi season, onion (11.20 t ha^{-1}), field pea (5.22 t ha^{-1}) mungbean (1.24 t ha^{-1}), potato (15.89 t ha^{-1}), pumpkin (25.34 t ha^{-1}), mustard (1.22 t ha^{-1}), bushbean (11.14 t ha^{-1}) and amranth (16.67 t ha^{-1}) were grown. Data of Jute is on processing and T. Aus is in the field.

A varietal combination of Boro and T. Aman in Boro - Fallow - T. Aman cropping pattern under supplemental irrigation was evaluated. In T. Aman season, BRRI dhan87 yielded significantly higher than BRRI dhan71 and BRRI dhan57, whereas in the Boro season, BRRI dhan58 produced significantly higher yeild than BRRI dhan63 with different varietal combination of T. Aman and Boro rice in Boro - Fallow - T. Aman cropping pattern. BRRI dhan87-BRRI dhan58 combination produced the highest total yield.

Four cropping patterns were tested using mustard, wheat, sesame, watermelon in T. Aman and Boro rice. Among the tested four cropping patterns, Mustard - Boro - T. Aman yielded relatively higher REY (16.06 t ha^{-1}), which was 19% higher than the existing Boro-Fallow-T. Aman cropping pattern.

In T. Aman and Boro season four anaerobic germination potential genotypes along with their donor, recipient and one drought tolerant genotype were tested in field flooded with 3-5 cm water. Among the tested genotypes, Ciherang-Sub1-*AG1-AG2* yielded significantly higher than the BR8210-10-3-1-2 line under flooding stress.

A study was conducted employing an on-farm cropping system research technique in Dhanbari upazila of Tangail district to intensify of Boro - Fallow - T. Aman cropping pattern with the inclusion of mustard in irrigated ecosystem of Madhupur Tract. BRRI dhan71, BRRI dhan75, and BRRI dhan87 were tested during the T. Aman season. Mustard (BARI Shorisha-14) was grown during the transition period. BRRI dhan89 and BRRI dhan92 were used during Boro season under the tested cropping pattern trial. Significantly higher REY (20.03 t ha^{-1}) and GM (147800 Tk ha^{-1}) was observed in BRRI dhan71 - Mustard - BRRI dhan92 and the lowest was observed in BRRI dhan49 - Fallow - BRRI dhan28 cropping pattern. The productivity of the existing cropping pattern of the irrigated ecosystem of the high and medium high land of Madhupur Tract soil might be boosted by including mustard in between T. Aman and Boro rice.

A total of 21 trials were conducted in different upazilas of Chittagong Hill Tracts during Aus and Aman 2020 through the inclusion of HYV Aus rice under Fallow - Fallow - T. Aman cropping system. In T. Aus season, the grain yield of BRRI dhan48 ranged from 4.21 to 4.66 t ha^{-1} and grain yields of BRRI dhan55 and BRRI dhan82 ranged from 4.22 to 4.41 t ha^{-1} and 4.37 to 4.61 t ha^{-1}, respectively. In T. Aman season, BRRI dhan75 produced grain yields ranging from 4.69 to 4.84 t ha^{-1} under the Fallow - T. Aus - T. Aman cropping pattern. BRRI dhan87 produced grain yields ranging from 5.27 to 5.78 t ha^{-1} at diverse locations. The higher total rice yield (10.39 t ha^{-1}) was observed from the pattern in combination with BRRI dhan82 and BRRI dhan87. T. Aus was added to the existing cropping pattern, which enhanced land productivity and farm income.

In a study of improving Jhum cultivation in hilly area by replacing indigenous rice with contemporary HYV Aus rice, grain yields of BRRI dhan48 ranged from 3.24 to 3.67 t ha^{-1}in the Jhum system. BRRI dhan83 produced a higher yield of 3.67 t ha^{-1} than the farmer's variety Bordhan (2.33 t ha^{-1}).

A trial was conducted in jhum system in hilly area in Aus 2020 to determine the best fertilizer management in HYV Aus rice in Jhum agriculture. Given farmers' preferences and ease of use, ring placement may be a feasible choice for efficient fertilizer management in the Jhum system, regardless of locations or varieties.

A study was undertaken in 30 farmers' field of different upazilas of Chittagang Hill Tracts during 2020-21 to enhance production by include mustard in the Boro - Fallow - T. Aman cropping pattern in piedmont plain land. T. Aman - Mustard - Boro, an improved cropping pattern, was tested and

compared to the conventional T. Aman - Fallow - Boro cropping pattern. In T. Aman season, BRRI dhan71, BRRI dhan75 and BRRI dhan87 were evaluated in the trials. Mustard (BARI Shorisha-14) was a transition period crop. In Boro season, BRRI dhan89 and BRRI dhan92 were tested in the trials. In the study area BRRI dhan49 in T. Aman season, BRRI dhan28 and Jonokraj (local) in Boro season were adopted as check. The higher REY (17.73 t ha^{-1}) was obtained from the pattern BRRI dhan75 - Mustard-BRRI dhan92. BRRI dhan92 has a higher yield, which has probably resulted in a higher REY. Given the rice equivalent yields, it is possible to deduce that by incorporating mustard in between T. Aman and Boro rice, the productivity of the present pattern might be enhanced, hence ensuring crop diversification and food security.

Under piloting of cropping pattern technologies programme, among the evaluated cropping patterns BARI Alu-32 - BJRI Tossa-8 - BRRI hybrid dhan6 cropping pattern had relatively higher REY (20.17 t ha^{-1}), which was 99% more yield than the existing cropping pattern, Boro - Fallow - T. Aman in Kishoreganj. In Khulna, introduction of Aus in existing CP, Watermelon - Fallow - T. Aman increase 18% more REY.

An improved *gher* system for tidal wetland non-saline ecosystem was developed through on-farm FSRD intervention approach at Kaliganj, Satkhira for maximizing the productivity of *gher* system by optimizing the land and water use and diversifying the production system to increase the farm income and family nutrition. The salient feature of the improved *gher* system is integration of Rice-Fish in *gher* and year-round intensive vegetables cultivation on dike. It is a unique system to provide carbohydrate, protein, vitamins and minerals around the year to ensure family nutrition and economic return. The average fish production was 3.73 t ha^{-1}, rice production was 5.72 t ha^{-1} and vegetables production was 3.93 t ha^{-1} from the *gher* system. The Gross margin (405152 Tk/ha) of improved *gher* system was 101% higher than the traditional *gher* system. The technology can be extrapolated in coastal area of non-saline tidal ecosystem.

CROPPING PATTERN DEVELOPMENT FOR FAVOURABLE ECOSYSTEM

Long term evaluation of rice based cropping pattern for input use, weed and pest infestation, productivity and soil health

A long term cropping pattern experiment was initiated and was carried out during 2020-21at BRRI research farm, Gazipur to determine the long-term implication of one, two, three, four and five cropped cropping patterns on system productivity, economics, weed and pest infestation, water and other input use, nutritional and energy output and soil health. Eight cropping patterns (CP) of CP_1: Boro (BRRI dhan92)-Fallow-Fallow; CP_2: Boro (BRRI dhan92)-Fallow-T. Aman (BRRI dhan87); CP_3: Boro (BRRI dhan88)-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan75); CP_4: Onion- Jute-T. Aman (BRRI dhan71); CP_5: Fieldpea-Mungbean-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan75); CP_6: Potato/Pumpkin (Relay) or Mungbean-T. Aus (BRRI dhan82)- T. Aman (BRRI dhan75); CP_7: Mustard-Mungbean-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan75); CP_8: Bush bean (BARI jharshim-1)-Onion-Amaranth (BARI sabuj data-1)-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan71) were tested in this study.

The yield of different T. Aman rice varieties in different treatments (CP_2, CP_3, CP_4, CP_5, CP_6, CP_7, CP_8) were 6.16 t ha^{-1} (BRRI dhan87), 5.03 t ha^{-1} (BRRI dhan75), 5.22 t ha^{-1} (BRRI dhan71), 5.14 t ha^{-1} (BRRI dhan75), 5.30 t ha^{-1} (BRRI dhan75), 5.04 t ha^{-1} (BRRI dhan75), 5.19 t ha^{-1} (BRRI dhan71). The yield of tested Rabi crops were 11.20 t ha^{-1} (onion), 5.22 t ha^{-1} (field pea), 1.24 t ha^{-1} (mungbean), 15.89 t ha^{-1} (potato), 25.34 t ha^{-1} (pumpkin), 1.22 t ha^{-1} (mustard), 11.14 t ha^{-1} (bush bean) and 16.67 t ha^{-1} (amaranth) (Table 1). Data of Jute is on processing and T. Aus is in the field.

Identification of rice variety in Boro - Fallow - T. Aman cropping system for sustainable productivity

The experiment was conducted during 2020-21 at BRRI research field, Gazipur to evaluate the suitability and performance of T. Aman and Boro varieties for sustaining the productivity in Bor -

Fallow - T. Aman cropping pattern. Following ten treatment combinations of T. Aman and Boro varieties and supplemental irrigation in T. Aman season were tested in RCB design with three replications.

The results illustrate that in T. Aman season, there was a significant yield difference among the varieties where BRRI dhan87 produced the highest yield (6.17 t ha^{-1}) and the lowest yield was given by BRRI dhan57 (3.65 t ha^{-1}) (Table 2). In Boro season, there was significant difference between the varieties. BRRI dhan58 produced higher yield than BRRI dhan63 in all the treatments. The highest yield of BRRI dhan58 was registered 6.61 t ha^{-1} from T_6 treatment. During T. Aman 2020 season, no supplemental irrigation was needed due to abundant rainfall. Considering the total rice yield from the pattern, Boro - Fallow - T. Aman, significantly higher yield (12.54 t/ha) was produced by T_2 followed by T_4 which was statistically similar with T_1, T_3, T_6 and T_8. The lowest cropping pattern yield of rice (9.36 t/ha) was found from BRRI dhan57-BRRI dhan63 varietal combination under treatment T_9. BRRI dhan87 and BRRI dhan58 produced maximum rice yield under Boro-Fallow-T. Aman cropping pattern.

Table 1. Yield of different crops under different cropping patterns, BRRI, Gazipur, 2020-21.

Treatment	Yield (t/ha)							
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8
Boro	7.61	7.43	6.63	-	-	-	-	-
T. Aus	-	-	-	-	-	-	-	-
T. Aman		6.16	5.03	5.22	5.14	5.30	5.04	5.19
Onion				11.20				-
Jute				-				
Field pea					5.22			
Mungbean					1.24		1.24	
Mustard							1.22	
Potato/pumpkin						15.89/ 25.34		
Bush bean								11.14
Amaranth								16.67

Note: Data of Kharif-1 crops was not included.

Treatment	T. Aman variety and crop management option	Boro variety
T_1	BRRI dhan87 + Supplemental irrigation (2-3)	BRRI dhan63
T_2	BRRI dhan87 + Supplemental irrigation (2-3)	BRRI dhan58
T_3	BRRI dhan87	BRRI dhan63
T_4	BRRI dhan87	BRRI dhan58
T_5	BRRI dhan71 + Supplemental irrigation (2-3)	BRRI dhan63
T_6	BRRI dhan71 + Supplemental irrigation (2-3)	BRRI dhan58
T_7	BRRI dhan71	BRRI dhan63
T_8	BRRI dhan71	BRRI dhan58
T_9	BRRI dhan57	BRRI dhan63
T_{10}	BRRI dhan57	BRRI dhan58

Table 2. Yield (t ha^{-1}) of different T. Aman and Boro rice varieties, BRRI, Gazipur, 2020-21.

Varietal combination + supplemental irrigation	T. Aman	Boro	Total
T_1= BRRI dhan87 + SI (2-3)-BRRI dhan63	5.85 abc	6.05	11.90 ab
T_2= BRRI dhan87 + SI (2-3)-BRRI dhan58	6.17 a	6.37	12.54 a
T_3= BRRI dhan87-BRRI dhan63	5.93 ab	5.90	11.83 ab
T_4= BRRI dhan87-BRRI dhan58	5.95 ab	6.56	12.51a
T_5= BRRI dhan71 + SI (2-3)-BRRI dhan63	5.27 bcd	5.80	11.07 bc
T_6= BRRI dhan71 + SI (2-3)-BRRI dhan58	5.03 cd	6.61	11.64 ab
T_7= BRRI dhan71-BRRI dhan63	4.84 d	6.04	10.88 bc
T_8= BRRI dhan71-BRRI dhan58	4.64 d	6.48	11.12 abc
T_9= BRRI dhan57-BRRI dhan63	3.65 e	6.09	9.36 e
T_{10}= BRRI dhan57-BRRI dhan58	3.71 e	6.42	9.74 c
CV (%)	5.57	5.49	4.31

*Means with the same letters are not significantly different

Productivity evaluation of different cropping patterns in medium high land and light texture soil.

The experiment was conducted at BRRI Research Farm Gazipur during 2020-21 with the four cropping patterns; CP_1: Mustard (BARI Sorisha-14) - Boro (BRRI dhan88) - T. Aman (BRRI dhan87), CP_2: Wheat (BARI Gom-32) - Sesame (Binatil-2) - T. Aman (BRRI dhan87), CP_3: Watermelon (Black horse) - Fallow - T. Aman (BRRI dhan87), CP_4: Boro (BRRI dhan88) - Fallow - T. Aman (BRRI dhan87). Among the tested four cropping patterns, Mustard - Boro - T. Aman yielded relatively higher REY (16.06 t ha^{-1}), which was 19% higher than the existing Boro - Fallow - T. Aman cropping pattern. (Table 3).

DEVELOPMENT OF CROPPING PATTERN FOR STRESS PRONE ENVIRONMENT

Effect of flooding stress on emergence, growth and yield of rice under anaerobic conditions in Boro - Fallow - T. Aman cropping pattern

The experiment was conducted at BRRI experimental farm, Gazipur during 2020-21 with the six genotypes tolerant to anaerobic condition induced by flooding during germination and one drought tolerant genotype (BR8210-10-3-1-2) having a bit flooding tolerance at early stage of life cycle. The genotypes were: 1. Ciherang-Sub1-*AG2*, 2. Ciherang-Sub1-*AG1-AG2*, 3. IR 15D 1055, 4. IR 15 D1037, 5. BR8210-10-3-1-2, 6. Ciherang-Sub1 (ck) and 7. Khao Hlan On (KHO). Emergence percentage, growth parameter, yield and yield components were recorded in both T. Aman and Boro seasons. In Boro season, among the tested genotypes, Ciherang-Sub1-*AG1-AG2* yielded significantly higher than BR8210-10-3-1-2 line but similar yield with other genotypes (Table 4).

Intensification of Boro - Fallow - T. Aman cropping pattern through the inclusion of mustard in irrigated ecosystem of Madhupur Tract.

This study used conducted following on-farm cropping system research methodology. Three villages of Jhupna, Mushuddi, and Shandalpur were chosen for this study, all of which are located in the Dhanbari upazila of Tangail district. A short PRA and FGDs were conducted to characterize the site. On-farm, farmer-managed validation trial of improved cropping pattern, Mustard - Boro - T. Aman was conducted in fifty farmer's fields during

Table 3. Yield and rice equivalent yield (REY) of different cropping patterns, BRRI, Gazipur 2020-21.

Treatment	Yield (t ha-^{1})			REY (t ha^{-1})
	Mustard/Wheat	Boro/Sesame	T. Aman	
CP_1: Mustard - Boro - T. Aman	1.54	6.33	6.26	16.06
CP_2: Wheat - Sesame - T. Aman	3.45	0.98	6.51	13.30
CP_3:Watermelon - Fallow - T. Aman	1.94	-	6.02	8.93
CP_4: Boro - Fallow - T. Aman	-	6.82	6.71	13.53

Price (Tk/kg): Rice = 20; Wheat = 28; Mustard = 45, Watermelon = 30, Sesame = 40

Note: Sesame was partially and watermelon was seriously damaged due to seepage from adjacent plot irrigation.

Table 4. Yield (t ha^{-1}) of different rice genotypes under flooding stress in Boro-Fallow-T. Aman cropping pattern, BRRI, Gazipur, 2020-21.

Treatment	T. Aman		Boro	
	Flood	Control	Flood	Control
Ciherang-Sub1-*AG2*	2.73	3.01	3.03	4.21
Ciherang-Sub1-*AG1-AG2*	3.14	3.70	3.15	3.80
IR 15D 1055	3.19	3.61	2.93	3.72
IR 15 D1037	2.91	3.27	2.92	3.56
BR8210-10-3-1-2	1.94	2.76	1.97	3.61
Ciherang-Sub1 (ck)	2.54	2.88	2.55	3.96
KHO (ck)	2.26	2.51	3.08	3.35
$HSD_{(0.05)}$	NS		0.94	

NS=not significant.

2020-21. Mustard (BARI Shorisha-14) was grown during the transition period. The tested cropping patterns were: BRRI dhan71 – Mustard - BRRI dhan89 (CP1), BRRI dhan71 – Mustard - BRRI dhan92 (CP2), BRRI dhan75 – Mustard - BRRI dhan89 (CP3), BRRI dhan75 – Mustard - BRRI dhan92 (CP4), BRRI dhan87 – Mustard - BRRI dhan89 (CP5), BRRI dhan87 – Mustard - BRRI dhan92 (CP6) and BRRI dhan49 – Fallow - BRRI dhan28 (CP7) (check). Cropping pattern based recommended fertilizer dose and other recommended management practices were followed. The activity was executed in collaboration with Department of Agricultural Extension. To compare system productivity, the mustard yield was converted to rice equivalent yield (REY).

Individual crop yield and REY of respective cropping patterns are presented in Table 5. In T. Aman season, grain yield of BRRI dhan71 ranged from 5.43 to 5.52 t ha^{-1} in different farmers' fields under T. Aman – Mustard – Boro cropping pattern. Under the tested cropping pattern, grain yield of BRRI dhan75 ranged from 5.57 to 5.66 t ha^{-1}, while grain yield of BRRI dhan87 ranged from 6.31 to 6.45 t ha^{-1} in different farmers' fields. The average grain yield of BRRI dhan49 was 4.78 t ha^{-1} as check. The yield of mustard ranged from 1.53 to 1.72 t ha^{-1} in different farmers' fields of the study area. Under the T. Aman – Mustard – Boro cropping pattern, grain yields of BRRI dhan89 ranged from 8.87 to 9.41 t ha^{-1}, whereas grain yield of BRRI dhan92 ranged from 9.32 to 9.87 t ha^{-1} in different farmers' fields during the Boro season. BRRI dhan28 yielded 5.67 t ha^{-1} as check (Table 5). The REY obtained from the pattern CP1, CP2, CP3, CP4, CP5, CP6 and CP7 were 19.54, 20.03, 19.45, 19.37, 19.99, 19.96 and 10.57 t ha^{-1}, respectively. The effect of cropping pattern on rice equivalent yield (REY) was significant ($P \leq 0.01$). The higher REY (20.03 t ha^{-1}) was observed in CP2 followed by the pattern CP5 (19.99 t ha^{-1}) and CP6 (19.96 t ha^{-1}) and the lowest was observed in CP7 (10.57 t ha^{-1}). The REY was statistically similar for the patterns CP1, CP3 and CP4. From the economic analysis, the higher gross margin (GM) was obtained from CP2 (1,47,800 Tk/ha) followed by CP5 (1,47,100 Tk/ha) and CP6 (1,46,600 Tk/ha). The lowest GM was observed in CP7 (32,900 Tk/ha). The pattern CP2, CP5 and CP6 gave 349%, 347% and 346% higher GM compare to the existing pattern CP7 (Table 6). BRRI dhan87 in T. Aman season, BRRI dhan89 and BRRI dhan92 in Boro season were quite high yielders and cropping pattern with these varieties provided the higher yield and delivered the higher economic return. Because of the intervention of suitable varieties in Boro and T. Aman and recommended management practices, Boro and T. Aman yields were increased considerably in improved cropping patterns. Together with this, the inclusion of mustard also boosted REY and GM. The productivity of the existing cropping pattern of the irrigated ecosystem of the high and medium high land of Madhupur Tract soil might be boosted by including mustard in between T. Aman and Boro rice, according to the total production and economic analysis. There is also the possibility of large productivity gains, which will aid crop diversity and food security.

Table 5. Yield of T. Aman, Mustard, and Boro under Madhupur Tract soil, Dhanbari, Tangail, 2020-21.

Cropping pattern	Yield (t ha^{-1})			REY (t ha^{-1})
	T. Aman	Mustard	Boro	
BRRI dhan71-Mustard-BRRI dhan89 (CP1)	5.43	1.72	9.33	19.54
BRRI dhan71-Mustard-BRRI dhan92 (CP2)	5.52	1.67	9.87	20.03
BRRI dhan75-Mustard-BRRI dhan89 (CP3)	5.57	1.61	9.41	19.45
BRRI dhan75-Mustard-BRRI dhan92 (CP4)	5.66	1.53	9.46	19.37
BRRI dhan87-Mustard-BRRI dhan89 (CP5)	6.45	1.68	8.87	19.99
BRRI dhan87-Mustard-BRRI dhan92 (CP6)	6.31	1.56	9.32	19.96
BRRI dhan49-Fallow-BRRI dhan28 (CP7) (Check)	4.78	-	5.79	10.57
CV (%)				3.2
LSD				0.26

Table 6. Economic performance of different Mustard – Boro – T. Aman cropping pattern under Madhupur Tract, Dhanbari, Tangail, 2020-21.

Cropping Pattern	GR ('000 Tk/ha)	TVC ('000 Tk/ha)	GM ('000 Tk/ha)
BRRI dhan71-Mustard-BRRI dhan89 (CP1)	351.8	212.7	139.1
BRRI dhan71-Mustard-BRRI dhan92 (CP2)	360.5	212.7	147.8
BRRI dhan75-Mustard-BRRI dhan89 (CP3)	350.1	212.7	137.4
BRRI dhan75-Mustard-BRRI dhan92 (CP4)	348.7	212.7	136.0
BRRI dhan87-Mustard-BRRI dhan89 (CP5)	359.8	212.7	147.1
BRRI dhan87-Mustard-BRRI dhan92 (CP6)	359.3	212.7	146.6
BRRI dhan49-Fallow-BRRI dhan28(CP7) (Check)	190.2	157.3	32.9

In the study site there were about 750 ha of land, out of which, Boro – Fallow – T. Aman cropping pattern covered 650 ha and other cropping patterns covered 100 ha of land (Table 7). About 6.6 ha land were brought under improved cropping pattern trial which gave yield advancement and high economic return as discussed in the earlier para. All the lands under Boro – Fallow – T. Aman cropping pattern of the site may not be possible to bring under this improved cropping pattern because of some environmental and socio-economic barrier. Field visit and FDG indicated that about 70% of the land of existing Boro – Fallow – T. Aman cropping pattern can be brought under improved cropping pattern of Mustard – Boro – T. Aman. If so, 623 t of mustard and Tk 2,83,10,100 GM can be produced from the site which certainly will improve the livelihood of the community.

Total cultivable land: 750 ha, ECP = Existing cropping pattern, ICP = Improved cropping pattern

Farmers are very happy with the mustard yield in between two rice. Most of them did not know that any high-value crops like mustard could be cultivated successfully during this transition period. Rice is their main crop and they are not interested to sacrifice rice yield. Through this study, they got extra benefit from mustard which helped them to curtail their household costs for edible oil.

DEVELOPMENT OF CROPPING PATTERN FOR HILLY AREA

Intensification of Fallow - Fallow - T. Aman area through the inclusion of modern Aus rice in plain land in hilly areas.

The study was conducted in farmers' field with the collaboration of Department of Agricultural Extension of four upazilas of Rangamati and Khagrachhari districts during 2020-21. Promising Aus varieties of BRRI dhan48, BRRI dhan55, and BRRI dhan82 and T. Aman varieties of BRRI dhan75 and BRRI dhan87 were evaluated where farmers' are commonly use BR11, BRRI dhan49 and Babilon in T. Aman season. A total of 21 trials were conducted in the studied area through the inclusion of HYV Aus rice under Fallow – Fallow – T. Aman cropping system.

The scenario of total rice yield of Fallow-T. Aus-T. Aman and Fallow- Fallow- T. Aman are presented in Table 8. The grain yield of BRRI

Table 7. Cropping pattern scenario of the study site after intervention of improved cropping pattern of Mustard-Boro-T. Aman, Dhanbari, Tangail.

Cropping pattern		Area (ha)	Target land area to be intervened (ha, % of the existing CP)	Predicted total mustard yield under ICP of the site (t)	Predicted total GM from ICP of the site (Tk)
ECP1	Boro-Fallow-T. Aman	650	195 ha, 30%	-	42,70,500
ECP2	Potato-Boro-T. Aman	100	100 ha, 100%	-	-
ECP3	Potato-Jute- T. Aman				
ECP4	Fallow-Fallow-T. Aman				
ECP5	Others				
ICP, Intervened CP	Mustard-Boro-T. Aman	6.6	455 ha, 70% (of 650 ha, ie, ECP)	623	2,83,10,100

Table 8. Yield of T. Aus and T. Aman rice in piedmont plain land, Chittagong Hill Tract, 2020-21.

Cropping pattern	Upazila	T. Aus variety	Yield (t/ha)	T. Aman variety	Yield (t/ha)	Total rice yield (t/ha)
Fallow -T. Aus-T. Aman	Rajasthali, Rangamati	BRRI dhan48	4.43	BRRI dhan75	4.84	9.27
Fallow -T. Aus-T. Aman	Dighinala, Khagrachhari	BRRI dhan48	4.56	BRRI dhan87	5.41	9.97
Fallow -T. Aus-T. Aman	Sadar, Khagrachhari	BRRI dhan48	4.39	BRRI dhan87	5.53	9.92
Fallow -T. Aus-T. Aman	Matiranga, Khagrachhari	BRRI dhan48	4.57	BRRI dhan75	4.78	9.35
Fallow -T. Aus-T. Aman	Rajasthali, Rangamati	BRRI dhan55	4.41	BRRI dhan87	5.62	10.03
Fallow -T. Aus-T. Aman	Dighinala, Khagrachhari	BRRI dhan55	4.35	BRRI dhan87	5.27	9.62
Fallow -T. Aus-T. Aman	Sadar, Khagrachhari	BRRI dhan55	4.22	BRRI dhan75	4.69	8.91
Fallow -T. Aus-T. Aman	Matiranga, Khagrachhari	BRRI dhan55	4.39	BRRI dhan75	4.74	9.13
Fallow -T. Aus-T. Aman	Rajasthali, Rangamati	BRRI dhan82	4.61	BRRI dhan87	5.78	10.39
Fallow -T. Aus-T. Aman	Dighinala, Khagrachhari	BRRI dhan82	4.46	BRRI dhan75	4.69	9.15
Fallow -T. Aus-T. Aman	Sadar, Khagrachhari	BRRI dhan82	4.37	BRRI dhan87	5.45	9.82
Fallow -T. Aus-T. Aman	Matiranga, Khagrachhari	BRRI dhan82	4.58	BRRI dhan87	5.72	10.3
Fallow –Fallow -T. Aman(check)	Rajasthali, Rangamati	-		BR11	3.36	3.36
Fallow –Fallow -T. Aman(check)	Dighinala, Khagrachhari	-		BRRI dhan49	4.18	4.18
Fallow –Fallow -T. Aman(check)	Sadar, Khagrachhari	-		BRRI dhan49	4.27	4.27
Fallow –Fallow -T. Aman(check)	Matiranga, Khagrachhari	-		Babilon	4.51	4.51

dhan48 ranged from 4.21 to 4.66 t ha^{-1}, BRRI dhan55 was 4.22 to 4.41 t ha^{-1} and BRRI dhan82 was 4.37 to 4.61 t ha^{-1}. In T. Aman season, BRRI dhan75 produced 4.69 to 4.84 t ha^{-1} and BRRI dhan87 produced 5.27 to 5.78 t ha^{-1} at the tested diverse locations. The higher total rice yield (10.39 t ha^{-1}) was observed from the pattern in combination with BRRI dhan82 and BRRI dhan87 at Rajosthali, Rangamati followed by the same combination at Matiranga, Khagrachhari (10.3 t ha^{-1}). T. Aus was added to the existing cropping pattern, which enhanced land productivity and farm income.

Improvement of jhum cultivation through the replacement of local rice with the modern Aus rice in hilly areas.

Thirty trials in Jhum cultivation system were conducted in seven upzilas of Bandarban, Rangamati and Khagrachhari districts with the collaboration of Department of Agricultural Extension during Aus 2020. Promising modern rice varieties like BRRI dhan48, BRRI dhan82, BRRI dhan83, BRRI dhan85 and BR26 were evaluated in the jhum cultivation system. In the study areas local farmers normally cultivated Khamarang, Khalabadia, Badui, Pidi, Ranqui, Mongthongno, Khoborok, Kokro, Churoi, Kanbui, Gallon, Compani, Amedhan, Gunda, Binni, Rangapati, Surjomani etc. which are low yielders. The majority of Jhumia farmers did not use fertilizer, pesticides, or other management practices. BRRI provided quality seeds, fertilizers, pest management measures as and when necessary. The grain yields of BRRI dhan48 ranged from 3.24 to 3.67 t ha^{-1} in Jhum system (Table 9). The higher yield of 3.67 t ha^{-1} was observed in Alikodom upazila of Bandarban district where the farmer's variety Bordhan yielded 2.33 t ha^{-1}. The grain yield of BRRI dhan82 ranged from 3.27 to 3.63 t ha^{-1}. The higher yield (3.63 t ha^{-1}) was observed at Rajosthali upazila under Rangamati district where the farmer's local variety Pidi produced 2.22 t ha^{-1} yield. BRRI dhan83 yielded 3.34 to 3.75 t ha^{-1}. The higher yield of 3.75 t ha^{-1} was observed at Alikodom upazila under Bandarban district where the farmer's local variety Kokro produced 3.17 t ha^{-1} yield. The grain yields of BRRI dhan85 ranged from 3.12 to 3.42 t ha^{-1}. The higher yield (3.42 t/ha) was observed at Matiranga upazila under Khagrachhari district where the farmer's local variety Surjomani produced 1.96 t ha^{-1} yield. Irrespective of location and variety, BRRI dhan83 produced higher grain yield at Alikodom (3.75 t ha^{-1}) where the locally adopted Kokro produced 3.17 t ha^{-1} under Jhum cultivation system. The grain yield of BRRI dhan26 ranged from 2.89 to 3.45 t ha^{-1}. The higher grain yield of BRRI dhan26 was 3.45 t ha^{-1} where the locally adopted Kapali produced

Table 9. Yield of Aus rice under Jhum cultivation, Chittagong Hill Tract, Aus 2020.

Upazila	HYV	Grain yield (t/ha)	Local variety	Grain yield (t/ha)
Sadar, Khagrachhari	BRRI dhan48	3.48	Khalabadia	2.16
Matiranga, Khagrachhari	BRRI dhan48	3.37	Badui	2.23
Baghaichhari, Rangamati	BRRI dhan48	3.41	Khamarang	2.09
Rajostholi, Rangamati	BRRI dhan48	3.58	Binni	2.27
Alikodom, Bandarban	BRRI dhan48	3.67	Bordhan	2.33
Thanchi, Bandarban	BRRI dhan48	3.24	Beti	1.89
Sadar, Khagrachhari	BRRI dhan82	3.41	Khalabadia	2.25
Matiranga, Khagrachhari	BRRI dhan82	3.27	Churoi	1.95
Baghaichhari, Rangamati	BRRI dhan82	3.33	Khamarang	2.19
Rajostholi, Rangamati	BRRI dhan82	3.63	Pidi	2.22
Rowangchhari, Bandarban	BRRI dhan82	3.39	Kanbui	3.09
Alikodom, Bandarban	BRRI dhan82	3.44	Bordhan	2.34
Sadar, Khagrachhari	BRRI dhan83	3.34	Shonamukhi	1.79
Matiranga, Khagrachhari	BRRI dhan83	3.48	Lankapora	2.07
Rajostholi, Rangamati	BRRI dhan83	3.51	Longur	2.18
Baghaichhari, Rangamati	BRRI dhan83	3.59	Gallon	2.29
Rowangchhari, Bandarban	BRRI dhan83	3.55	Mongthongno	3.32
Alikodom, Bandarban	BRRI dhan83	3.75	Kokro	3.17
Thanchi, Bandarban	BRRI dhan83	3.54	Binni	2.34
Sadar, Khagrachhari	BRRI dhan85	3.28	Amedhan	2.45
Matiranga, Khagrachhari	BRRI dhan85	3.42	Surjamoni	1.96
Rajostholi, Rangamati	BRRI dhan85	3.31	Bordhan	2.65
Baghaichhari, Rangamati	BRRI dhan85	3.36	Ranqui	3.19
Rowangchhari, Bandarban	BRRI dhan85	3.22	Gunda	1.88
Alikodom, Bandarban	BRRI dhan85	3.41	Gallon	2.27
Baghaichhari, Rangamati	BRRI dhan26	3.19	Kokro	3.21
Rajostholi, Rangamati	BRRI dhan26	3.45	Kapali	2.17
Alikodom, Bandarban	BRRI dhan26	3.37	Bordhan	2.43
Rowangchhari, Bandarban	BRRI dhan26	2.89	Mongthongno	3.12
Thanchi, Bandarban	BRRI dhan26	3.32	Khoborok	2.14

2.17 t ha^{-1} at Rajosthali upazila of Rangamati district. Among the local varieties, higher grain yield of 3.32 t ha^{-1} was obtained from Mongthongno followed by Kokro (3.21 t ha^{-1}) and Ranqui (3.19 t ha^{-1}) irrespective of location.

Farmers in ethnic minority societies expressed interest in sticky rice types with little aroma, such as Kanbui, Kokro, Pidi, and others. Drought resistant, strong tillering capacity, and high yielding varieties are also required for the Jhum system.

Fertilizer management in HYV Aus rice in Jhum cultivation

The experiments were conducted in jhum system at Matiranga upazila of Khagrachhari district, Rajasthali upazila of Rangamati district, Thanchi upazila of Bandarban district in Aus 2020. Four nitrogen (N) fertilizer treatments were used: T_1=Farmer's practice i.e. neither manure nor fertilizer (control), T_2=Localized placement (Ring placement around dibbing hole), T_3=Row placement in between dibbling lines, T_4= ½ Basal + ¼ at tiller initiation and ¼ at maximum tillering stage.

Promising modern Aus rice varieties like BRRI dhan48, BRRI dhan83 and BRRI dhan85 were used in the trials. Urea, TSP and MoP were applied as a source of N, P and K, respectively at the rate 60-10-40 kg/ha. TSP and MoP were applied in the dibbling hole during seeding. Urea was applied as per treatments. Normal cultural practices in cluding weeding and insecticide spraying were done when needed. The crop was plagued with common weeds, which were uprooted and removed. Insect attacks were reported, particularly by rice hispa and rice stem borer, which were controlled by spraning Diazinon and Malathion sprays. The seeds of rice were sown by dibbing method with the help of *tagol* (one kind of knife) in May 2020. The rice crops were harvested at maturity in September 2020.

Table 10. Yield of Aus rice under different fertilizer application methods in jhum cultivation system, Chittagong Hill Tract, 2020.

Treatment	Grain yield (t ha^{-1})				
	Variety	Matiranga	Rajosthali	Thanchi	Mean
T_1	BRRI dhan48	2.23	2.27	2.19	2.23
T_2	BRRI dhan48	3.57	3.58	3.41	3.52
T_3	BRRI dhan48	3.36	3.51	3.29	3.39
T_4	BRRI dhan48	3.48	3.34	3.50	3.44
T_1	BRRI dhan83	2.39	2.24	2.43	2.35
T_2	BRRI dhan83	3.65	3.54	3.49	3.56
T_3	BRRI dhan83	3.57	3.48	3.35	3.47
T_4	BRRI dhan83	3.49	3.42	3.27	3.39
T_1	BRRI dhan85	2.31	2.16	1.89	2.12
T_2	BRRI dhan85	3.39	3.48	3.61	3.49
T_3	BRRI dhan85	3.43	3.55	3.32	3.43
T_4	BRRI dhan85	3.31	3.42	3.53	3.42

The mean grain yield of BRRI dhan48 in Jhum system ranged from 2.23 to 3.52 t ha^{-1} under different N-treatments (Table 10). At Matiranga upazila under Khagrachhari district, the treatment T2 produced the higher yield (3.57 t ha^{-1}) followed by the treatment T4 (3.48 t ha^{-1}). The lowest grain yield (2.23 t ha^{-1}) was observed in T1 treatment. At Rajosthali upazila under Rangamati district, the treatment T2 produced the higher yield (3.58 t ha^{-1}) followed by the treatment T3 (3.51 t ha^{-1}). The lowest grain yield (2.27 t ha^{-1}) was observed in T_1 treatment. At Thanchi upazila, BRRI dhan48 yielded 2.19 to 3.50 t ha^{-1} under different N-treatments. The treatment T1 produced the lowest yield (2.19 t ha^{-1}). The mean grain yield of BRRI dhan83 ranged from 2.35 to 3.56 t ha^{-1}. At Matiranga upazila under Khagrachhari district, the treatment T2 produced higher yield (3.65 t/ha) followed by the treatment T3 (3.57 t ha^{-1}). The lowest grain yield (2.39 t ha^{-1}) was observed in T1 treatment. At Rajosthali the grain yield of BRRI dhan83 varied from 2.24 to 3.54 t ha^{-1} and the higher yield was obtained from the treatment T2 (3.54 t ha^{-1}). At Thanchi upazila under Bandarban district, the higher grain yield of BRRI dhan83 was observed with T2 treatment (3.49 t ha^{-1}) followed by T3 treatment (3.35 t ha^{-1}). The lowest grain yield (2.43 t ha^{-1}) was observed in T1 treatment. The mean grain yield of BRRI dhan85 ranged from 2.12 to 3.49 t ha^{-1}. At Matiranga upazila the treatment T3 produced the higher yield (3.43 t ha^{-1}) followed by the treatment T2 (3.39 t ha^{-1}). The lowest grain yield (2.31 t ha^{-1}) was observed in T1 treatment. At Rajosthali upazila the treatment T2 produced the higher yield (3.55 t ha^{-1}) followed by the treatment T3 (3.48 t ha^{-1}). The lowest grain yield (2.16 t ha^{-1}) was observed in T1 treatment. At Thanchi upazila BRRI dhan85 yielded 1.89 to 3.61 t ha^{-1} and the treatment T1 produced the lowest yield (1.89 t ha^{-1}). The treatments T3 and T4 produced the grain yields of 3.32 t ha^{-1} and 3.53 t ha^{-1}, respectively. Irrespective of location and variety, the treatment T2 performed better among all the treatments. Ring placement may be a viable option for efficient fertilizer management in the Jhum system, given farmers' preferences and ease of use. The experiment may be repeated in next year for valid conclusion.

Inclusion of mustard in Boro – Fallow –T. Aman cropping pattern in piedmont plain land

The study was conducted in thirty farmers fields of different upazilas of Bandarban, Rangamati and Khagrachhari districts under Chittagang Hill Tracts during 2020-21. The improved cropping pattern, T. Aman – Mustard – Boro was tested and evaluated compared to the existing T. Aman – Fallow – Boro cropping pattern. The tested cropping patterns were, CP1= BRRI dhan71 – Mustard – BRRI dhan89, CP2 = BRRI dhan71– Mustard – BRRI dhan92, CP3 = BRRI dhan75 – Mustard – BRRI dhan89, CP4 = BRRI dhan75 – Mustard – BRRI dhan92, CP5 = BRRI dhan80 – Mustard – BRRI dhan89, CP6 = BRRI dhan80 – Mustard – BRRI dhan92, CP7 = BRRI dhan87 – Mustard – BRRI dhan89, CP8 = BRRI dhan87 – Mustard – BRRI dhan92, CP9 = BRRI dhan49 – Fallow – BRRI

dhan28 , CP10 = BRRI dhan49 – Fallow – Jonokraj. Mustard (BARI Shorisha-14) was transition period crop. This activity was executed in collaboration with Department of Agricultural Extention. In the study area BRRI dhan49 in T. Aman season, BRRI dhan28 and Jonokraj (local) in Boro season were adopted as check. BRRI provided quality seeds, fertilizers and pesticides while rests of the management were done by the farmers. The yield of mustard was converted to rice equivalent yield (REY) for comparing the system productivity.

Total 11 prescuts individual crop yield and REY of respective cropping patterns. In T. Aman season, grain yields of BRRI dhan71 ranged from 4.53 to 4.92 t ha^{-1} in different farmers' fields under T. Aman – Mustard – Boro cropping pattern. The grain yields of BRRI dhan75 and BRRI dhan87 ranged from 4.81 to 4.98 t ha^{-1} and 5.27 to 5.33 t ha^{-1} under the tested patterns, respectively. The grain yields of BRRI dhan49 used as check ranged from 4.27 to 4.36 t ha^{-1} under T. Aman – Fallow – Boro cropping patterns. The mustard yield ranged from 1.33 to 1.62 t ha^{-1} under different mustard-based patterns. In the Boro season, the yield of BRRI dhan89 varied from 7.35 to 7.85 t ha^{-1} under respective cropping patterns. BRRI dhan92 yielded 7.84 to 8.47 t ha^{-1} where the locally adopted BRRI dhan28 and Jonokraj produced 4.91 and 6.8 t ha^{-1}, respectively. BRRI dhan87 in T. Aman and BRRI dhan92 in Boro season showed better performance among the tested varieties in the trials. The rice equivalent yield obtained from the pattern CP1, CP2, CP3, CP4, CP5, CP6, CP7 and CP8 were 16.13, 17.54, 16.27, 17.73, 16.86, 16.87, 9.27 and 11.07 t ha^{-1}, respectively. The higher REY (17.73 t ha^{-1}) was obtained from the pattern CP4 followed by the pattern CP2 (17.54 t ha^{-1}). BRRI dhan92 has a greater yield, which has probably resulted in a higher REY. Given the rice equivalent yields, it is possible to deduce that by incorporating mustard in between T. Aman and Boro rice, the productivity of the present pattern might be enhanced, hence ensuring crop diversification and food security. Farmers are ecstatic with the mustard output, which comes in between two rice crops. Most of them had no idea that high-value crops like mustard could be successfully grown during this phase of transition. Rice is their primary crop, and they have no desire to reduce rice productivity. They reaped other benefits from mustard, including lower household edible oil expenses.

PILOTING OF CROPPING PATTERN TECHNOLOGY

Piloting of cropping pattern technologies to increase the productivity in Kishoreganj and Khulna.

The study was conducted in Kishoregnaj and Khulna districts. In Pakundia and Kotiadi, Kishoreganj major crops are rice, wheat, jute, pulses and oil seed. Major cropping patterns of this area are Boro-Fallow-T. Aman and Boro-Fallow-Fallow. This upazila has 700 ha (6% of net cropped area) single cropped area and 6,580 ha double cropped area (54% of net cropped area) khatun et al. (2017). So, there is an ample opportunity to intervene in this 60% area of this upazila to

Table 11. Yield of component crops of Mustard – Boro – T. Aman cropping pattern in piedmont plain land, 2020-21.

Cropping pattern	T. Aman	Yield (t ha^{-1})		REY (t/ha)
		Mustard	Boro	
CP1=BRRI dhan71-Mustard- BRRI dhan89	4.53	1.35	7.85	16.13
CP2=BRRI dhan71- Mustard-BRRI dhan92	4.92	1.62	8.12	17.54
CP3=BRRI dhan75-Mustard-BRRI dhan89	4.81	1.48	7.35	16.27
CP4=BRRI dhan75-Mustard-BRRI dhan92	4.98	1.54	8.47	17.73
CP5=BRRI dhan87-Mustard-BRRI dhan89	5.27	1.49	7.45	16.86
CP6=BRRI dhan87-Mustard-BRRI dhan92	5.33	1.33	7.84	16.87
CP7=BRRI dhan49- Fallow- BRRI dhan28 (1)	4.36	-	4.91	9.27
CP8=BRRI dhan49-Fallow-Jonokraj (2)	4.27	-	6.8	11.70
CV (%)				3.9
LSD				0.46

increase the farm productivity through different cropping pattern technology. Among the evaluated cropping patterns BARI Alu-32 - BJRI Tossa Pat-8 - BRRI hybrid dhan6 CP had relatively higher REY (20.17 t ha^{-1}), 99% more yield than the existing CP, Boro-Fallow-T. Aman followed by Mustard-Corn+Blackgram-T. Aman (Table 12). In Khulna, introduction of Aus in existing CP, Watermelon - Fallow – T. Aman increase 18% REY. Taking into accounts the all cropping patterns across the country, Watermelon-T. Aus- T. Aman cropping patter provided highest REY (37.82 t ha^{-1}).

INTEGRATED FARMING SYSTEM RESEARCH AND DEVELOPMENT

Integrated farming research and development for livelihood improvement in the plain land eco system

Year round vegetables production in homestead

The activity was conducted at the FSRD site Tengra, Sreepur, Gazipur during 2020-21. BARI developed 'Goyeshpur' model was used in Sreepur, FSRD site for homestead year round vegetable production. Seeds of different vegetables were distributed among 12 farmers. Intercultural operation and management practices were done by the farmers following recommended practices. During kharif season sweet gourd, bottle gourd, bitter gourd, red amaranth and stem amaranth were sown in bed. On the other hand, during rabi season spinach, country bean, cucumber, red amaranth, radish, tomato, and pat shak were distributed.

After intervention vegetables and fruits, production of nine different niches was increased. Vegetables production was maximum during Kharif-2 season (79 kg/farmer) followed by Rabi (76 kg/farmer) and kharif-1 (55 kg/farmer). Among the nine production niches open sunny places (90 kg) were the most productive unit in homestead vegetables production followed by trellis (30 kg). Fruits production from other places of homestead was about 82 kg during February to December 2020.

Both vegetables production and income was increased after intervention. Most productive unit was open sunny place (90 kg/farmer) followed by trellis (30 kg/farmer). Minimum productive unit was roof top (4 kg/farmer) because farmers was not interested to use it. After intervention income was increased about 93% per farmer. Fruits production from other places of homestead was also increased about 51%.

Table 12. Yield and REY of different cropping patterns in Kishoreganj and Khulna 2020-21.

Location and CP	Yield (t ha^{-1})							REY (t ha^{-1})
Kishoreganj	Mustard	Potato/ Watermelon	Corn	Black gram	Jute/Aus	Boro	T. Aman	
Existing CP- BRRI dhan28-F-BRRI dhan72	-	-	-	-	-	6.02	4.12	10.14
Improved CP								
BARISharisha14-BRRI dhan88/96/HBD5-BRRI dhan87	1.45					6.14	5.89	15.29
BARIAlu32-BJRI tosha pat8-BRRI hybrid dhan6	-	17.36			2.39		5.51	20.17
BARI sharisha14-BARI hybrid bhutta9+BARI Mash1-BRRI HBD6	1.38		7.95	0.74			5.43	16.74
Khulna								
Existing CP- Watermelon-F-BR10	-	21.31	-	-	-	-	5.08	31.71
Improved CP: Watermelon (Pakija)-BRRI dhan48 - BRRI dhan87		23.12	-	-	3.59	-	5.33	37.82

Price (Tk/kg): Rice-20/-; Black gram- 50/-; Mustard-45/-; Watermelon-25/-; Potato-10/-; Corn-16/-; Jute- 50/-

Consumption, distribution and selling of vegetables increased about 18%, 116% and 114% respectively. After managing fruit trees consumption, distribution and selling of fruits were also increased about 47%, 40% and 57% respectively. Average cost of production per farmer per year was Tk 1,129 and average gross return per farmer from homestead vegetables production was Tk 5233. In case of fruits production in the homestead, average cost of production per farmer per year was Tk 740 and average gross return per farmer from homestead fruits production was Tk 2,540.

Improvement of the existing Boro - Fallow-T. Aman cropping pattern through inclusion of oil seed and pulse crops

The experiment was conducted during 2020-21 at the FSRD site Tengra, Sreepur, Gazipur. Two improved cropping patterns viz., CP_2: Mustard-Boro-T. Aman, CP_3: Mustard-Mungbean-T. Aus-T. Aman were tested against existing CP_1: Boro-Fallow-T. Aman cropping pattern. For each pattern three dispersed farmers were treated as replication. Rice variety BRRI dhan84 was used in Boro season. BRRI dhan48 was used in T. Aus and BRRI dhan71 was used in T. Aman season. In case of mustard and mungbean; BARI sorisha-14 and BARI Mung-6 were used, respectively. Average size of the plot was one bigha (35 decimal) per farmer. The management practices was followed as recommendation in the experiment. The yield of each crop was converted to rice equivalent yield for comparing the system productivity.

In CP_3 (Mustard-Mungbean-T. Aus- T. Aman) seed yield of mustard were 1.22 t ha^{-1}, yield of mungbean was 0.80 t/ha, grain yield of T. Aus rice was 4.62 t/ha and T. Aman rice was 4.86 t/ha in 2019-20 (Table 15). Farmers' pattern produced lower yield due to imbalanced use of fertilizers and poor management practices and varieties. Total productivity of four crops pattern and farmers pattern were evaluated in terms of rice equivalent yield (REY) and it was calculated from the yield of component crops. REY 17.03 t/ha/year was found in four crop pattern and farmers existing pattern produced 9.68 t/ha/year rice eqivalent yields. Inclusion of mustard and mungbean in rabi season in existing cropping pattern increased REY by 76% compared to farmer practice. From the economic point of view, Mustard-Mungbean-T.Aus-T.Aman cropping pattern showed its superiority over Boro-Fallow-T.Aman (farmers pattern) cropping pattern. Gross return of four crops pattern was found 305120 Tk/ha and farmers pattern was 174440 Tk/ha which was about 75% higher than farmer's pattern. The gross margin was significantly higher (264%) in four crops pattern (62720 Tk/ha) (Table 13). The marginal benefit cost ratio (MBCR) was found 1.53 which indicated the superiority of the four crops pattern over farmers' pattern. Farmer opinioned that cultivation of four crops in a year increased crop productivity undoubtedly but it is very difficult to manage.

Table 13. Yield and economic analysis of alternate and existing cropping pattern at the FSRD site during 2020-21.

Observation	Improved cropping pattern				Existing cropping pattern		
Crop	Mustard	Mungbean	T. Aus	T. Aman	Boro	Fallow	T. Aman
Seed /grain yield (t ha^{-1})	1.22	0.8	4.62	4.86	4.38	-	4.2
Straw yield (t ha^{-1})	2.12	-	5.07	5.32	5.05	-	4.87
Rice equivalent yield (t ha^{-1})	3.51	2.89	5.18	5.45	4.94	-	4.74
Whole pattern rice equivalent yield(t ha^{-1})	17.03				9.68		
Gross return (Tk ha^{-1})	305120				174440		
Total variable cost (Tk ha^{-1})	242400				157200		
Gross margin (Tk ha^{-1})	62720				17240		
MBCR	1.53						

Unit price (Tk. kg^{-1}): Rice= 18, Mustard=50, straw=2, Stover=1 and Mungbean= 65

An improved cropping pattern for highland in Madhupur Tract soil: Mustard-Mungbean-T. Aus-Blackgram

The experiment was conducted during 2020-21 at the FSRD site Tengra, Sreepur, Gazipur with six disperse replications. Improved cropping patterns: Mustard-Mungbean-T. Aus-Blackgram was tested against farmers existing Fallow-Fallow-T. Aman cropping pattern. Rice variety BRRI dhan48 was used in Aus season. BARI Sarisha-14, BARI Mung-6 and BARI Mash-4 were used in case of mustard, mungbean and blackgram, respectively. Average size of the plot was one bigha (35 decimal) per farmer. The yield of each crop was converted to rice equivalent yield for comparing the system productivity.

Total 14 presents yield and economic performance of improved and existing cropping pattern during 2020-21. In 2020-21, average grain yield in improved cropping pattern of Mustard (BARI Sarish-14)-Mungbean (BARI Mung-6)-T. Aus (BRRI dhan48)-Blackgram (BARI Mash-4) were recorded as 1.25, 0.87, 4.78 and 0.92 t ha^{-1}, respectively with rice equivalent yield (REY) of 14.65 t/ha/year where the existing cropping pattern Fallow-Fallow-T. Aman produced 4.35 t/ha yield of T. Aman (Swarna) with REY 4.83 t $ha^{-1}year^{-1}$ (Table 16). Total productivity of four crops pattern and farmers' pattern were evaluated in terms of rice equivalent yield (REY) and it was calculated from the yield of component crops. From the cost return analysis, it was observed that, in 2020-21 improved cropping pattern produced the higher gross margin (72,240 Tk/ha) over the existing cropping pattern. The average REY and gross margin of the improved four crop cropping pattern was increased by 196% and 385%, respectively compared to the farmers existing cropping pattern. The marginal benefit cost ratio (MBCR) was found 1.51 during 2020-21 which indicated the superiority of the four crops cropping pattern over farmers' pattern. Farmer opined that cultivation of four crops in a year increased crop productivity and income undoubtedly but it is very difficult to manage.

Semi-aquatic production system of vegetables, fish and fruit in mini pond

Semi-aquatic production system of vegetables, fish and fruit system in mini pond was conducted during 2020-21 at the FSRD site Tengra, Sreepur, Gazipur. Three derelict ponds were selected in the project site. Before planting aroids, land was prepared and basal fertilizers were applied. BARI panikachu-3 was transplanted January. About 60 days after transplanting Monosex Telapia was supplied in the pond and released maintaining stocking density: 80 piece/dec. Rabi (Bottle gourd, sweet gourd, country bean and yard long bean) and kharif (Snake gourd, sponge gourd, bitter gourd and ash gourd) vegetables were cultivated in trellis on the dyke of the pond. Fruits (Papaya) were cultivated on the bank of the pond. Data were collected according to the plan. Recommended management practices were followed for different crops. After about 60 days of transplanting, aroids started to give stolon and continued for 3 to 4 months. Aroids were harvested within seven months from planting.

Table 14. Yield and economic analysis of improved and existing cropping pattern at the FSRD site during 2020-21.

Observation	Improved cropping pattern				Existing cropping pattern		
Crop	Mustard	Mungbean	T. Aus	Blackgram	Fallow	Fallow	T. Aman
Seed /grain Yield (t ha^{-1})	1.25	0.87	4.78	0.92	-	-	4.35
Straw yield (t ha^{-1})	2.36	-	5.25	-	-	-	4.30
Rice equivalent yield (t ha^{-1})	3.59	3.14	5.36	2.56	-	-	4.83
Whole pattern Rice equivalent yield(t ha^{-1})	14.65				4.83		
Gross return (Tk ha^{-1})	263700				86940		
Total variable cost (Tk ha^{-1})	191460				74400		
Gross margin (Tk ha^{-1})	72240				12540		
MBCR	1.51						

Unit price (Tk kg^{-1}): Rice= 18, Mustard=50, straw=2, Stover=, Blackgram=50 and Mungbean= 65

Yield of stolon, aroid, vegetables and fish of the reporting period. The highest vegetables yield in dyke was 281 kg during 2020 from the mini pond of Farmer-1 (Table 15). Maximum yield of aroids (1600 piece) and stolon (855 kg) was also found in the pond of Farmer-1 during 2020 (Table 15). Maximum gross return from the pond of Farmer-1 was Tk. 60,350 followed by Farmer-2 18550 Tk. The lowest return oftained from the pond of Farmer-3 which was Tk. 4,550 Tk. Considering benefit cost ratio the highest BCR was found 5.12 followed by 5.11 and the lowest is 2.61.

Integrated cultivation of rice-fish in gher and intensive cultivation of vegetables on the gher dyke

Five non-saline ghers of four different farmers were selected to conduct this experiment at the FSRD site, Kaliganj, Satkhira during 2020-21. Vegetables of different species with suitable combination were selected that those could be cultivated on gher dyke in sequence and could be harvested round the year. T. Aman rice BR10 was cultivated along with fish in non-saline gher. The land rent (Tk 8500-12500 per 33 decimal lands for one year) was calculated under fish production. Trellis was used over the gher water body aside the dyke to use the space and creepers were allowed to climb on it. Recommended management practices and good agriculture practices were followed for the respective crop. Several fish species suitable for this environment were stocked in polyculture system before the start of rainy season. Integrated pest management systems were followed to avoid pesticide use.

The average production of rice, fish and vegetables were 5.72 t ha^{-1}, 3.73 t ha^{-1} and 5.93 t ha^{-1}, respectively (Table 16).

The average expenditure for five ghers was 346484 Tk/ha where average gross return and gross margin was 751676 Tk/ha and 405192 Tk/ha, respectively. The highest average BCR of 2.19 was for fish cultivation, followed by rice (2.13) and vegetables production (2.12) (Table 17).

Table 15. Yield and profitability level of different mixed farming combinations, Tengra, Sreepur, Gazipur 2020-21.

Year	Farmer's number	Area (m^2)	Veg. on dyke	Yield (kg)			Gross return (Tk)	TVC (Tk)	Gross margin (Tk)	BCR
				Aroid		Fish				
				Stem	Stolon					
2020	Farmer-1	1130	281	1600	855	185	75070	14700	60350	5.11
	Farmer-2	378	145	300	240	85	23050	4500	18550	5.12
	Farmer-3	140	-	100	45	40	7300	2800	4500	2.61

Vegetables: 20 Tk/kg, Aroid stem: 20 Tk/kg, Stolon: 20 Tk/kg, Fish: 110 Tk/kg

Table 16. Integrated rice, fish and vegetables production (t/ha) in non-saline gher system at FSR&D site, Kaliganj, Satkhira during 2020-21.

Farmer	T. Aman*	Fish**	Vegetable***
Mizanur Rahman	5.80	3.88	3.01
Jahanara	5.76	3.81	2.31
Monirul	5.86	4.19	3.76
Gobindo Mondol	5.50	3.55	5.43
Shubol Chandra	5.65	3.19	5.17
Average	5.72	3.73	3.93

Table 17. Cost and return (Tk/ha) of gher cultivation system at FSR&D site, Kaliganj, Satkhira during 2020-21 (average of five farmers).

Component	Expenditure	Gross return	Gross margin	BCR
Fish	256103	558880	302777	2.19
Rice	53594	114310	60716	2.13
Vegetables	36787	78486	41699	2.12
Total	346484	751676	405192	-

Price (Tk/kg): Rice = 20, Fish = 150, Vegetables = 20

Fig 1. Integrated rice-fish-vegetables production system in *gher*.

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SUMMARY

Per hectare, gross margin of rice cultivation in Aman season (Tk 76,518) was higher followed by Boro (Tk 68,304) and Aus season (Tk 43,817.2). Similarly, per hectare net returns for Aman (Tk 44,995) was higher, followed by Boro (Tk 34,159) and Aus paddy (Tk 13,660.2). Overall, rice cultivation was profitable at current years' due to higher yield and market price. Gross profit ratios are 40.66, 52.83 and 41.33 for Aus, Aman and Boro, respectively. A high-profit ratio is an indication that the farmers are selling their produce at high-profit level.

The majority of aromatic paddy produced in Bangladesh is grown in the districts of Dinajpur and Sherpur. BRRI dhan34 cultivated in 1.92 percent area of the Dinajpur district and 0.01 percent of the Sherpur district of Bangladesh's total Aman acreage and produced 2,55,615 and 1,789 tons of clean rice, respectively. At the same time, Tulshimala rice adopted 0.22 percent area of Sherpur district and produced 19,799 tons of clean rice. Both BRRI dhan34 and Tulshimala is profitable farm enterprise and also an important source of cash income. The Tobit marginal effects findings indicate that ln farm size, price difference, market demand, eating quality, extension service, distance to UAO, and credit are positive and significant. Increasing farm size, price difference, market demand, eating quality, extension service, distance to UAO, and credit would boost the adoption of more aromatic cultivars in the research region.

Rice seed production is dominated by Bangladesh Agricultural Development Corporation (BADC) through the production of truthfully labelled Seed (TLS) in its contract growing zones. Contract growers (CG) play a key role supplying seed to the farmers through BADC and non-contract growers (non-CG) supplies their seed to local farmers, dealers, and private seed companies etc. Good quality seed alone can increase the yield by 15-20%. The study was conducted in Tangail district taking 60 seed growers evenly from the contract and non-contract growers of both Aman and Boro seasons. In Boro season, CGs used 33 kg seed per hectare while non-CGs used 39 kg per hectare on average. Both type of growers used more fertilizer than the recommended dose in two seasons. In Boro season, the total cost of contract growers and non-contract growers was Tk 1,64,527 and Tk 1,57,684, respectively, while In Aman season, it was Tk 1,43,687 and Tk 1,37,623, respectively. In Boro season, the cost of seed production was Tk 27.11 per kg for CGs and Tk 25.46 for non-CGs, while in Aman season, it was Tk 28.05 for CGs and Tk 27.13 for non-CGs. Labor unavailability and the high wage rate of labor were the prime constraints of seed production. Mechanization in transplanting and harvesting is required to address as those practices are highly labor-intensive.

Haor areas usually contribute 18% to the national rice production. The cropping practices particularly Boro rice crop mainly depends on nature. Early flood, hailstorm and drought are the main constraints to grow modern Boro rice. This study aims to reveal the understanding of climate variability and marketing practices of the farmers as well as value chain actors in the *haor* areas. Purposive sampling technique was applied to select the study areas, namely, Ajmiriganj and Baniachong upazila of Habiganj district. Fifty farmers and 15 traders from each upazila were interviewed. About 79% and 83% of the respondent farmers of Ajmiriganj and Baniachong upazila, respectively, reported about increased temperature over last 20 years in their respective areas. Again, according to the 72% and 78% of the farmers from Ajmiriganj and Baniachong, respectively, the intensity of day time heat has increased over the last two decades. It is evident from the results that Baniachong is more affected than Ajmiriganj as the flood depth as well as recession duration is more in that case. Farmer-Bepari-Aratdar-Miller appeared as the most frequently used marketing channel in both the study areas. Paddy cultivation is appeared as more profitable for the farmers of Ajmiriganj in contrast to Baniachong. However, for both the study areas rice farming was a profitable enterprise considering both cash cost and full cost basis, due to the good price of paddy and straw last year.

At the expansion of telecommunication network and development of roads and transportation in the fur flung villages and higher use of mobile phone, has cut the length of marketing chain, though the price is being marked up absorbing the profit by the intermediary actor himself. In the midstream of rice value chains, consumers' demand-driven operation and changes were recorded. Furthermore, auto-rice millers reported an inclusive use of whitening and polishing rice to acquire the expected grain quality that has higher market demand. *Aratdar* and commission agents directly send paddy to auto-mills at a price mostly set by the millers. The resilience of the rice value chain is financed by the actors themselves.

The monthly wholesale price of four spatially separated rice markets namely, Dhaka, Rangpur, Sylhet and Barishal from 2012 to 2020 have been analyzed to investigate the market integration, price leadership and extent of price adjustment. The Johansen co-integration test discovered at least two co-integrating vectors implying that the four rice markets in Bangladesh during the study period linked together and therefore the long-run equilibrium is stable. Granger causality test revealed that Dhaka acts as the central market and leads the price of Rangpur, Sylhet and Barishal while Rangpur also leads the price of Sylhet and Barishal. All though, VECM confirms that all the four markets are poorly integrated in the short-run and only Sylhet and Barishal markets show convergence to the equilibrium in the long-run though the extent is trivial. Dhaka market shows more rigidity in case of long-run adjustment process to equilibrium followed by Rangpur. Results highlight the compulsion of government investment for better market infrastructure and transportation networks.

ESTIMATION OF COSTS AND RETURN OF MV RICE CULTIVATION AT THE FARM LEVEL

Economic decisions are primarily concerned with the most profitable level of input use in the production process. The viability of technology mostly depends on its cost and return. Therefore, it is indispensable to know the cost and return of rice cultivation, where farmers used different types of technologies. Moreover, through the cost and return analysis, researcher and planners can get an indication in developing a technology which will help the farmers in increasing return and reducing cost. Thus, the present study has been undertaken to assess the profitability of rice cultivation in the country with the following specific objectives:

- Determine the level of inputs used in MV Aus, MV T. Aman and MV Boro rice cultivation;
- Estimate the cost of MV rice cultivation in different seasons; and
- Evaluate the profitability of MV Aus, MV T. Aman and MV Boro rice cultivation at the farm level.

Multistage random sampling technique was adopted to select farmers from all the 14 agricultural regions of Bangladesh. Farm-level data on input use pattern, prices of inputs and outputs and yields were collected from 210, 280 and 280 farmers for the Aus, T. Aman and Boro season, respectively. Thus, the number of total respondents were 770 rice-growing farmers. Data were collected through face to face interview and over the telephone due to COVID-19 pandemic situation and nationwide lockdown using a structured questionnaire. Mainly, the descriptive statistical technique was applied to analyze the data, and tabular technique was used to present the results.

Cultivation costs

Per hectare, human labour costs were Tk 43,430, Tk 44,750 and Tk 51,540 for MV Aus, MV T. Aman and MV Boro rice cultivation, respectively. Fertilizer cost of Boro (Tk 13,055/ha) and T. Aman rice (Tk 87,97 /ha) was higher than that of Aus (Tk 6,450/ha) rice cultivation. Irrigation cost was higher (Tk 17,097/ha) for MV Boro rice cultivation than that of MV Aman (Tk 1,500/ha) (Table 2). Boro season irrigation cost was a bit higher than last year due to a considerable amount of rainfall did not occur during the season. Per hectare total variable cost of Boro rice and T. Aman rice cultivation were higher than in T. Aus season. (Table 2).

Table 1. Per hectare input used for MV rice cultivation in different seasons of Bangladesh, 2020-21.

Input item	Aus	Aman	Boro
Human Labour (man-day/ha):	101	105	118
Hired	39	36	38
Family	15	14	16
Hired contract (transplanting, weeding and harvesting)	47	55	64
Seed (kg/ha)	35	34	38
Fertilizer (kg/ha):			
Urea	137 (125)	148 (150)	191 (250)
TSP	69 (44)	52 (56)	76 (94)
MoP	71 (67)	93 (75)	105 (123)
DAP	78 (44)	91 (56)	148 (94)
Gypsum	13 (33)	35 (50)	55 (62)
ZnSo4	2 (7)	5 (7)	8 (10)
Mg	0	3	4.5
Theovit	2.5	4	5

Note: Parentheses indicate average BRRI recommended fertilizer doses (Adhunik Dhaner Chas, 2020). Source: Field survey 2020-21

Table 2. Per hectare cost of MV rice cultivation in different seasons of Bangladesh, 2020-21.

Input-wise cost (BDT/ha)	Aus	Aman	Boro
Seed	1925	2006	2470
Seedling development	2587	2461	2690
Land preparation (ploughing and laddering)	6621	6250	7445
Human labour:	43430	44750	51540
Hired	16770	14400	16340
Family	6450	5600	6400
Hired contract (transplanting, weeding and harvesting)	20210	24750	28800
Fertilizer cost	7017	8797	13055
Irrigation	0	1500	17097
Pesticide:	4722	5240	4991
Herbicide	447	1037	1086
Insecticide and fungicide	4275	4203	3905
Power thresher	4093	2917	4054
Total variable cost	63945	68321	96942
Interest on operating capital	1066	1423	2016
Land rent	22641	24500	25729
Total fixed cost	30157	31523	34145
Total cost	94102	99844	131087

Source: Field Survey 2020-21

Profitability

Per hectare yield of Boro paddy (6,253 kg) was higher, followed by T. Aman rice (4,610 kg) and T. Aus rice (4,234 kg). Due to the favourable climate, low paste and disease infestation and a considerable amount of irrigation facilities, Boro season rice yield was higher compared to the last year. Similarly, per hectare, gross margin of rice cultivation in Aman season (Tk 76,518) was higher followed by Boro (Tk 68,304) and Aus season (Tk 43,817.2) (Table 3). BCR based on cash cost was the highest (2.12) in Aman season, followed by 1.70 and 1.69 in Boro and Aus, respectively (Table 3). Gross profit ratios are 40.66, 52.83 and 41.33 for Aus, Aman and Boro, respectively. A high-profit ratio is an indication that the farmers are selling their produce at high-profit level.

Table 3. Per hectare profitability of MV rice cultivation in different seasons in Bangladesh, 2020-21.

Items		Aus	Aman	Boro
1	Total costs (Tk/ha) (2+3)	94102	99844	131087
2	Total variable costs (BDT/ha)	63945	68321	96942
3	Total fixed cost (BDT/ha)	30157	31523	34145
4	Yield (kg/ha)	4234	4610	6253
5	Market value of paddy (BDT/ha) (4*11)	96535.2	126314	156325
6	Market value of straw (BDT/ha)	11227	18525	8921
7	Gross benefit (GB) (BDT/ha) (5+6)	107762.2	144839	165246
8	Gross margin (GM) (BDT/ha) (7-2)	43817.2	76518	68304
9	Gross profit ratio ((GM*100)/GB)	40.66	52.83	41.33
10	Net return (BDT/ha) (7-1)	13660.2	44995	34159
11	Cost of production (BDT/kg)	22.23	21.66	20.96
12	Selling price of grain (BDT/kg)	22.8	27.4	25
13	BCR (cash cost basis) (7/2)	1.69	2.12	1.70
14	BCR (full cost basis) (7/1)	1.15	1.45	1.26

Source: Field survey 2020-21

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DRIVERS INFLUENCING ADOPTION DECISION OF AROMATIC RICE IN SOME SELECTED AREAS OF BANGLADESH: AN ECONOMETRIC APPROACH

Aromatic cultivars are grown throughout the country. More fragrant rice is produced in cooler regions. Many places in Bangladesh produce a lot of fragrant rice commercially, such as Dinajpur, Thakurgaon, Panchagarh, Rangpur, Naogaon, Rajshahi, Mymensingh, and Sherpur district. Bangladesh has approximately 54 aromatic and fine grain rice types that are cultivated in various parts of the country, which is worth mentioning. Given the importance of scented rice, Bangladesh Rice Research Institute (BRRI) has released seven aromatic and premium quality rice cultivars, including the BR5, BRRI dhan34, BRRI dhan37, BRRI dhan38, BRRI dhan70, BRRI dhan80 and BRRI dhan90. Kalijira, Chinigura, Kataribhog and Tulshimala are some of the indigenous fragrant varieties with thin grains and excellent smells.

Among the aromatic varieties in Bangladesh, BRRI dhan34 and Tulshimala are the widely adopted rice varieties, mostly cultivated in Bangladesh's Dinajpur and Sherpur districts. Therefore, the current research was intended to get a more profound knowledge of the economic insights and drivers of the most popular fragrant rice variety.

The research relied on both primary and secondary sources of information. We chose Dinajpur and Sherpur district purposively because of the greater adoption of aromatic cultivars during the Aman season. A random selection of two upazilas from each district was made. For face-to-face interviews, 100 farmers were randomly chosen. In order to interview the farmers, a pre-tested structured questionnaire was used. The data were analyzed using both descriptive and inferential statistics.

In 2020-21, BRRI dhan34 and Tulshimala rice were cultivated on 3.88 percent and 0.41 percent of Bangladesh's total Aman rice area, respectively, producing 5,06,548 and 35,667 tons. In particular, Dinajpur district adopted 1.92 percent of BRRI dhan34 and produces 2,55,615 tons of clean rice. In the Sherpur district, 0.01 percent of BRRI dhan34 and 0.22 percent of Tulshimala rice was adopted and produced 1,789 and 19,799 tons of clean rice, respectively. It should be emphasized that no Tulshimala rice was used in the Dinajpur district.

Profitability of BRRI dhan34 and Tulshimala rice cultivation

Table 4 shows the per hectare cost and returns of BRRI dhan34 and Tulshimala rice in the Dinajpur and Sherpur districts. The per hectare yields of BRRI dhan34 and Tulshimala aromatic varieties were 3.12 (ton/ha) and 2.97 (ton/ha). The per hectare gross income of BRRI dhan34 (BDT 1,62,375 t/ha) was

considerably higher than Tulshimala (BDT 1,47,007 t/ha), mainly because of the higher production per hectare and higher grain price of BRRI dhan34. Similarly, the net income of BRRI dhan34 (BDT 56,947/ha) was also higher than Tulshimala (BDT 44,708/ha). The results indicate that cultivation of BRRI dhan34 and Tulshimala were profitable farm enterprise and an essential source of cash income for the rural farm households.

Outcomes of the Tobit model

Table 5 shows the estimated outcomes from the Tobit censored regression models. Censored regression (Tobit model) contained the variables believed to help determine the acceptance choices of alternative rice varieties. To check off the dataset's diagnosis, multicollinearity and heteroscedasticity do not affect selecting the appropriate parameters. The F value always indicated the level of model fitness, and the current model has a greater level of overall significance.

Table 5 presents the findings of the Tobit censored regression model indicating that nine out of the sixteen variables used in the model (Tobit) were important in understanding the variability in the intensity of aromatic cultivars adoption.

The marginal effects show that ln farm size, price difference, market demand, eating quality, extension service, distance to UAO and credit are positive and significant. Implying increasing of ln farm size, price difference, market demand, eating quality, extension service, distance to UAO, and a credit will help to adopt more aromatic cultivars in the study area. While on the other hand, occupation only farming and yield difference was negative and significant means increasing these factors will decrease the adoption of aromatic cultivars in the research area.

AN ECONOMIC INVESTIGATION OF RICE SEED PRODUCTION STATUS IN A SELECTED AREA OF BANGLADESH

Understanding the seed production system requires studying the seed growers incorporating all the costs incurred in the process of making seed and identifying the different agronomical practices needed which is of utmost importance to see the difference between rice and seed production. The present study is aimed to find out the economics of rice seed production of both contract and non-contract growers during the Aman and Boro seasons as well as to document the constraints faced by the growers.

Madhupur upazila of Tangail district was purposively selected for the study as it is one of the largest contract seed growing zones of Bangladesh Agricultural Development Corporation (BADC). sixty seed producing farmers were randomly interviewed of which 30 were contract growers and the rest 30 were independent seed producing farmers. Boro and T. Aman seasons were taken into account these two are the prime rice growing

Table 4. Per hectare profitability of BRRI dhan34 and Tulshimala in 2020-21.

Item		BRRI dhan34	Tulshimala
1	Total costs (Tk/ha) (2+3)	105428	102299
2	Total variable costs (Tk/ha)	67841	69044
3	Total fixed cost (Tk/ha)	37587	33255
4	Yield (kg/ha)	3128	2965
5	Market value of paddy (Tk/ha) (4*11)	141792	126012
6	Market value of straw (Tk/ha)	20583	20995
7	Gross benefit (GB) (Tk/ha) (5+6)	162375	147007
8	Gross margin (GM) (Tk/ha) (7-2)	94534	77963
9	Gross profit ratio ((GM*100)/GB)	58.22	53.03
10	Net return (Tk/ha) (7-1)	56947	44708
11	Cost of production (Tk/kg)	33.70	34.50
12	Selling price of grain (Tk/kg)	45.33	42.5
13	BCR (cash cost basis) (7/2)	2.39	2.13
14	BCR (full cost basis) (7/1)	1.54	1.44

Source: Field survey 2020-21

Table 5. Estimation of Tobit model for determinants of adoption of aromatic rice varieties (n=100).

Variable	Coefficient	Robust standard error	Marginal effect
Age	0.00200	0.00202	0.0020
Education	-0.00590	0.00663	0.0059
Occupation only farming	-0.15439**	0.0630	0.1543**
Family size	0.00563	0.01881	0.0056
Family member involve in farming	0.00669	0.05782	0.00669
Ln farm size	0.09085***	0.02652	0.09085***
Price difference	0.04808**	0.02223	0.04808**
Market demand	0.19073***	0.07384	0.19073***
Eating quality	0.15915***	0.05840	0.15915***
Training	0.04503	0.04457	0.04503
Extension service	0.21002***	0.07933	0.21002***
Distance to UAO	0.03534***	0.00711	0.03534
Distance to local market	-0.02785	0.01881	0.02785
Credit	0.23836***	0.07372	0.23836***
Yield difference	-0.10914**	0.04730	0.10914**
Disease infestation	-0.06385	0.04687	0.06385
Constant	-0.83230	0.42663	
Log pseudo likelihood	-134.765		
Prob > F	0.000		
Pseudo R^2	0.791		
Breush-pagan Heteroskdasticity			
$chi^2(1)$	2.06		
Prob > chi^2	0.1514		
Mean VIF	1.79		

** and *** indicates significance at the 5 and 1 percent levels.

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seasons of the country. Mainly, the descriptive statistical technique was applied to analyze the data, and tabular technique was used to present the results obtained from the analysis.

The demographic table (Table 6) revealed that the average education years of contract growers were higher than the non-contract growers as BADC tends to select quality farmers emphasizing on farming experience, knowledge about rice farming, and level of education. The average farm size of the contract growers were larger by 407 decimals than the non-contract growers that justifies that BADC select farmers with more cultivable land.

Seedling age was the same for both contract and non-contract growers in Boro season but in Aman season, it was two days less in case of contract growers. Contract growers used more human labour as they had to do the intercultural operations (i.e., weeding, roguing, perching etc)

Table 6. Demographic profile of seed growers.

Particular	Contract grower	Non-contract grower
Family size (no.)	5	5
Age (year)	50	46
Experience (years)	24 (10)	20 (12)
Education (years)	9	5
Farm size (decimal)	695	288
Occupation		
Agriculture	90	94
Business	7	3
Service	3	3

Source: Field survey 2021

more intensively in contrast to non-contract growers in both the season. Moreover, having significantly larger farm sizes, CGs used more hired labour than the non-CGs. CGs used lower seeds than the non-CGs in Boro and Aman seasons by 6 kg/ha and 2 kg/ha (Table 7). To cultivate one acre of land CGs are provided with 10 kg foundation seed by BADC while non-CGs buy theirs from BADC or private companies, and sometimes they practice overdose for not knowing the exact amount required. Both the growers used TSP doubled the amount recommended by BRRI while DAP application was significantly lower.

Per hectare human labour cost by contract growers was 85,019 Tk for CGs and it was 78,032 Tk for non-CGs in Boro season (Table 8). In Aman season, per hectare human labour cost was Tk 82,057 for CGs while it was Tk 78,441 for non-CGs. Per hectare human labour cost of CGs in both the seasons was higher due to dependency on hired labour and reluctance to use family labour. In both Boro and Aman seasons, fertilizer cost by CGs was

Table 7. Input use pattern of seed growers in Boro and Aman season.

Input item	Boro		Aman	
	Contract grower	Non-contract grower	Contract grower	Non-contract grower
Seedling age	33	33	29	31
Transplanting date	13 Nov-25 Dec	16 Nov-16 Dec	06 Jun-19 Jun	03 Jun-02 July
Human Labour (man-day/ha):	170	156	164	157
Hired	59	58	59	58
Family	22	31	25	30
Hired contract	89	67	80	70
Seed (kg/ha)	33	39	36	38
Fertilizer (kg/ha):	649 (633)	610 (633)	567 (394)	512 (394)
Urea	264 (250)	206 (250)	224 (150)	170 (150)
TSP	174 (94)	167 (94)	148 (56)	159 (56)
MoP	130 (123)	148 (123)	126 (75)	126 (75)
DAP	21 (94)	28 (94)	22 (56)	11 (56)
Gypsum	52 (62)	54 (62)	44 (50)	44 (50)
ZnSo4	8 (10)	7 (10)	3 (7)	2 (7)

Note: Parentheses indicate average BRRI recommended fertilizer doses (Adhunik Dhaner Chas, 2020). Source: Field survey 2020-21

Table 8. Input-wise per hectare cost in Boro and Aman season.

Input-wise cost (BDT/ha)	Boro		Aman	
	Contract grower	Non-contract grower	Contract grower	Non-contract grower
Seed	1663	1947	1669	1761
Seedling development	503	484	477	543
Land preparation	11179	10323	10660	10456
Human labour:	85019	78032	82057	78441
Hired	29417	29206	29341	28817
Family	11047	15413	12607	14820
Hired contract	44555	33414	40109	34805
Fertilizer cost	12764	12040	10648	9473
Irrigation	17142	19247	6206	5269
Pesticide:	6019	5195	5142	4652
Herbicide	1543	629	871	689
Insecticide and fungicide	4476	4566	4271	3963
Power thresher	5153	5423	5331	5599
Total variable cost	128396	117281	109583	101375
Interest on operating capital	1070	977	913	845
Land rent	24014	24014	20583	20583
Total fixed cost	36131	40404	34104	36248
Total cost	164527	157684	143687	137623

Source: Field survey 2021

higher than the non-CGs. Total cost of contract growers and non-contract growers was Tk 1,64,527 and 1,57,684 respectively in Boro season while in Aman season it was Tk 1,43,687 and Tk 1,37,623 respectively.

Per hectare yield of CGs in Boro season was 6,070 kg and non-CGs was 6,194 kg. In Aman season, CGs per hectare yield was 5,121 kg while it was 5,072 kg for non-CGs. The gross margin for CGs in both the seasons was higher than the non-CGs. For CGs, BADC determines the seed price after analyzing the costs and market price. That's why CGs unit price was higher in both the seasons in comparison to non-CGs. The benefit-cost ratio (cash cost basis) was 1.97 for CGs and 1.59 for non-CGs in Boro season, while the benefit-cost ratio (cash cost basis) was 2.15 for CGs and 1.64 for non-CGs in Aman season.

Table 10 cultists Major constraints faced by the contract growers from which it is evident that unavailability of labour, high disease and insect infestation, and high wage rate of labour were the prime problems in the study area.

UNDERSTANDING CLIMATE VARIABILITY AND MARKET INSIGHTS OF RICE IN HAOR ECOSYSTEMS

Changing courses of the river systems and frequent monsoon flooding in Bangladesh gives a diverse wetland, such as rivers, baors (resulting from loss

Table 9. Profitability analysis of rice seed production.

Item	Boro		Aman	
	Contract grower	Non-contract grower	Contract grower	Non-contract grower
Total costs (BDT/ha)	164527	157684	143687	137623
Total variable costs (BDT/ha)	128396	117281	109583	101375
Total fixed cost (BDT/ha)	36131	40404	34104	36248
Yield (kg/ha)	6070	6194	5121	5072
Market value of paddy (BDT/ha)	245815	173430	207408	142009
Market value of straw (BDT/ha)	7294	13342	28416	24700
Gross benefit (GB) (BDT/ha)	253109	186772	235824	166709
Gross margin (GM) (BDT/ha)	124713	69491	126241	65334
Gross profit ratio (GM*100)/GB	49.27	37.21	53.53	39.19
Net return (BDT/ha)	88582	29087	92137	29086
Unit price of grain (BDT/kg)	40.5	28	40.5	28
Cost of production (BDT/kg)	27.11	25.46	28.05	27.13
BCR (cash cost basis)	1.97	1.59	2.15	1.64
BCR (full cost basis)	1.54	1.18	1.64	1.21

Source: Field survey 2021

Table 10. Constraints of rice seed production.

Constraint	% of respondent
Unavailability of labor	48
High disease and insect infestation	41
High wage rate of labor	35
Hailstorm and heavy rainfall	18
Drying and grading cost high	10
High irrigation cost	8
High price of insecticides	5

Source: Field survey 2021

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of river flows), beels and haors (natural depressions), and flood lands. The haor basin in the north eastern zone of Bangladesh is an important wetland ecosystem. The total area of the haor-type wetland ecosystem in Bangladesh is 80,000 square kilometers. The total cultivated area in seven haor districts is about 1.26 million hectares of which 0.68 million is under typical haor. Since haor goes under flooding (5-10 m) from late May to October, almost 80% of this area is covered by Boro rice, while only about 10% area is covered by T. Aman (wet season rice, cultivation period usually from June- July to October-November) production. Flood, especially flash flood causes severe damage to Boro rice just before harvesting almost every year. This study is important to find out the understandings as well as impacts of climate variability of rice cultivation in the haor ecosystem and get a market insight to derive policy implication for the haor areas.

Farm level data were collected from Ajmiriganj and Baniachong upazila of Habiganj during July 2021. Purposive sampling technique was applied to collect the data from 50 farmers and 15 traders from each upazila by structured questionnaire.

Table 11 illustrates the perception of farmers about climate change and extreme events over last 20 years in both the study areas. All the respondent farmers stated that they have the perception of climate change. About 79% and 83% of the respondent farmers of Ajmiriganj and Baniachong upazila, respectively, reported about increased temperature over the last 20 years in their respective areas. Again, according to the 72% and 78% of the farmers from Ajmiriganj and Baniachong, respectively, the intensity of day time heat has increased over the last two decades. Besides, respondent farmers of both the areas mentioned that events like unpredicted rainfall, changes of monsoon season, occurrences of drought, long summer season etc has been increased in their respective areas over the last 20 years.

Table 12 demonstrates the years of flood occurrence along with the arrival date, specific stages of the crop that time, flood depth, duration and recession date over the last 20 years in Ajmiriganj and Baniachong. In Ajmiriganj, severe flood occurred in 2004, 2017 and 2020 while Baniachong's farmers experienced it severely in 2016, 2017 and 2020 during the last 20 years. In almost every case, flood arrived at the end of the March to mid April that were too much prolonged as the recession time were end of October to mid November. Farmers also reported that most of the time the crops remain at heading, ripening or harvesting stage during the arrival of flood. It is evident from the results that Baniachong is more affected than Ajmiriganj as the flood depth as well as recession duration is more in that case.

Table 11. Farmers' perception on climate change and extreme events over last 20 years in Haor ecosystems.

	% farmers' response							
	Ajmiriganj				Baniachong			
	Increase	Decrease	No change	No response	Increase	Decrease	No change	No response
Perception of climate change	100				100			
Temperature	79	7	14	-	83	6	11	-
Intensity of day time heat	72	14	10	3	78	6	11	6
Rainfall	14	79	7	-	17	61	22	-
Unpredicted rainfall	62	10	7	21	78	17	-	6
Changes of monsoon season	38	21	24	17	28	6	17	50
Lack of surface water	21	28	38	14	17	44	22	17
Occurrence of drought	55	10	24	7	56	11	17	17
Downstream of flood	-	3	52	41	11	22	-	67
Occurrence of northwester	14	52	21	14	11	50	17	22
Short winter season	29	32	29	11	17	61	6	17
Long summer season	43	7	32	18	44	11	11	33
High cold	14	46	7	32	28	61	6	6

Source: Field survey 2021

Table 12. Yearly details about flood occurrence and crop stages.

Year	Arrival date	Crop stage	Flood depth (CM)	Duration (day)	Recession time (day)
Ajmiriganj					
2004	10 May	When harvesting	50-122	100-150	17 Oct
2017	5 Apr	Booting, flowering and Heading	76-200	20-120	15 Nov
2020	11 Apr	Ripening	40-190	75-150	15-30 Nov
Baniachong					
2016	29 Mar	Booting	91-450	150-210	30 Oct-10 Nov
2017	21 Mar	Heading	200-300	210	15 Nov
2020	11 Apr	Ripening	60-180	210	30 Oct-10 Nov

Source: Field survey 2021

Table 13 represents the variety wise affected area and yield loss due to flood occurred in the study areas in 2020. It is apparent that varieties that have comparatively longer duration are more affected by the flood. In Ajmiriganj, different hybrid varieties and BRRI dhan29 got severely affected in terms of area and yield while BRRI dhan28 experienced more damage in Baniachong as this area is abundant with this specific variety along with some hybrids.

Table 14 and 15 show the paddy marketing channel and nature of paddy sale along with marketing cost, respectively. Farmer-Bepari-Aratdar-Miller appeared as the most frequently used marketing channel in both the study areas. From Table 6, it is evident that about 84% and 95% of paddy of Ajmiriganj and Baniachong, respectively, being sold at farmgate just after the harvesting. Inadequate facilities of storage, poor transportation system force the farmers to do so. Rest of the paddy are being sold to the nearest local markets where vans and boats are the most frequently used vehicle for transporting paddy in Ajmiriganj and Baniachong, respectively. Farmers mentioned about high transportation cost due to poor transportation facilities which is also evident by the table as the average carrying cost is found as 22 and 20 Tk/maund in Ajmiriganj and Baniachong, respectively, though the average distance to market is not that much.

Table 13. Yield loss due to occurrence of flood in the study areas in 2020.

	Transplanting date	Harvesting	% Affected area	% Yield loss
Ajmiriganj				
Binadhan-7	25 Dec	3 Apr-18 April	4.56	58.33
BRRI dhan28	25 Dec	3 Apr-18 April	23.16	80
BRRI dhan29	15 Dec	28 Apr-30 May	20.17	99.38
Hybrid	15-25 Dec	15 Apr-30 May	52.11	98.18
Baniachong				
BR3	15-25 Dec	13-25 Apr	0.79	100.00
BRRI dhan28	15-25 Dec	13-25 Apr	69.82	89.91
Hybrid	15-25 Dec	13-25 Apr	26.50	89.29

Source: Field survey 2021

Table 14. Paddy marketing channel in the study areas.

Paddy marketing channel	Ajmiriganj	Baniachong
Farmer-Bepari-Aratdar-Miller	47	30
Farmer-Bepari-Miller	17	12
Farmer-Aratdar-Miller	13	0
Farmer-Bepari	4	12
Farmer-Millers' Agent	0	12
Farmer-Faria-Aratdar-Miller	4	6
Farmer-Faria-Bepari	9	0
Farmer-Miller	0	6
Farmers-Bepari-Ashuganj	0	18
Farrmers-Bepari-Bhairab	4	6

Source: Field survey 2021

Table 15. Nature of paddy sale and marketing cost.

	Ajmiriganj	Baniachong
Average farmgate sale (%)	86.2	94.6
Average local market sale (%)	15.8	5.4
Average distance from market	4.00	0.50
carrying vehicles (% farmers)		
Boat	0	22
In Head	0	11
Trolly	8	6
Van	42	17
Average carrying cost (Tk/md)	22	20
Boat	0	20
Trolly	25	20
Van	20	20

Source: Field survey 2021

Table 16 and 17 highlight the input use pattern and production cost along with profitability of the respondent farmers, respectively, in the study areas during Boro 2020-21. Results makes it evident that farmers of Baniachong used comparatively more hired labour than the farmers of Ajmiriganj. This is because, most of the lands which are used to paddy production located on the typical haor areas which require professional wage worker who have experience in cultivating paddy in that ecosystem. Again, the contract cost is also higher in case of Baniachong as it is one of remote areas which have very vulnerable transportation system. Respondent farmers of Baniachong use less fertilizer than the respondents of Ajmiriganj where the location might again play the role behind such practice. As a remotest area, farmers of Baniachong are not well aware about the optimum use of the inputs like fertilizer. Even extension personals are often feel difficulties to reach those farmers in time.

Due to higher labour cost and lower yield resulting from proper extension service and awareness, the gross return of farmers of Baniachong (BDT 1,19,996) is lower than that of Ajmiriganj (BDT 1,39,742). Paddy cultivation is appeared as more profitable for the farmers of Ajmiriganj as the benefit cost ratio on full cost basis is 1.68 compared to 1.33 which is the benefit cost ration of the farmers in Baniachong on full cost basis. However, for both the study areas rice farming was a profitable enterprise considering both cash cost and full cost basis, due to the good price of paddy and straw last year.

Table 16. Input use pattern of farmers in Ajmiriganj and Baniachong.

Input item	Ajmiriganj	Baniachong	Price	
			Ajmiriganj	Baniachong
Human labour (man-day/ha):	70	84	500	500
Hired	39	56	500	500
Family	32	28	500	500
Hired contract (transplanting, weeding and harvesting)	17665	22147	-	-
Seed (kg/ha)	22	30	199	56
Fertilizer (kg/ha):				
Urea	280	249	16	16
TSP	110	90	18	20
MoP	95	74	18	22
DAP	115	88	18	16
Gypsum	25	3	10	10
Sulpher	1	0	300	-
ZnSo4	3.5	2	180	150

Source: Field survey 2021

Table 17. Cost of production and profitability of respondent farmers in the study area.

Input-wise cost (BDT/ha)	Ajmiriganj	Baniachong
Seed	4400	1661
Seedling development	3344	3200
Land preparation (ploughing and laddering)	7370	6611
Human labour:	35154	42215
Hired	19297	28033
Family	15858	14182
Hired contract (transplanting, weeding and harvesting)	17665	22147
Fertilizer cost	11405	9157
Urea	4481	3986
TSP	1972	1792
MoP	1710	1631
DAP	2064	1411
Gypsum	248	33
Sulpher	300	0
ZnSo4	630	303
Irrigation	8517	8084
Pesticide:		
Herbicide	692	216
Insecticide and fungicide	2120	1531
Power thresher	3464	4337
Total variable cost	66868	75821
Interest on operating capital	557	632
Land rent	15698	14090
Total fixed cost	16255	14722
Total cost	83123	90542
Yield	6425	5517
Straw	6425	5517
Paddy price (Tk/kg)	21.25	21.25
Gross return	139742	119996
Gross margin	72875	44175
Net return	56619	29454
BCR (on cash cost)	2.1	1.6
BCR (on total cost)	1.68	1.33
Unit cost (Tk/kg) (total cost)	13	16

Source: Field survey 2021

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RESILIENCE OF RICE VALUE CHAIN: RECENT TRANSFORMATION AND VULNERABILITIES

Value chain resilience is conceptualized as the capacity of a value chain to continue and develop in its provision of food security and other services in the face of disturbances, through the preparation for, response to and recovery from unexpected shocks; the avoidance of tipping points; and adaptation to ongoing change (Vroegindewey and Hodbod, 2018). Bangladesh has clinched third place in global rice production with an increased output of 36 million metric tones in 2020-21 amid the pandemic situation and COVID-19-induced lockdown. It is undoubtedly an indication of inherent resilience of the rice value chains that has enabled the rice sector to grow through a quick adaptation to ongoing changes. Thus, this study has been designed to

- Revisiting rice value chains in the face of recent transformations and disturbances; and
- Scrutinizing the resilience and vulnerabilities of the rice value chain actors.

Mymensingh, Netrakona and Sherpur districts of Mymensingh division were selected purposively

for the study as these are the surplus areas in terms of rice production in Bangladesh. The study was based on information of farmers and traders of selected areas of Bangladesh where rice production, it's processing and value addition is highly concentrated. A total of 52 sample farmers and 65 different market actors were interviewed with structured questionnaires in June 2021. To get the data, interviews were conducted with key informants in the value chain. Collected data were feed into qualitative understanding in mapping the value chain and measuring resilience to changes and financial losses.

During the field survey different types of traders were found; namely Faria, Bepari, Aratdar, agent of rice miller and paddy processor, rice Aratdar, wholesaler and retailer. The sample paddy traders include Bepari and Aratdar, agent of rice miller, rice millers (husking, semi and auto), rice Aratdar, wholesaler and retailer.

Value chain structure. The overall findings showed that, at the upstream of the value chain in general, farmers mostly market their products with the help of Bepari. With the higher use of mobile phone, expansion of telecommunication network and development of roads and transportation and, it has become hard to differentiate among the roles of Bepari, Aratdar and commission agent now-a-days. Within a day of collecting the paddy from farmers, it is quite possible to send paddy to the auto-rice mills situated even in another regions. Undoubtedly, it cuts the length of marketing chain, though the price is being marked up absorbing the profit by the intermediary actor himself.

In the midstream of rice value chains, some consumers' demand-driven operation and changes were recorded. Traditional rice value chain contained in the rural area, is the local supply of paddy grown and consumed by the farm household or sold to the nearby market for local consumption. Numbers of semi-auto mills in the study area is falling drastically. Semi-auto mills mainly process paddy by single parboiling to cater the semi-urban consumers who prefer not to eat polished rice.

Surveyed auto-rice mills found collecting paddy across the country from different regions. Aratdar and commission agents directly send paddy to auto-mills (with prior contact or just informing over phone) at a price mostly set by the millers. These traders charge the upstream actors (like farmers and Bepari) at the same rate maintaining own profit.

The study result shows that, downstream rice value chain is characterized by a transitional approach that entails the rice traders (like Aratdar, wholesalers, branded wholesaler) buying directly from mills. Rice market all over the country seemed highly integrated. At the bottom of the value chain wholesale market traders sell the rice finally to retailers.

Longest and shortest rice value chains that connect large geographical areas are mentioned below:

Lengthiest Value Chain

Farmer → *Bepari* → Paddy *Aratdar-cum-commission agent* → Miller → (Semi-auto) → Miller (Auto-mill) → Miller (Semi-auto) → Rice *Aratdar* → *Aratdar*-cum-wholesaler → Retailer → Consumer

Shortest Value Chain

Farmer → *Aratdar* → Miller (Auto-mill) → Rice *Aratdar*-cum-wholesaler → Retailer → Consumer

Resilience and vulnerabilities of the rice value chain actors

Sample value chain actors were asked about major problems faced in recent years without referring any specific biophysical or market calamities. They were asked to rank the phases of rice value chain according to risks and vulnerability. Most of the farmers refer to yield and price (Table 18). Summary of the responses indicates that the drivers of resilience was not backed by direct government supports. It reveals that the COVID-19-induced lockdown was not imposed strictly in the rural areas. Moreover, the anticipation of pandemic driven famine influenced the farm price to hike.

Table 18. Farmers drivers to resilience and copping strategy.

Value chain phase	Drivers of resilience	Key disruption towards vulnerability	Impact of disruption	Copping strategy
Input acquisition	Easy access and availability of inputs in local market	• Paid higher prices • Visited multiple times as demand was high and sometime shops remained close • Quality not assured	• Higher cost of production	• Buying in smaller quantity • Contact over mobile phone
Farming	• High yielding varieties • Diligent family labour • Cropping patter suitability • Practical knowledge and experience • Growth oriented mind set and willingness	• Pest and disease • Timeliness of prevention • Labour cost and mechanization • Low return to investment	• Yield loss • low productivity • Financial pressure and dependence on other income sources	• Consultation and experience sharing • Renting out rice lands • Shifting to other crops
Processing	• Mechanization • Diligent family labour	Dependence on weather	• Impurities and moisture content	Early selling
Storing	• Easy to preserve for medium term • Personal arrangements	• Dependence on weather • Rats and insects	Inefficiency	Early selling
Transportation	Easy access and availability	High fare	• Added cost of marketing	
Market access	• Easy access to local markets • Personal contact with traders • Availability of price information	• Price volatility • Delayed payment by traders • Harassment in public procurement system	• No market power • Profit forgone	Belated selling

SPATIAL MARKET INTEGRATION AND PRICE TRANSMISSION OF RICE IN BANGLADESH: CO-INTEGRATION AND VECTOR ERROR CORRECTION MODEL APPROACH

In the last 30 years, many Asian countries including Bangladesh have executed market-oriented policies resulting in the lessening of government intrusion in agricultural markets especially rice markets that raise the concern of market inefficiencies in those markets at the same time. Unless agricultural markets are integrated, producers and consumers will not realize the gains from liberalization, since the correct price signals will not be transmitted through the marketing channels. Again, without spatial integration of markets, price signals will not be transmitted from urban food deficit to rural food surplus areas, prices will be more volatile, agricultural producers will fail to specialize according to long-run comparative advantage and gains from the trade will not be realized. Thus, analysis of co-integration and price adjustments of spatially separated markets of rice in a regular interval with updated data could be an effective approach to judge the market efficiency of the country. So, an attempt has been made here to analyze market integration and price transmission of four spatially different rice markets of Bangladesh.

The monthly wholesale price of rice of Dhaka, Rangpur, Sylhet and Barishal markets covering from 2012 to 2020 have been analyzed for the study. Data have been collected from the Department of Agricultural Marketing. Those four markets were selected for analyzing the market integration and price adjustment among the central (Dhaka), surplus (Rangpur), moderate deficit

(Sylhet) and moderate surplus (Barishal) market of the country in terms of the production and consumption of the respective area (Source: DAE, 2015), and obviously, based on the availability of the continuous price series from the data source. The logarithmic transformation has been done for all the four individual price series before analyses. Unit root tests were done by Augmented Dickey-Fuller (ADF) test whereas rank of co-integration was identified using Johansen co-integration test. Later, Granger causality and Vector Error Correction Model (VECM) were applied to find the price leadership and extent of price adjustment among the markets, respectively.

Table 19 presents the unit root test results for the four individual price series obtained by the ADF test confirming that the variables used in our study are integrated of order 1 i.e., all three series are I (1). These results permit us to apply the Johansen co-integration test to explore the number of co-integrating relations among the underlying variables.

Table 20 exemplifies the results obtained from Johansen co-integration test. For the multivariable model, the co-integration test is by using Johansen's maximum likelihood procedure based on two test statistics, namely, the trace and eigenvalue. The optimum lag was 1, based on the Akaike Information Criterion (AIC) and Schwartz Criterion (SC). The results of both Trace and Maximum-eigen statistics indicate the rejection of no co-integration as well as one co-integrating equation among the four markets. Therefore, there are at least two co-integrating equations in our estimation. This result implied that Dhaka, Rangpur, Sylhet and Barishal markets are co-integrated. The price of those markets may vary to a different level in the short-run but they are expected to move together as a system in the long-run during the study period. This necessitated the estimation of the movement of price in the long-run and short run, using VECM.

Table 21 demonstrates the highlights of Granger causality test. Before estimating the VECM, this causality test has been done to trace the price leader in the system. The results of causality tests are inferred from the F statistic. The results suggest that price changes in Dhaka Granger-cause price changes in Rangpur, Sylhet and Barishal at a 1% level of significance. Again, price changes in Rangpur Granger cause price changes in Sylhet and Barishal at a 1% and 5% level of significance, respectively. These findings justify the common perception that the price of Dhaka leads the price of Rangpur, Sylhet and Barishal which enables us to consider Dhaka market as the most dominant market among those four markets during the study period which is also belongs to the high deficit region at the same time. Furthermore, there are no causal relationship found between Sylhet and Barisal during the study period.

Table 19. Results of unit root test.

Market	Test statistics (H_0: The series has a unit root)				I(d)
	At Level	p-value	At First Difference	p-value	
Dhaka	-1.8376	0.3605	-6.8197	0.0000	I (1)
Rangpur	-1.5685	0.4951	-9.3372	0.0000	I (1)
Sylhet	-0.8857	0.7894	-8.5741	0.0000	I (1)
Barisal	-1.6432	0.4571	-8.4263	0.0000	I (1)

Source: Author's estimation

Table 20. Results of Co-Integration Analysis.

Null hypothesis	Trace statistic	Probability	Maximum-eigen statistic	Probability
r=0	70.79553	0.0001	36.04939	0.0032
r=1	34.74614	0.0124	22.16221	0.0357
r=2	12.58393	0.1310	10.34589	0.1902
r=3	2.238045	0.1346	2.238045	0.1346

Source: Author's estimation

Table 21. Results of Granger Causality Test.

Sourced market	Target market			
	Dhaka	Rangpur	Sylhet	Barishal
Dhaka		14.0483***	18.8414***	26.3121***
Rangpur	1.16632		13.8768***	4.15263**
Sylhet	0.2327	3.2491		0.88037
Barishal	0.00838	2.93927	3.91692	

Source: Author's estimation

Table 22 reveals the results of VECM analysis that has been done to measure the extent of price adjustment among the studied markets both in long-run and short-run. The short-run results from the VECM revealed that all the estimated short-run coefficients except for four are statistically insignificant at the 5% level. The coefficients' values range between 0.005 and 0.40. This suggests that the transmission of price changes from one market to another during the same month is weak. The speed of adjustment is given by the size of the adjustment coefficient. In both the co-integration equations, only coefficients of Sylhet and Barishal satisfy the necessary condition of being convergence to equilibrium. Therefore, Sylhet and Barishal adjust the price to equilibrium in the long-run after deviated in short-run. In equations 1 and 2, Sylhet showed faster adjustment (27% and 29%) than that of Barishal (21% and 27%), respectively. On the other hand, Dhaka showed the weakest adjustment (2%) in equation 1 followed by Rangpur (7%) in equation 2, even though these are not statistically significant. Therefore, the short-run results indicate that these four markets are not well integrated at short-run while long-run integration is evident by the sign and significance of the respective coefficients, suggesting that all the four considered markets do eventually move together in the long-run during the study period.

Table 22. Results of VECM analysis.

Variable	D (LSYL)	D (LBARIS)	D (LDHAKA)	D (LRANG)
CointEq1	-0.277458*** (0.07481)	-0.212669*** (0.05966)	-0.022505 (0.06565)	0.078847 (0.09236)
CointEq2	-0.294205*** (0.08730)	-0.272758*** (0.06962)	0.041789 (0.07661)	-0.071260 (0.10779)
D (LSYL (-1))	-0.037095 (0.11057)	0.089179 (0.08817)	-0.121133 (0.09703)	0.208868 (0.13652)
D (LBARIS (-1))	0.247042 (0.13808)	0.025911 (0.11011)	-0.070533 (0.12117)	-0.005129 (0.17048)
D (LDHAKA (-1))	0.283641 (0.15277)	0.245652** (0.12183)	0.378198*** (0.13406)	0.060613 (0.18862)
D (LRANG (-1))	-0.053080 (0.10078)	-0.078790 (0.08037)	0.038374 (0.08844)	0.076093 (0.12443)
C	0.002717 (0.00389)	0.002232 (0.00310)	0.002572 (0.00341)	0.002124 (0.00480)
R-squared	0.306043	0.325015	0.109728	0.196403
F-statistic	7.276676	7.944994	2.033652	4.032683
Log likelihood	195.1247	219.1188	208.9781	172.7814
Akaike AIC	-3.549522	-4.002241	-3.810907	-3.127951
Schwarz SC	-3.373635	-3.826354	-3.635020	-2.952064

Source: Author's estimation

Using monthly wholesale price data for the period 2012-2020 from four regional markets in Bangladesh, this study has investigated the nature and extent of market integration in the most recent era. The overall results of the market integration analysis indicate that, although Dhaka, Rangpur, Sylhet and Barishal markets are co-integrated i.e. they have a stable long-run relationship, these markets are only weakly integrated in the short-run. Granger causality results indicated that there was unidirectional causality originating from Dhaka to Rangpur, Sylhet and Barishal, and from Rangpur to Sylhet and Barishal while no causal relationship between Sylhet and Barishal. The short-run results indicate that these four rice markets are not well integrated at short-run while long-run coefficients confirm that Dhaka, Rangpur, Sylhet and Barishal markets do move together as a system in long-run. The price adjustment is the highest in case of moderately deficit market Sylhet followed by moderate surplus market Barishal while the lowest adjustment process was found for the high deficit but central market Dhaka followed by surplus market Rangpur during the study period. These results necessitate another investigation to find out the exact causes behind this kind of poor short-run co-integration and slow or no price adjustment among those markets in the long-run. However, past studies often define this condition as structural rigidity resulting from poor infrastructure, insufficient transportation networks, uneven market power, poor flow of market information etc. Thus, in order to make rice surplus region to be better integrated with deficit regions, the government should invest in better transportation and infrastructure facilities.

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Summary

Among the T. Aman varieties, no stable varietiey is found. while BR3, BR 25, BRRI dhan33, BRRI dhan39, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan70, BRRI dhan76, BRRI dhan77, BRRI dhan90 and BRRI dhan95 appeared to be below average stable. BR4, BR10, BR11, BR22, BR23, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan49, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan94, BRRI hybrid dhan4 and BRRI hybrid dhan6 were found having average stability among the T. Aman varieties. BRRI dhan91 was found as unstable varieties in T. Aman season. Among the aromatic rice BRRI dhan5, BRRI dhan34, BRRI dhan37 and BRRI dhan38 were found as below average stable in T. Aman season.

Many of our researchers are unfamiliar with the available bioinformatics methods, tools, and databases, which could lead to missed opportunities or misinterpretation of research findings. We review some of the key concepts, methods, software packages, and databases used in bioinformatics, with an emphasis on those relevant to rice research under this study.

Different statistical analysis such as principal component analysis, factor analysis, cluster analysis quantifies the perceived gain in experimental efficiency from using paired end rather than single end read data to provide reliable isoform specific gene expression estimates in RNA-Seq.

A web application named „Salary Management System‟ has been developed for BRRI HQ employees. Salary related all works starts under this application and it works successfully to till now. Also, BRRI‟s labour management system (LMS) and casual leave (CL) application system have been degitalized.

BR11 and BR22 was recorded the highest average grain yielder and ideal genotypes among long duration varieties, and BRRI dhan49 was the most stable genotype with above-average yield in medium duration where BRRI hybrid dhan6, BRRI dhan87 were the most stable genotypes and above average yielder for short duration. In long duration, accordingly three mega-environments were identified and the winning genotype in those environments was BR11 and BR22 for the first; BR22 and BR10 closed the second mega environment. BR10 and BRRI dhan76 were the winaing genotype for the thirld mega-environment as long duration varieties. In medium duration, the biplot grouped the test locations into three mega-environments and BRRI dhan54 was the winning genotype in the first mega-environment while BRRI dhan49 was the winner in the second and BRRI dhan51 was the winner in the last mega-environment. Also, two mega-environments were identified in short duration, BRRI dhan87, BRRI hybrid dhan6, BRRI dhan95 were the winning genotypes for respective mega environment. Among the study locations, Sonagazi for long duration, Kushtia and Rajshahi for medium duration and Satkhira and Rajshahi showed the ideal and highly representative environment for testing short duration genotypes respectively.

For reducing micro climatological risk factors weather based rice advisory systems considers and manage the full spectrum of risks from weather extremes or climate variability. This novel approach can help rice growers in a better and more coordinated way in response to weather extremes or climate variability that exceeds their inherent coping capacity. This can significantly reduce the disaster risk of the rice farming communities, which is a major development challenge in Bangladesh.

In fertilizer experiment, BR26 produced the highest average yield (4.24 t/ha) at 80 kg N/ha, BRRI dhan48 and BRRI dhan82 produced the highest yield 4.42 t/ha and 4.14 t/ha at 60 kg N/ha, respectively. The highest average yielder variety were found BRRI dhan48 (4.17 t/ha) when applied Alternate Wetting and Drying 30cm and and lowest was BRRI dhan82 (3.62 t/ha) when rainfed condition for irrigation experiment. In time of planting experiment, the highest and lowest performance was found BRRI dhan48 when the transplanting time 10 May (4.29 t/ha) and BRRI dhan82 (3.53 t/ha) when the transplanting 10 May, respectively.

In Aman season, BRRI dhan90 is suitable in north and north-west parts and BRRI dhan91 is suitable in western side and some central-western side of Bangladesh. Central north and central west part of Bangladesh are more suitable for BRRI dhan92 in Boro season.

More or less in all season eastern side of Bangladesh is characherised by high rainfall and low temperature area and western side as low rainfall and high temperature area.

In Rabi season, 41% croped area, 11% is fallow land, 30% homestead and land, 2% settlement, 2% water, 8% forest and 6% valley of Habiganj district.

About, 11% area of Bangladesh affected by flood 2020. These areas are mainly north-central and north-eastern part of Bangladesh.

In the reporting year, two types of training were conducted under "Capacity Building through Training" programme. A total of 68 participants were trained through the training programmes. The participants of these training were scientists and SA, FM and AFM of BRRI.

ICT cell of this division has developed „BRRI Rice doctor‟ mobile and web apps both in English and Bengali version with the help of different divisions of BRRI. Developed dynamic view connectivity, Bangla search and inner banner system for BRKB web apps. Besides this cell, modified RKB mobile apps and developed push notification for RKB and Initiatives have been taken to strengthen and disseminate modern rice technology and its management information at the farmers door step through RKB Mobile Apps.We developed Vehicle Requisition Management System (VRMS) of BRRI. So that, the requester informed through SMS on the basis of demanding vehicle for official or personal purpose as well as driver get confirmation SMS for their upcoming duty. Also, we developed "BRRI Alapon" Telephone Directory Mobile App. We established video conferencing system (VCS) at BRRI to communicate with Ministry of Agriculture and other government organizations.We organized five-day-long, two day-long, day-long „Public Service Innovation‟ training workshops in the reporting year. A total of 350 participants were trained through the innovation, SPS trainings and e-Nothi in-house trainings. In addition, Cyber security system has been strengthened for BRRI

STABILITY ANALYSIS OF BRRI VARIETIES

The main objectives of the study were to determine the stability index of BRRI released varieties, maintain season, year and location-wise database and identify the bio-physical and socio-economic factors causing instability. Experiments are being conducted in T. Aman season with BRRI released rice varieties since 2001-2020 at Gazipur and different regional stations. The collaborative regional stations in the T. Aman season are Rajshahi, Rangpur, Cumilla, Sonagazi, Barishal, Satkhira and Kushtia. In T. Aman, the numbers of varieties were 47. The design was RCB with three replications and the effective plot size (harvest area) was 3×2 m^2, leaving the two border row from each side. Recommended crop management practices were followed. Stability analysis of the experimental data were performed by using a newly developed model. The model deals with the performance of the genotypes across the geographical locations differing in land, soil and other biotic and abiotic factors over the years characterizing fluctuation of weather variable, floods, drought etc.

Among the T. Aman varieties, BRRI dhan49, BRRI dhan79 and BRRI dhan87 were found stable with stability index 2.01, 2.05 and 2.03 respectively while BR3, BR 25, BRRI dhan33, BRRI dhan39, BRRI dhan56, BRRI dhan57, BRRI dhan62, BRRI dhan70, BRRI dhan76, BRRI dhan77, BRRI dhan90 and BRRI dhan95 appeared to be below average stable. BR4, BR10, BR11, BR22, BR23, BRRI dhan30, BRRI dhan31, BRRI dhan32, BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan66, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan78, BRRI dhan80, BRRI dhan93, BRRI dhan94, BRRI hybrid dhan4 and BRRI hybrid dhan6 were found having average stability among T. Aman varieties. BRRI dhan91 was found as unstable varieties in T. Aman season. Among the aromatic rice BRRI dhan5, BRRI dhan34, BRRI dhan37 and BRRI dhan38 were found as below average stable in T. Aman season (Table 1).

Table 1. Stability parameters of grain yield for T. Aman.

Variety	Stability parameter 2001-2020			Stability index	Stability rank	Nature of stability
	Si	Di	Pi	Gi	Ri	
Non-aromatic rice						
BR 3	18.73	-8.82	85.00	0.71	37	BAS
BR 4	12.64	1.32	82.00	1.14	22	AS
BR 10	13.89	9.87	70.00	1.23	16	AS
BR 11	14.18	8.15	79.00	1.24	15	AS
BR 22	14.17	7.58	81.00	1.24	14	AS
BR 23	15.45	3.46	82.00	1.08	28	AS
BR 25	15.57	0.33	77.00	0.99	31	BAS
BRRI dhan30	12.87	7.61	82.00	1.32	10	AS
BRRI dhan31	14.23	2.80	81.00	1.10	25	AS
BRRI dhan32	16.19	8.82	85.00	1.24	13	AS
BRRI dhan33	19.70	-10.02	76.00	0.60	40	BAS
BRRI dhan39	18.17	-1.35	71.00	0.84	35	BAS
BRRI dhan40	13.96	6.99	84.00	1.26	12	AS
BRRI dhan41	16.09	5.82	84.00	1.14	21	AS
BRRI dhan44	14.32	8.60	56.00	1.21	18	AS
BRRI dhan46	16.11	2.96	54.00	1.02	30	AS
BRRI dhan49	10.51	13.11	48.00	2.01	3	S
BRRI dhan51	14.15	5.71	38.00	1.13	23	AS
BRRI dhan52	9.74	9.90	43.00	1.55	4	AS
BRRI dhan53	14.90	3.94	35.00	1.09	26	AS
BRRI dhan54	18.26	8.60	35.00	1.12	24	AS
BRRI dhan56	16.77	-3.75	35.00	0.83	36	BAS
BRRI dhan57	21.95	-19.98	39.00	0.36	43	BAS
BRRI dhan62	27.25	-21.44	29.00	0.23	46	BAS
BRRI dhan66	13.08	6.40	28.00	1.29	11	AS
BRRI dhan70	18.76	-9.93	23.00	0.66	39	BAS
BRRI dhan71	11.44	8.86	20.00	1.33	9	AS
BRRI dhan72	11.66	14.46	19.00	1.45	6	AS
BRRI dhan73	15.78	7.01	25.00	1.22	17	AS
BRRI dhan75	15.42	2.98	23.00	1.08	27	AS
BRRI dhan76	14.65	-3.06	23.00	0.95	32	BAS
BRRI dhan77	13.68	-5.89	24.00	0.93	33	BAS
BRRI dhan78	9.78	5.11	14.00	1.42	8	AS
BRRI dhan79	7.55	10.28	13.00	2.05	1	S
BRRI dhan80	9.34	5.50	13.00	1.43	7	AS
BRRI dhan87	11.32	22.11	11.00	2.03	2	S
BRRI dhan90	NA	-13.14	9.00	0.66	38	BAS
BRRI dhan91	NA	-38.54	9.00	0.00	47	US
BRRI dhan93	NA	6.50	9.00	1.17	20	AS
BRRI dhan94	NA	1.76	9.00	1.05	29	AS
BRRI dhan95	NA	-3.37	9.00	0.91	34	BAS
BRRI Hybrid dhan4	15.98	6.55	32.00	1.20	19	AS
BRRI Hybrid dhan6	13.57	17.77	16.00	1.46	5	AS
Aromatic rice						
BR 5	19.02	-22.48	76.00	0.30	44	BAS
BRRI dhan34	18.94	-26.15	80.00	0.23	45	BAS
BRRI dhan37	17.52	-22.57	84.00	0.37	42	BAS
BRRI dhan38	16.34	-20.37	81.00	0.45	41	BAS

Note: AS=Average stable, BAS=Below average stable, S=Table, US=Unstable

SCOPES OF BIOINFORMATICS IN RICE RESEARCH

Bioinformatics plays an essential role in today‟s biological science. As the amount of molecular data grows exponentially, there is a parallel growth in the demand for tools and methods in data management, visualization, integration, analysis, modeling, and prediction. Now, many of our researchers are unfamiliar with the available bioinformatics methods, tools, and databases, which could lead to missed opportunities or misinterpretation of research findings. The main objective of the study is to (i) Review the application of bioinformatics in rice research and (ii) Develop analytical skills on the application of bioinformatics in rice research.

Under this study, we review some of the key concepts, methods, software packages, and databases used in bioinformatics, with an emphasis on those relevant to rice research and we found that Bioinformatics is an interdisciplinary research area. It is the discipline of quantitative analysis of information relating to biological macromolecules such as DNA, RNA and proteins using appropriate tools (e.g., statistical, mathematical, biological database, etc.) with the aid of computers. The ultimate goal of bioinformatics is to better understand a living cell and how it functions at the molecular level.

As the amount of molecular data grows exponentially in the world, the demand for Bioinformatics is equally growing with the molecular data. Also the subfields of Bioinformatics increased day by day. Bioinformatics converts molecular OMICS data into information and knowledge that can improve/discover drugs/vaccine/varieties.

STATISTICAL MODELING AND RNA-SEQ DATA ANALYSIS

Statistical tests of the reproducibility of the non-uniformity of reads show a consistent sequence specific bias across biological and technical replicates of a gene. This effect could be due to bias in RNA fragmentation, bias in other biochemical sample preparation steps or boundary effects when a gene of fixed length is fragmented. The last cause of bias can be modeled using Monte Carlo simulations of a fixed length mRNA sequence subject to a Poisson fragmentation process and incorporated into the insert length model. Improvements to the model could be made by increasing the precision of the estimate of the probability mass function of read lengths, for example by simulating a fragmentation and filtering process by Monte Carlo and matching the output of the simulations to the empirical distribution function $q(\cdot)$. De novo discovery of isoforms from a sample is an important and difficult statistical problem that we have not addressed in this paper. Another shortcoming of the model is that in order to statistical inference it has to be accurate, with the current short read technology, the number of isoforms should be relatively small. By using the classical statistical concept of minimal sufficiency, a computationally feasible solution to isoform estimation in RNA-Seq is conducted step by step. Different statistical analysis such as principal component analysis, factor analysis, cluster analysis quantifies the perceived gain in experimental efficiency from using paired end rather than single end read data to provide reliable isoform specific gene expression estimates.

DIGITALIZED SALARY MANAGEMENT SYSTEM FOR BRRI EMPLOYEE

One of the most important work of Finance and Accounts (F&A) of BRRI HQ is to prepare the monthly salary of the HQ employees. For this, they collect employees salary related information and preserve in the salary register books. After that they prepared salary related reports. Some of the reports have been prepared manually and the rest by using software. In this circumstances, Agricultural Statistics Division developed “Digitalized Salary Management System” for BRRI HQ employee. The web application developed using XAMPP, HTML,

PHP, Javascript (JS) and JQuery. Now the system is in live in the BRRI LAN

(172.16.101.128/st). The system included labour information, attendance report, wages report and other reports with printable format.

DIGITALIZED LABOUR MANAGEMENT SYSTEM OF BRRI

Farm Management Division (FMD) of BRRI works for labour management to collect attendance information from all divisions and sections. After that FMD was used to do the entry, updates, monitoring and reporting the information manually. So that, many of these existing practices and procedures took long time to prepare wages sheet per month. In this circumstance, Agricultural Statistics Division developed an updated version (LMSV1) of the digitalized labour management system (LMS) for BRRI HQ. The system is a web application and developed using XAMPP, HTML, PHP, Javascript (JS) and JQuery. Now the system is in live in the BRRI LAN (172.16.101.17/lmsV1). The system included labour informations, attendance report, wages report and other reports with printable format.

DIGITALIZED CASUAL LEAVE APPLICATION SYSTEM

Agricultural Statistics Division developed a web application of a casual leave (CL) using XAMPP, HTML, PHP, Javascript (JS) and JQuery. This is a very easy to access, accurate, consistent and most flexible casual leave (CL) application procedure with the usual system (hard copy application). Now, this system is ready to use only for the Agricultural Statistics Division. All kinds of reports related to casual leave can be generated by this web application whenever the user needs.

GENOTYPE × ENVIRONMENT INTERACTION OF BRRI VARIETIES

The development of rice varieties is affected by the environment, genotype and their interaction. Yield performance of different varieties varies across testing environments and its grain yield performance is a function of genotype (G), environment (E) and genotype × environment interaction (GEI). The experiment was conducted in multienvironment trials for T. Aman 2020. Forty-seven BRRI released T. Aman rice varieties were evaluated in nine environmental conditions of Bangladesh, such as Barishal (E1), Bhanga (E2), Cumilla (E3), Gazipur (E4), Kushtia (E5), Rajshahi (E6), Rangpur (E7), Satkhira (E8), and Sonagazi (E9). The experimental sites covered all ecosystems of Bangladesh. The experiments were carried out in randomized complete block design (RCBD) with three replications and evaluated for rice grain yield. Each experimental plot comprised of 3m × 2m. Standard agronomic practices were followed and plant protection measures were taken according to Adhunik dhaner chash, BRRI (2019). AMMI model was used to quantify the effect of different factors (genotype, location) of the experiment. The model further provides graphical representation of the numerical results (GGE biplot analysis) with a straight-forward interpretation of the underlying causes of G × E. The major objective of the present study was to identify BRRI released rice genotypes that have both high mean yield and stable yield performance across different environments for different ecosystems of Bangladesh.

ANOVA of combined analysis

The combined analysis revealed that the yield of rice genotypes was significantly influenced by environment and contributed 40.80, 32.53 and 27.68% of the total variation for medium, long and short duration respectively. Additionally, the relative contribution of genotype sum of squares was found 30.17, 24.32 and 10.54% for long, short and medium duration respectively. Genotype by environment (G × E) contributed the most 39.52% to the total variation for long duration followed by 34.23% and 27.92% for short and medium duration. Greater portion of total variation was explained by environmental main effect indicating that the environments were diverse and a major part of variation in grain yield reflected from environmental changes. The highly significant

genotype × environment interaction effects for grain yield confirmed that genotypes responded differently to the variation in environmental conditions. The yield variations could be attributed to the different environmental (climatic) conditions and to different edaphic conditions at different locations. In this case application of stability analysis for identifying widely and/or specifically adaptation of rice genotypes are essential.

Evaluation of test environments

The GGE biplot explained 72.82%, 69.98%, and 66.94% of the total variation of the environments for long, short and medium duration respectively. In long duration, there were three clusters of environments, one contains Barishal, Cumilla, Kushtia, and Rajshahi; another contains Bhanga, Satkhira and Sonagazi; the other cluster contains Gazipur, Rangpur. Among them Barishal and Cumilla were closely associated. Gazipur and Rangpur had the longest vector having highly discriminating location. Overall, the locations Satkhira and Sonagazi were highly representative and can be considered ideal environments for evaluating long duration genotypes. The closest association were observed between the environments Kushtia and Rajshahi; and Barishal, Gazipur and Rangpur. The location Bhanga showed negative or no correlation with Satkhira, Cumilla and Rangpur. The ideal environment was found Kushtia and Rajshahi for medium duration. Satkhira and Cumilla had the longest vector having highly discriminating locations. Considering the above Kushtia and Rajshahi were the ideal locations for testing genotypes for medium duration varieties with its appreciable discriminating ability and representativeness and position nearest to the circle point of AEA axis.

In short duration GGE biplot showed three distinct clusters. One cluster in dud Barishal, Kushtia, Rajshahi, Rangpur and Satkhira and the second cluster contained Cumilla, Gazipur and Sonagazi and the rest cluster contain only one location Bhanga). Bhanga showed the longest vector, making it more discriminating than the other environments. Considering the criteria of ideal environment, Rajshahi and Satkhira showed a smaller angle with the AEA and hence was highly representative environment for testing short duration genotypes.

Performance and stability of rice genotypes across tested environments

Within a single mega-environment, genotypes should be evaluated on both mean performance and stability across environments. Table 2 shows the yield performances and summary of ideal genotypes and genotypes with stable and high mean yields in different categories (long, medium and short duration). BR11 recorded the highest average grain yield (4.53 t/ha) in long duration. BR22, BRRI dhan44, BRRI dhan46 and BR11 were the most stable genotypes with above-average yields. Thus, the BR11 and BR22 were the most ideal genotype with the highest mean yield and stability among the tested genotypes. The genotype BRRI dhan49 was the most stable genotype with above-average yield (4.67 t/ha) in medium duration. BRRI dhan79 (4.65 t/ha)), BRRI dhan51 (4.62 t/ha)), BRRI dhan80 (4.52 t/ha)) and BRRI dhan52 recorded the above-average yields. Other stable genotypes with above-average yields were BRRI dhan52 (4.48 t/ha) (Table 2). BRRI hybrid dhan6 (5.36 t/ha) and BRRI dhan87 (5.07 t/ha) recorded the highest average grain yield, most stable and ideal genotype in short duration. Also, BRRI hybrid dhan4 (4.95 t/ha), BRRI dhan72 (4.85 t/ha), and BRRI dhan71 (4.68 t/ha) were the most stable genotypes and above average yielder (Table 2).

Identification of which-won-where and mega-environment

One of the most attractive features of a GGE biplot is its ability to show the which-won-where pattern of a genotype by environment dataset. This plot consists of a polygon with perpendicular lines, called equality lines, drawn onto its sides. These lines divide the polygon into various sectors. Genotypes located on the vertices of the polygon are the best performers in one or more environments falling within a particular sector. One mega-environment had four locations, Gazipur, Rangpur, Satkhira and Sonagazi; the second consisting of two locations-Bhanga and Rajshahi; and the rest mega-environment contains Barishal,

Cumilla and Rajshahi. Hence, the winning genotype in those environments was BR11 and BR22 for first; BR22 and BR10 were closed to second mega environment. BR10 and BRRI dhan76 were the wining genotype for the thirld mega-environment. BRRI dhan91, BR5 and BRRI dhan34, BRRI dhan37 and BRRI dhan38 were the low yielder of long duration genotypes.

The first mega-environment had three locations, Cumilla, Satkhira and Sonagazi. The second had two locations-Kushtia and Rajshahi. The third contained three locations-Barishal, Gazipur and Rangpur. BRRI dhan54 was the winning genotype in the first mega-environment while BRRI dhan49 was the winner in the second and BRRI dhan51 was the winner in the last mega-environment. The first mega-environment had six locations-Bhanga, Cumilla, Gazipur, Rajshahi, Satkhira and Sonagazi with BRRI dhan87 and BRRI hybrid dhan6 being the winning genotypes. The second mega-environment had three locations-Barishal, Kushtia and Rangpur. BRRI dhan87, BRRI dhan95 were the winner in this mega-environment. BRRI dhan70, BR25, BRRI dhan32, BRRI dhan54 and were the low yielder of medium duration genotypes.

Table 2. Grain yield performance of BRRI released T. Aman rice varieties during 2020.

Category	Variety	Barishal	Bhanga	Cumilla	Gazipur	Kushtia	Rajshahi	Rangpur	Satkhira	Sonagazi	Average yield (t/ha)
Long duration	BR3	5.37	5.16	5.16	4.18	3.64	3.60	4.68	3.56	5.98	**3.70**
	BR4	3.77	3.48	4.24	2.40	4.35	4.13	3.72	4.53	4.68	**3.92**
	BR5	3.17	2.76	4.23	1.77	4.04	2.58	3.68	2.36	3.44	**3.11**
	BR10	3.87	4.86	4.49	1.54	5.05	5.22	3.90	4.82	5.00	**4.31**
	BR11	3.97	4.99	4.38	3.43	2.95	5.36	5.14	5.36	5.17	**4.53**
	BR22	3.93	4.94	4.65	2.71	5.06	4.48	5.61	4.19	5.02	**4.51**
	BR23	4.30	3.27	4.44	3.28	5.09	3.68	3.68	4.69	4.86	**4.14**
	BRRI dhan30	4.43	4.54	4.36	2.47	4.47	5.16	4.16	4.50	4.53	**4.29**
	BRRI dhan34	3.23	3.09	4.25	1.25	3.15	3.29	3.14	3.32	3.96	**3.19**
	BRRI dhan37	3.20	2.84	3.77	1.81	2.51	2.86	4.08	3.27	3.73	**3.12**
	BRRI dhan38	3.13	2.68	3.72	2.00	3.52	2.85	4.02	3.77	3.59	**3.25**
	BRRI dhan40	3.87	4.30	4.24	2.70	4.34	5.30	3.65	4.44	4.60	**4.16**
	BRRI dhan41	3.27	3.51	4.72	2.03	5.39	4.60	4.14	4.42	4.62	**4.08**
	BRRI dhan44	3.53	4.78	4.44	2.80	4.22	4.62	5.10	4.77	5.39	**4.41**
	BRRI dhan46	4.90	4.24	4.05	2.71	4.82	4.20	5.76	3.53	5.02	**4.36**
	BRRI dhan76	5.43	4.79	4.51	1.18	5.08	4.75	3.09	4.26	4.71	**4.20**
	BRRI dhan77	4.23	3.92	4.46	2.19	3.92	4.83	4.08	2.96	4.90	**3.94**
	BRRI dhan91	3.47	2.06	2.44	1.11	2.47	3.67	2.79	2.83	2.56	**2.60**
	Long duration average	**3.84**	**3.79**	**4.14**	**2.31**	**4.12**	**4.18**	**4.13**	**3.98**	**4.43**	**3.88**
	$LSD_{0.05}$						**0.62**				
Medium duration	BR25	3.17	4.34	5.36	2.48	4.46	4.62	2.58	3.55	4.62	**3.91**
	BRRI dhan31	3.07	4.35	4.99	2.80	4.65	4.99	4.26	4.62	4.53	**4.25**
	BRRI dhan32	3.27	4.32	4.91	2.80	5.07	5.01	4.47	3.61	4.77	**4.25**
	BRRI dhan49	3.90	5.39	3.70	3.56	4.49	5.04	5.11	5.23	5.58	**4.67**
	BRRI dhan51	5.07	4.10	4.47	3.87	5.18	5.43	4.56	4.16	4.72	**4.62**
	BRRI dhan52	4.07	4.43	4.46	3.40	4.86	5.34	4.15	4.75	4.89	**4.48**
	BRRI dhan54	3.57	4.02	5.57	1.87	4.52	4.91	2.29	5.38	4.55	**4.08**
	BRRI dhan70	3.03	4.79	3.83	1.80	3.45	4.41	3.12	3.09	5.00	**3.61**
	BRRI dhan78	3.40	4.19	5.46	3.06	4.78	5.19	3.54	4.38	5.05	**4.34**
	BRRI dhan79	5.00	5.09	3.81	3.20	5.07	5.43	4.31	4.64	5.27	**4.65**
	BRRI dhan80	4.00	4.80	4.63	3.32	4.85	4.99	4.52	4.77	4.82	**4.52**
	BRRI dhan93	4.63	4.39	3.77	3.77	5.07	5.81	3.70	4.96	3.77	**4.43**
	BRRI dhan94	4.63	4.73	3.48	3.48	5.30	5.55	4.32	3.08	3.48	**4.23**
	Medium duration	**3.91**	**4.53**	**4.50**	**3.03**	**4.75**	**5.13**	**3.92**	**4.32**	**4.70**	**4.31**
	$LSD_{0.05}$						**0.67**				
Short duration	BRRI dhan33	3.25	4.11	3.38	3.34	4.46	4.23	3.12	4.71	4.63	**3.91**
	BRRI dhan39	3.67	4.53	4.89	3.76	5.20	4.85	3.28	4.37	4.60	**4.35**
	BRRI dhan53	3.07	3.93	4.47	2.99	4.89	4.83	4.83	4.98	4.59	**4.28**
	BRRI dhan56	3.23	3.33	5.65	2.84	4.90	4.98	3.04	4.85	4.36	**4.13**
	BRRI dhan57	3.90	3.44	3.76	3.20	3.78	4.41	2.56	3.74	3.95	**3.64**
	BRRI dhan62	3.17	4.19	3.25	3.35	2.45	4.04	4.10	3.82	4.69	**3.67**
	BRRI dhan66	3.57	3.91	6.01	3.24	5.11	5.60	4.14	4.69	4.39	**4.52**
	BRRI dhan71	4.07	4.61	4.97	4.59	4.74	4.97	4.02	4.62	5.54	**4.68**
	BRRI dhan72	4.47	5.49	5.51	3.83	4.82	5.05	3.93	5.24	5.35	**4.85**
	BRRI dhan73	3.63	4.03	4.83	3.63	4.93	4.75	3.31	4.74	4.92	**4.31**
	BRRI dhan75	3.13	5.26	4.12	4.33	4.83	5.21	2.74	5.29	5.41	**4.48**
	BRRI dhan87	4.10	6.49	5.67	2.76	5.55	5.22	3.87	5.45	6.50	**5.07**
	BRRI dhan90	4.00	4.79	2.47	2.47	4.89	4.44	3.17	4.07	2.47	**3.64**
	BRRI dhan95	4.57	4.99	2.34	2.34	4.96	5.49	4.43	5.11	2.34	**4.06**
	BRRI hybrid dhan4	4.57	6.42	5.17	4.18	3.78	4.97	5.85	5.05	6.52	**4.95**
	BRRI hybrid dhan6	5.00	6.47	6.95	3.96	4.88	5.61	3.59	5.53	6.27	**5.36**
	Short Duration	**3.84**	**4.75**	**4.59**	**3.43**	**4.64**	**4.92**	**3.62**	**4.77**	**4.78**	**4.37**
	$LSD_{0.05}$						**0.57**				

MAINTENANCE OF RICE DATABASE

Secondary data of rice and other important crops are collected periodically from Bangladesh Bureau of Statistics (BBS), Agricultural Marketing Directorate (AMD), Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC) and other sources periodically and recorded accordingly. Databases are being updated regularly and uploaded at BRRI website.

MINIMIZING AGRO MICRO CLIMATOLOGICAL RISK FACTORS FOR MAXIMIZING SUSTAINABLE RICE PRODUCTION IN BANGLADESH

The weather forecast and advisory service focused on food security and responsiveness to climate change in Bangladesh. Whereas, weather forecasts based rice advisory system has potential for reducing poverty by increasing the rice yield, avoiding insect and disease outbreaks, ensuing efficient water management, labour and energy utilization. It reduces losses and risks of pollution with judicious use of agricultural chemicals through proper management in time and also provides guidelines for selection of the best-suited rice varieties according to the anticipated climatic conditions. This is how the system the reduces the overall costs of production and increases the income of the farmers.

Considering this context, the objective of this study is to perform weather forecasts at weekly basis and validate forecast based rice crop management system through rice advisory generation in Boro season for sustainable rice production in Bangladesh. The seven-day basis weather forecast and rice advisory were generated in Boro season (November 2020 to May 2021) for BRRI HQ and eight regional stations of BRRI. A team comprising of multidisciplinary researchers (agronomist, plant pathologist, entomologist, soil scientist, plant physiologist, irrigation specialist, agricultural statistician, and agricultural economist) participated to generate location-specific weather forecast for six parameters, viz rainfall, relative humidity, wind speed, soil moisture, minimum and maximum temperature and prepared advisories using local language Bengali at different growth stages of Boro rice based on weather forecasts. Weather research and forecasting (WRF) model for forecasting, which is a next-generation mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs were used for the weekly weather forecast (both English and Bangla). Tables 3 and 4 show as a sample how the weather forecast and advisory looks like.

So, we can conclude that uptake of the weather forecast based rice crop management systems can contribute to the overall food security of the country and achieving sustainable development goals by increasing the agricultural productivity and incomes of small-scale food producers.

Table 3. Weather forecast for BRRI HQ, Gazipur from 27.03.2021 to 02.04.2021.

Agriculture weather element	27.03.2021	28.03.2021	29.03.2021	30.03.2021	31.03.2021	01.04.2021	02.04.2021
Total rainfall (mm)	0	0	2.0	0.27	0.32	0.4	7.22
Min. tem. (^{0}C)	18.08	17.25	19.84	24.38	25.29	24.3	24.21
Max. tem.(^{0}C)	37.78	38.7	38.89	39.88	39.99	39.32	36.08
Min. RH (%)	8.16	9.23	18.9	21.27	18.61	14.36	38.33
Max. RH (%)	24.94	71.36	93.29	92.45	94.17	94.08	88.92
Min. wind speed (m/s)	0.71	0.81	3.06	3.16	1.57	3.49	2.6
Max. wind speed (m/s)	3.64	4.19	5.39	8.24	7.81	6.34	6.52
Soil moisture	0.0	0.0	0.01	0.0	0.0	0.0	0.0
Solar radiation	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. Weather forecast based rice advisories at BRRI HQ and different RSs in Boro season: a probable problems and measures.

Growth stage: Booting
Production management / Probable problems and tasks
Fertilizer management No fertilizer is required. Weed management At this time shama and fulka grasses may grow. It should be cleansed if there are shama and fulka grasses present. Irrigation At this time, the AWD approach is not applicable. There should be 5 cm of standing water in the field, and there should be no shortage of water. Insect management Rice can be attacked by stem borer, brown grasshoppers, white-backed grasshoppers, leaf-folder insects and rats. At this stage it is needed to monitor the land regularli using light traps, bury the stalks, catch insects with hand nets, and destroy eggs and worms. However, approved pesticides such as Cartap Plus/ Virtako/ Diazinon/ Carbofuran/ Melathion/ Darsburn can be used in moderation to control stem borer (5% white head infestation) and leaf-wrapping insects (25% damaged leaf). At this time in 50% of the field, if 2-4 laying female brown grasshoppers or 10-15 young insects or both are seen, pesticides like Ebamactin/Suffin/Mipsin/Ploenum can be applied in moderate amounts on the hill roots. Rats can be controlled by digging rat holes, using different types of traps or using a variety of biological methods. Disease management There is a possibility of leaf blast disease due to the current weather and the chance of rain. In the event of disease, a Trooper or Native amount (8 gms of medicine + 10 liters of water = 5 decimal of the field) should be sprayed in the afternoon. Water must also be kept in the field. It's important to remember that the aforesaid medicine should be used twice in the afternoon, at seven days interval.

SIMULATING CLIMATE CHANGE IMPACT ON RICE GROWTH AND YIELD IN BANGLADESH USING DSSAT MODEL

The study was conducted in BRRI HQ Gazipur and nine RSs of BRRI. These areas were chosen based on prevailing different agro micro climatological conditions for T. Aus rice production to allow for comparative analysis since they occur in different regions of the country at diverse variations. Three experiments namely, fertilizer (0 kgN/ha, 40 kgN/ha, 60 kgN/ha, 80 kgN/ha and 100 kgN/ha) irrigation (AWD 15cm, AWD 30cm, and rainfed condition) and planting time (30 April, 10 May, 20 May and 01 June) were conducted separately in each study area for T. Aus 2020 season including three BRRI released Aus varieties, namely BR26, BRRI dhan48 and BRRI dhan82. The objectives of the study were to find out the economic fertilizer rate, best irrigation practice, determine water requirement and water productivity, and optimum planting time for maximum growth and yield for T. Aus season. And to determine the genetic coefficients of Aus rice varieties by using the decision support system for the agro technology transfer (DSSAT) model.

In fertilizer experiment, BR26 produced the highest yield (5.55 t/ha) at Rajshahi and the lowest yield (1.96 t/ha) at Sirajganj when N applied at 100 kg/ha and 0 kg/ha. The highest performance of BRRI dhan48 was 5.46 t/ha when N applied at 80 kg/ha at Gazipur and the lowest was 1.77 t/ha when N applied at 0 kg/ha at Sirajganj. BRRI dhan82 the produced highest yield (5.07 t/ha) at Rajshahi and he lowest yield (1.83 t/ha) at Sirajganj when N applied at 0 kg/ha. In fertilizer experiment, BR26 produced the highest average yield (4.24 t/ha) at 80 kg N/ha, BRRI dhan48 and BRRI dhan82 produced the highest 4.42 t/ha and 4.14 t/ha at 60 kg N/ha, respectively (Fig. 1).

In irrigation experiment, BR26 produced the highest yield (5.09 t/ha) at Kushtia when irrigation practice applied AWD 30 cm condition, and the lowest (1.77 t/ha) at Sirajganj when irrigation was applied AWD 15 cm condition. The highest performance of BRRI dhan48 was 5.15 t/ha at Rajshahi and the lowest was 1.40 t/ha at Sirajganj when irrigation practice applied AWD 15 cm and Rainfed condition, respectively. BRRI dhan82 proveded highest yield (5.03 t/ha) at Rajshahi and lowest (1.34 t/ha) at Sirajganj when irrigation practices applied AWD 15 cm condition for both.

The highest average yielder variety were found BRRI dhan48 (4.17 t/ha) when applied AWD 30cm and the lowest was BRRI dhan82 (3.62 t/ha) when rainfed condition prorailed for irrigation

experiment (Fig. 2). BR26 produced the highest yield (5.12 t/ha) at Rangpur when it was transplanted on 10 May, and the lowest yield (1.12 t/ha) at Sirajganj when transplanting time was 01 June. The highest performance of BRRI dhan48 was 5.62 t/ha at Rajshahi and the lowest was 1.14 t/ha at Sirajganj when the transplanting time 10 May and 1 June respectively. BRRI dhan 82 recorded the highest yield (5.59 t/ha) at Rajshahi and the lowest yield (0.99 t/ha) at Sirajganj when it was transplanted on 20 May and 1 June respectively. In planting time experiment, the highest and the lowest performance was found BRRI dhan48 when the transplanting time was 10 May (4.29 t/ha) and BRRI dhan82 3.53 t/ha when the transplantied 10 May, respectively (Fig. 3).

SUITABILITY MAPPING OF BRRI DHAN90 TO BRRI DHAN92

Our land is not homogenous all over Bangladesh. As we need to increase production with limited land, so it will be very helpful if we have variety wise suitability map based on soil properties. BRRI dhan90 to BRRI dhan92 are very prospective varieties. So, the suitability maps of these varieties are very important. The objectives of the study were to construct edaphic suitability maps for newly released BRRI varieties and also find out variety-wise suitable areas for production.

Soil physical properties namely, land type, top soil texture, relief, soil consistency, soil moisture, soil permeability, soil reaction, soil salinity, drainage and slope were considered to determine areas suitable for growing respective rice varieties. The suitability scale 1 to 3 was assigned to each soil characteristic in relation to respective rice varieties cultivation: 1- for the suitable, 2- for moderate and 3- for not suitable. So, proactivity will increase if we cultivate rice varieties according to their suitable area.

BRRI dhan90 is a variety of T. Aman season. It is suitable in north and north-west parts of Bangladesh. Fig. 4 shows the suitability map of BRRI dhan90. BRRI dhan91 is a variety of T.Aman season. Western side and some central-western side of Bangladesh are suitable for BRRI dhan91. Fig. 5 shows the suitability map of BRRI dhan91 and BRRI dhan92 these are varieties of Boro season. Almost all over the country these varieties are suitable or moderately suitable except hilly areas. Mainly central north and central west part are more suitable. Fig. 6 shows the suitability map of BRRI dhan92.

CLIMATE MAPPING OF TEMPERATURE AND RAINFALL

Data on daily maximum and minimum temperature and rainfall of 35 weather stations of BMD for the year 2019 were used for the study. Year and station-wise maximum value of maximum temperature and minimum value of minimum temperature and total rainfall were determined. Then by using geo-statistical tools of Arc GIS10.3 software maps were prepared. In the maps scenario of climatic factors were described.

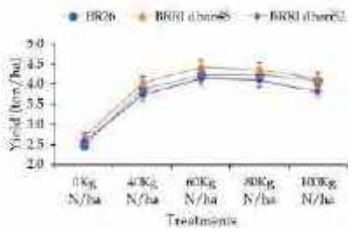

Fig. 9. Average yield performances with standard error of different nitrogen doses for BR26, BRRI dhan48 and BRRI dhan82 in ten different locations in Bangladesh during Aus 2020 season.

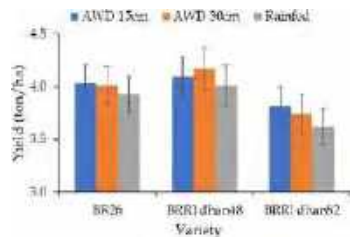

Fig. 10. Average yield performances with standard error of different irrigation management for BR26, BRRI dhan48 and BRRI dhan82 in ten different locations in Bangladesh during Aus 2020 season.

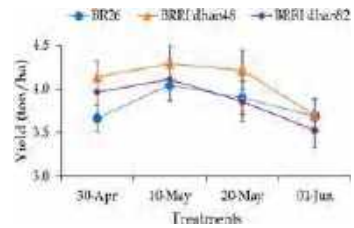

Fig. 11. Average yield performances with standard error at different time of transplanting for BR26, BRRI dhan48 and BRRI dhan82 in ten different locations in Bangladesh during Aus 2020 season.

Fig. 4. Suitability map of BRRI dhan90.

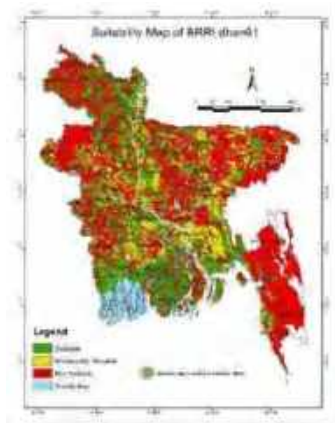

Fig. 5. Suitability map of BRRI dhan91.

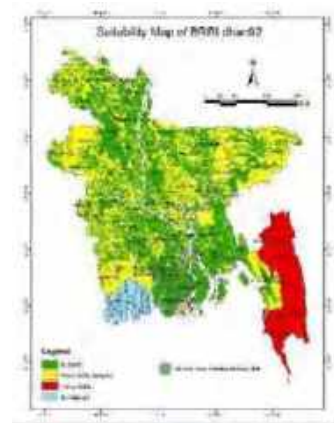

Fig. 6. Suitability map of BRRI dhan92.

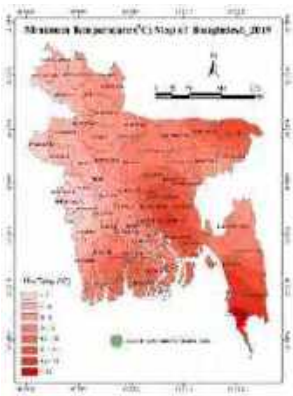

Fig.7. Maximum temperature map of Bangladesh for 2019.

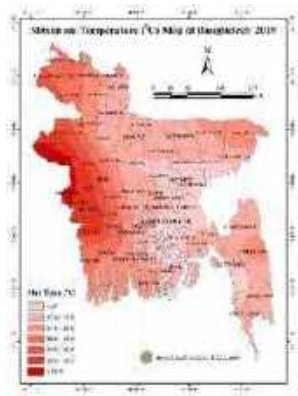

Fig.8. Minimum temperature map of Bangladesh for 2019.

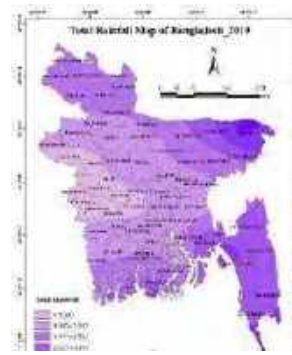

Fig.9. Total rainfall map of Bangladesh for 2019.

Maximum temperature was high in western side of Bangladesh. Fig. 7 shows the maximum temperature map of Bangladesh for 2019. In 2019 minimum temperature was low in northern side of Bangladesh and minimum temperature was high in south-eastern side of Bangladesh. Fig. 8 shows the minimum temperature map of Bangladesh for 2019. Total rainfall was the highest in eastern side of Bangladesh. Figure 9 shows the total rainfall map of Bangladesh for 2019.

More or less in all seasons eastern side of Bangladesh is marked as high rainfall and low maximum temperature area and western side is marked as low rainfall and high maximum temperature area.

LAND USE AND LAND COVER MAPPING IN SOME SELECTED AREAS OF BANGLADESH

Land use/land cover map is important in any kind of paining (i.e. agricultural, socioeconomic, environmental, natural resources management etc) and policy making issue of a specific area. Land use/land cover maps also gives information about landform, climate and socioeconomic condition of a specific area, is also helpful for future change detection analysis. In Bangladesh very few areas has good land use/land cover maps. Thus, it is important to prepare a land use/land cover map for agricultural paining and others use. The objectives of the study are to identify the various objects of

land use/land cover (agriculture land, fallow land, forest, urban area, orchard, water body etc of a specific area and calculate the area of the objects of land use and land cover. Satellite Images: Sentinel-2A, image were collected from Copernicus Data Hub of European Space Agency (ESA). Images were collected for Rabi season (22 march 2021). Ground reference data of various features like crop, fallow land, settlement, homestead, water body, forest and valley were collected by studying global positioning system through field survey. Some ground reference data were collected from Google Earth Pro. All three bands (NIR, Red, Green) were stacked where two stacked images were mosaic. Then only Habiganj district area was extracted out by Habiganj district shape file. A supervised classification approach was conducted on processed image using maximum likelihood classification. In the map, seven class or features were considered and figure 10 shows land use land cover map of Habiganj district for Rabi season. Also, Table 5 shows area and features of Habiganj district.

In future, it can be improved by considering more classes. This land use land cover map has been prepared for Rabi season. If we do Kharif 1 and Kharif 2 season land use and land cover map then we will get seasonal changing pattern of land use and land cover in Habiganj.

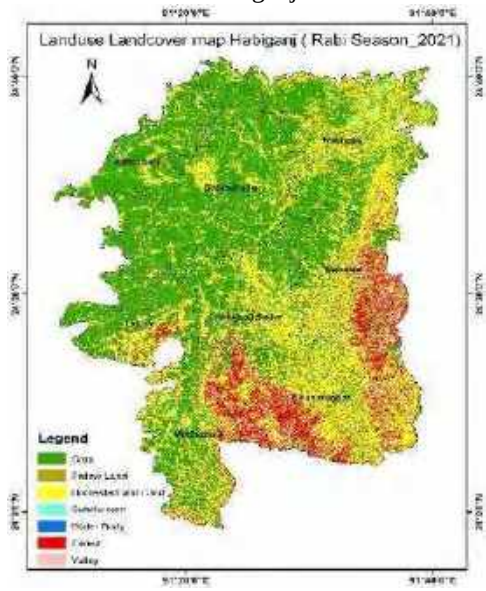

Fig.10. Land use and land cover map of Habiganj district.

Table 5. Area and features of Habiganj district.

Feature	Area (ha)	Percentage
Crop	105646	41
Fallow	29607	11
Homestead and Land	76958	30
Settlement	5751	2
Water	4073	2
Forest	21896	8
Valley	16693	6
Total	260625	100

FLOOD MAPPING USING REMOTE SENSING

Flood map is important to understand and communicate the local flood risk, and take future mitigation measures. These efforts make a safer community in which to live and work. Flood map in needed also to help determine a property‟s flood risk and decide whether flood insurance is required for a loan. The objectives of the study are to prepare a flooding area map of Bangladesh in 2020 using remote sensing and to categorize the most flood affected districts of Bangladesh in 2020. Remote sensing and Geographic Information System (GIS) is a great tool for Flood monitoring and mapping. Flooding in Bangladesh normally occurs during the monsoon season. Passive optical sensor, images capturing from the solar reflectance of the earth‟s surface or atmosphere being unable to penetrate cloud cover and this is the main disadvantage of optical satellites for flood monitoring. Thus we used Sentinel-1, SAR data which can penetrate closed, to prepare flooded areas. According to BWDB in 2020 there were six spells of flood in Bangladesh but primarily flood started in June and 3 spell of flood was the most sever which stands from 20 July to 8 August 2020. Thus, two times data were collected; one is “Before Flood” dated 28 May 2020 to 4 June 2020 and “During Flood” dated 20 July 2020 to 25 July 2020. Then flood map of Bangladesh on 25 July 2020 was prepared. The formula is like:

During flood (flood water + permanent water)–Before flood (permanent water =Flood water) Figure 11 shows water body before flood of Bangladesh in 2018. Figure 12 shows water body during flood of Bangladesh in 2020. figure 13 shows Flood map of Bangladesh in 2020., Many

areas in Bangladesh affected by flood among them severly affected districts were Sirajganj, Tangail, Netrakona, Jamalpur, Naogaon, Sunamganj, Bogura, Habiganj, Kishorganj, Kurigram, Sylhet, Mymensingh, Pabna, Gaibandha, Brahmanbaria. About, 11% areas of Bangladesh flood affected. These areas are mainly in north-central and north-eastern parts of Bangladesh. Old Brahmaputra Floodplain, Tista Floodplain, Low Ganges-River Floodplain and Karataya-Bangali Floodplain were severely flood affected.

CAPACITY BUILDING THROUGH TRAINING

To set up the experiments, collecting, compiling, reporting, analyzing and presenting of the required data and increase the accuracy of the findings as well as developing skills on research two training programmes were conducted in 2020-21. The topics were planning experiments, problem data, field experimentation, experimental design, factorial experiment, CRD, RCBD, LSD, SPD, Strip PD, SSPD, Strip SPD and augmented design in the training of „Experimental Data Analysis‟. Another topic was the „Experimental field layout, data collection and data preparation‟ under this training programme.

A total of 68 participants were trained through the training programmes. Through the training on „Experimental Data Analysis‟ 8 participants were trained. The participants were CSO, PSO, SSO and SO of BRRI. The second training programme was „Experimental field layout, data collection and data preparation‟. A total of 60 participants including FM, AFM and SA were trained through this training.

ICT ACTIVITIES

Strengthening cyber security system for BRRI

We have already designed the architecture of cyber security system of BRRI. Also, the virtual private network (VPN) has been configured and successfully completed outer and inner tunnels. Now, our server, computer network, software, application, files, source code and database are protected from unauthorized access and hacking attacking.

BRRI Alapon Telephone Directory Mobile App

The BRRI Telephone Directory Mobile app is titled as “BRRI Alapon” according to the monthly progress review meeting of innovation team in September 2020. This mobile app has been developed for BRRI official to communicate with each other by using different apps like Imo, Viber, Whatsup, WeChat etc. The app have features like chat, online calls, group messaging and location

Fig.11. water body before flood of Bangladesh in 2020.

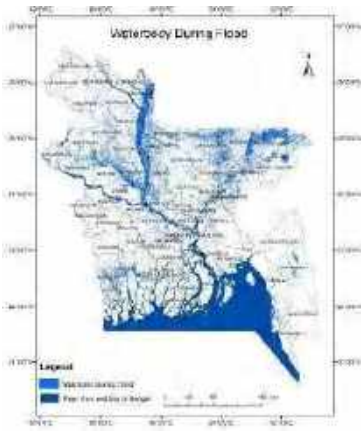

Fig.12. water body during flood of Bangladesh in 2020.

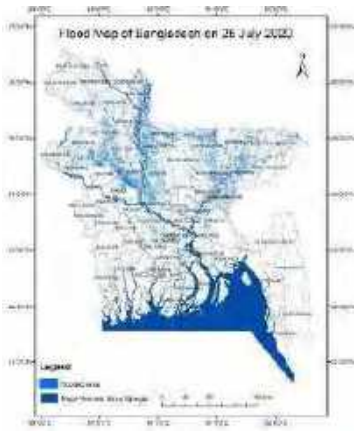

Fig.13. Flood map of Bangladesh in 2020.

sharing. „BRRI Alapon‟ available in Apple‟s App Store (iStore) and Google Play Store for Android phone user. Anybody can call and exchange messages in a more secured way using this app. App to app call, email and SMS is completely free for user. Database already has been developed for this app. All types of data have been collected from divisions, sections and regional stations of BRRI for developing the telephone directory mobile app.

Vehicle requisition management system of BRRI

Vehicle Requisition Management System (VRMS) is a transportation pool management activity of BRRI, are is a complex were and updating the allottee individually in time is a tedious work. The designated officials of Transport section have to work after office to manage the official vehicle requests and to convey the confirmation to the requester and driver over the phone. VRMS ease the allotment work using a simple requisition management system that doesn‟t require any advanced computing skills and the confirmation is sent using SMS and email. So that, the requester informed through SMS on the basis of demanding vehicle for official or personal purpose as well as driver get confirmation there‟re SMS for their upcoming duty (Fig. 14). The database has already developed and architecture design has been finalized. The information of all vehicle of BRRI (driver‟s name, mobile number and vehicle reg. number etc) has been collected from transport section.

Training on innovation, service process simplification (SPS) and e-nothi management for enhancing capacity of BRRI employees

Innovation and Service Process Simplification (SPS) tool is essential to introduce the culture of innovative practices that would accelerate and simplify the research activities and service delivery process of BRRI. Agricultural Ststistics Division has implemented all innovation activities and conducted various training on public service innovation (PSI), service process simplification (SPS), simple implementation project (SIP) and e-nothi management and several annual innovation work plan of BRRI. Day-long „Innovation and SPS‟ workshop has already completed on 11 October 2020 and two day-long „Public Service Innovation‟ training has completed on 12-13 October 2020 in spite of Covid-19 situation following social distance and health rules. „e-nothi system‟ in-house training has been conducted from 31 May to 15 June 2021 for all divisions and sections of BRRI HQ.

Fig. 14. Vehicle requisition management system of BRRI.

BRRI Rice Doctor mobile and web app

BRRI Rice Doctor mobile and web application which is used in, modern rice cultivation practices, insect-pest and disease related dynamic diagnosis tools. It can also be useful for scientists, researchers, teachers, students and private input dealers. An English and Bengali version of Rice Doctor mobile apps and web apps has been developed to solve all the problems and solutions for rice cultivation. The apps also include a push notification and a Bangla text to speech option to facilitate users to view up-to-date information by sending text messages to specific problems. The 'Feedback' option has been added to provide the necessary advice to improve the quality of the app (Fig. 15).

Strengthening and dissemination of modern rice technology and its management information at the farmers' door step through RKB Mobile Apps.

Rice knowledge bank (RKB) is being regularly updated with the latest rice-related information. For dissemination, we have trained 60 DAE officers in two batches. Also, a web page has been developed to get feedback from those DAE officers. All officers gave their feedback through the web page. We have participated in showcasing programme at Bangladesh agricultural research council (BARC). Senior secretary of the cabinet division and secretary of the ministry of Agriculture (MoA) were present in the programme. A total of 14,981 users have downloaded this app from the play store.

BRKB website management

Bangladesh Rice Knowledge Bank (BRKB) website is managed, maintained and modified in collaboration with training, breeding and other research divisions. it is being updated regularly the latest information. In this reporting year, we have developed 67 web and mobile based fact sheets and all the fact sheets have been uploaded into BRKB website.

Dynamic view connectivity system and Bangla searching system for BRKB Website

We developed dynamic view connectivity and Bangla searching system for BRKB website. Dynamic view connectivity works dynamically between BRKB website and Facebook page (Fig. 16). Bangla searching system has the ability to search both in Bengali and English language. It searches and automatically characterizes Bangla and English content of BRKB website.

Fig. 15. Pictorial view of BRRI Rice Doctor mobile app.

Fig. 16. BRKBS Dynamic view connectivity system.

Web mail and group mail

We have created individual e-mail account into BRRI domain for all scientists and all class-one officers as per requirement of MoA. We have updated the BRRI mail server from 8.8.12_GA version to 8.8.15_GA version. Now, our mail server is more secure than the previous one. In this reporting year, we provided 121 webmail related solutions such as creating account, changing password, removing block, lockout, spam and others. BRRI web mail and group mail have been hosted into BCC (Bangladesh Computer Council) server. At present, the total number of users of web mail and group mail are 361.

Developing secure system for BRRI web mail and group mail

We incorporated secure sockets layer (SSL) in BRRI web mail. Spamming filtering system (SFS) scan all users of BRRI web mail every other hour and find out the user who occurs spamming. When a web mail user creates some or heavy spamming, automatic active and close system (AACS) automatically detect the user and also block the user. As a result, BRRI web mail system is safe from the block of Gmail, yahoo, webmail or others e-mail server. We have developed AACS and also incorporated in BRRI web mail, now our web mail is more secure.

Online application system of BRRI

BRRI started online application system for the first time since 23 May to 12 June 2019. Already completed another online application process from 4 March to 24 March 2020. Applicants complete their application through this system and receive admit card, notification written test data, result and all kinds of information through this online system and SMS based application. This system developed by Teletalk Bangladesh Limited.

e-Nothi management system of BRRI

At present, hundred percent e-Nothi systems is being used in all divisions and sections of BRRI as well as RSs. The in-house training on „e-Nothi system‟ has been conducted for all divisions and sections‟ e-Nothi user of BRRI HQ, from 31 May to 15 June 2021 for developing their skill.

e-Tender system of BRRI

BRRI has been incorporated e-Tender (e-GP) system as a first organization among the NARS institute and also a first organization under Ministry

of Agriculture (MoA). BRRI has already submitted about 346 tenders into e-GP system and the submission process is being continued. In this reporting year, we have submitted about 140 tenders into e-Gp system.

Digitalized labour salary management system (LSMS) of BRRI

Farm Management Division of BRRI works for labour salary to collect data and preparation, entry, updates, monitoring and reporting of data manually. So that, many of these existing practices and procedures take long time to prepare salary sheet per month. In this circumstance, Agricultural Statistics division digitalized LSMS for BRRI including labours information, pay slips, allowances, deductions, leave, savings and net pays etc. The proposed system will stay up to date with pay checks and deductions, calculating allowances and others with printable format.

Management of BRRI local area network and internet connectivity

ICT network and internet connectivity of BRRI is managed and maintained by ICT Cell, Agricultural Statistics Division with the help of the network developer company. We have increased our digital data network (DDN) bandwidth connectivity from 120 Mbps to 157 Mbps. We established new and high configured router where internet speed capacity increased to 1000 Mbps; the internet speed capacity was 25 Mbps in the previous device. We also established local area network (LAN) connectivity at five regional stations i.e. Rangpur, Barishal, Sonagazi, Cumilla and Habiganj.

BRRI web portal management

BRRI web portal (*www.portal.gov.bd*) is developed, managed and updated by ICT Cell of Agricultural Statistics Division. BRRI web portal/website is being uploaded regularly by latest information. BRRI web portalis in Bangla and English languages. In this reporting year we updated about 1,000 pages and uploaded about 5,000 documents like PDF, JPG, report, Word and other files on the BRRI website. We sent 12 monthly website reports fourth quarto the ministry of agriculture (MoA).

BRRI networks update, maintenance and extension

BRRI Networks Facebook group is a big forum for all the scientists, officers and staffs of BRRI. ICT Cell created this Facebook group to post research related work for noble work of rice and related activities, various problems and their solutions, official interactions in this forum. The Facebook group of "*BRRI Network"* link is https://www.facebook.com/groups/1409267722690061/. Thus, the BRRI Network is continuing with regular updating posted by everybody of this group. At present, 437 individuals have joined this group. It is increasing gradually. It has stored at least 6,000 and more photos of all national programme and research activities of HQ and all RSs. It has also uploaded around 220 necessary pdf and word file document for all members.

Personal data sheet database

We have created personal data sheet **(**PDS) database for all scientists, officers, clerks as per requirement of the Ministry of Agriculture (MoA). It has been increased up to 339 users into BRRI PDS database. PDS database is updated regularly with latest information. It is a routine work.

Video conference system

We have established video conferencing system (VCS) at BRRI to communicate with MoA and others government organization. Besides, we have created Skype account for all divisional heads and regional station heads. The communications between BRRI headquarter and others" regional stations has been conducted by Video Conference System in every monthly co-ordination meeting. Sunday seminar in-house training and workshop have been conducted by video conference system. Also, maximum meeting are being conducted by video conference system using Zoom platform. In this reporting year, we have conducted about 130 meetings and seminars etc through the video conference system.

Integrating digital signature with e-Nothi system of BRRI and its management

Controller of Certifying Authority (CCA), ICT division has taken initiative to integrate digital signature with e-Nothi system for developing

integrity, accountability and confidentiality for file and information management. As a result, both digital and electronic (scanned format) signature will be available in e-Nothi system. User will get option to choose any one signature for initialising any file. So, BRRI provided 100 update version of digital signature certificate through four days long training co-operated by CCA, ICT Division. The digital signature certificate provided to BRRI scientists and officers for using all types of e-mail, web mail and e-Nothi system.

Rice pest corner

We have developed Rice Pest Corner with the information of insect and pest and disease management. Rice Pest Corner has been developed for farmers, extension personnel, scientists, researchers, teachers, students and other users who want to learn and control insect and disease and other problems that can occur in rice cultivation.

Heritage of BRRI

Basically, Heritage refers to something inherited from the past. So, ICT cell of Agricultural Statistics Division creates a menu named Heritage (*http://www.brri.gov.bd/site/page/cdf8a394-1652-4607-a1d1-b87de15b20f8*). It has created individual pages like former DG and Directors, CSO, PSO, SSO, Officers and Staff etc. It has included almost former scientists personnel photo, short description as well as a link where anybody can find out their detail information.

Innovation team activities

BRRI has implemented all innovations under Innovation Action Plan Guideline 2015 and several annual innovation work plan of BRRI. This division organized two day-long, day-long „Public Service Innovation‟ workshop, day-long „Innovation and SPS‟ workshop regularly by Aspire to Innovate (A2i), Ministry of ICT (MoICT) and Cabinet Division. We organize monthly innovation team meeting regularly and review performance properly.

ICT and related fair

ICT Cell of Agricultural Statistics Division participated several ICT and related fairs such as Digital World Fair, Development Fair, Tatha Mela and World Food Fair etc.

SUPPORT SERVICES

The scientists of this division are also engaged in helping scientists of other disciplines in planning experiments, statistical data analysis and interpretation of results. Sixty different types of analyses were performed during the reporting period. A number of maps were prepared using GIS and supplied to the scientists of other divisions whenever required.

Overall, ICT cell of Agricultural Statistics Division has taken initiative in accordance with government perspectives but BRRI Networks facebook group is first introduced among all partners National Agricultural Research System (NARS) and also first among all research institutes. The ICT cell of Agricultural Statistics Division provides e-Nothi management system, e-Tender and other internet related support services to other divisions and sections.

Farm Management Division

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SUMMARY

This experiment was conducted at the West Byde of BRRI farm, Gazipur during T. Aman 2020 and Boro 2020-21 seasons to find out the suitable transplanting date and spacing for short duration rice varieties. During T. Aman season, transplanting date 15 July to 31 July produced statistically identical and the highest grain yield (5.40 to 5.75 tha^{-1}). The spacing (15cm×15cm) produced the highest grain yield (5.27 tha^{-1}) in T. Aman season of short duration (growth duration 113 to 115 days) rice varieties which is statistically identical with the spacing 20 cm×15 cm. On the other hand, during Boro season, 31 December produced the highest grain yield (7.85 tha^{-1}) which was statistacally similar with 15 December (7.54 tha^{-1}) and the lowest in 1 February (6.48 tha^{-1}). Among the spacing the 20 cm×15 cm produced the highest grain yield (7.65 tha^{-1}) followed by 25 cm×15 cm spacing and the lowest in 20 cm×20 cm spacing.

This experiment was initiated on a permanent layout at the BRRI farm, Gazipur during T. Aman 2019 to Boro 2020-21 to find out the suitable management practices for yield maximization of rice and soil health. Seven treatments in randomized complete block (RCB) design with three replications were imposed and each treatment was assigned in 5m×4m sized plot. The treatments combinations were T_1 = Absolute Control (No nutrient supply), T_2 = BRRI dose N-P-K-S@83-17-53-12 kg ha^{-1} in T. Aman and 138-21-75-21 kg ha^{-1} in Boro season, T_3 = Soil Test Based (STB) Fertilizer Dose N-P-K-S @ 67-10-40-10 kg ha^{-1} in T. Aman And 134-16-75-10 kg ha^{-1} in Boro, T_4 = STB dose + 1 t/ha cowdung, T_5 = STB dose + 1 t/ha poultry manure, T_6 = STB dose + 1 t/ha vermicompost and T_7 = STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC. 30 days old seedling of BRRI dhan87 in T. Aman and 42-day-old seedling of BRRI dhan89 in Boro season were transplanted at 20 cm×20 cm spacing in both seasons. Grain yield, tiller number, panicle number, plant height and Grain number were significantly affected by the different nutrient management in both T. Aman and Boro season. STB dose with Poultry litter (1 tha^{-1}), STB dose with VC (1 tha^{-1}) and BRRI recommended dose were performed better in all the parameter except 1000-grain weight (TGW). On the other hand, control plot (No nutrient supply) should the lowest result.

Survey and monitoring of labouurers' wage rate at different locations around BRRI HQ such as Joydebpur, Chowrasta, Salna, Board Bazar, Konabari, Tongi were conducted throughout the year. The average wage rate day^{-1} varies from Tk 505-553. The wage rate day^{-1} during the peak periods of the year Tk 540 to 570 in May, Tk 520 to 575 in July-August and Tk. 530 to 575 in December -January were existed.

The average labour wage rate with food varied between Tk 389-436 and without food Tk. 543-614 respectively at different locations surrounding of BRRI R/S. The working time (8 hrs day^{-1}) of labourers was more or less similar except Satkhira and Gopalgonj.

Farm Management Division produced about 12695 kg rice of which 11095 Kg seed (TLS), 667 kg non- seed and 933 kg mixed rice.

This division also produced 7839 kg breeder seed of which 1942 kg, 2817 kg and 3080 kg in Aus, T. Aman and Boro season respectively.

In Boro 2020-21, about 4,760 kg seeds of different rice varieties have been distributed among the farmers on the eve of the centenary of our national great leader and Father of the nation Bangabandhu Sheikh Mujibur Rahman.

BRRI has 717 labourers of which 497 regular and 220 irregular. In BRRI HQ, total labourers number is 444 of which 289 regular and 155 irregular laborers. Total labourer utilization in different divisions was 193147 man days of which 51.12 %, 45.15 % and 3.73 % were utilized for research, support service and holidays, respectively. It was observed that total labour wages was Tk 10,92,93,485/- of which Tk 5,58,70,830/- and Tk 4,93,46,008/- and Tk 40,76,647/- were paid to the labourers for research work, support service works, leaves and holidays, respectively.

BRRI has 286.33 ha of land of which 172.64 ha is cultivable. A total of 77.59 ha of land were utilized by different research divisions in different season of which 7.57 ha in Aus, 36.54 ha in T.

Aman and 33.48 ha in Boro season. This division manages the BRRI flower garden to maintain the aesthetic view of the office premises and it has created visible flower garden during summer and winter season.

RESEARCH ACTIVITIES

Effect of transplanting date and spacing on the yield and yield components of short duration rice varieties in T.Aman and Boro seasons

PI: K P Halder **CI:** M M Rashid, M R Manir, M S Islam and Setara Begum

To find out the optimum transplanting date and spacing of short duration rice varieties in T. Aman and Boro season

This experiment was conducted at the West Byde of BRRI farm, Gazipur during T. Aman 2020 and Boro 2020-21 seasons to find out the suitable transplanting date and spacing for short of duration rice varieties. In T. Aman the treatments were four transplanting date (D_1= 15 July, D_2= 31 July, D_3= 16 August and D_4= 1 September), three spacings (S_1 = 15cm ×15cm, S_2 = 20 cm×15 cm and S_3 = 25 cm ×15 cm). In Boro the treatments were four transplanting date (D_1 = 15 December, D_2 = 31 December, D_3 = 16 January and D_4 = 1 February), three spacings (S_1 = 20 cm×15 cm, S_2 = 25 cm×15 cm and S_3 = 20 cm×20 cm). In each season, the treatments were arranged in a Split Plot design as transplanting date in the main plots and spacing in the sub plots. Each treatment was replicated in three times. Fertilizers were applied as per BRRI recommended dose. BRRI dhan75 and BRRI dhan81 were transplanted in T. Aman and Boro season, respectively. Twenty five and 35- day old seedling were transplanted in T. Aman and Boro seasons, respectively. All other intercultural operations were done as and when necessary. Yield and yield component data were taken at maturity stage. The collected data were analyzed using 'R' Software programme.

Experiment of T.Aman 2020

The interaction between transplanting date and spacing was insignificant in all the parameters of yield and yield components (Table 1). Therefore, only the main effect has been described and discussed below:

Effect of transplanting date. Transplanting date 15 July produced the highest number of tiller m^{-2} followed by 31 July and the lowest in 1 September but no significant difference with 16 August. The same trend also observed in number of panicle m^{-2}. The highest number of filled grain panicle^{-1} was found in 31 July followed by 15 July and lowest in 1 September but different transplanting date had no significant effect on percentage of unfilled grain. Transplanting date 31 July produced the highest grain yield (5.75 tha^{-1}) followed by 15 July. The lowest grain yield (4.21 t ha^{-1}) was recorded in 1 September (Table 1).

Effect of spacing. The closest spacing (15cm × 15cm) produced the highest number of tiller and panicle m-^{2}; and number of unfilled grain panicle^{-1}, which was gradually decreased with increasing spacing. The (25 cm ×15 cm) produced the highest number filled grain per panicle which was statistically identical with 20 cm×15 cm spacing and found lowest in (15 cm ×15 cm) spacing. The 1000 grain weight (TWG) was not significantly affected by spacing. The highest grain yield (5.27 t ha^{-1}) was observed in closer (15 cm×15 cm) spacing which was statistically identical with the yield (5.09 t ha^{-1}) of 20 cm×15 cm spacing. The grain yield gradually decreased with increasing spacing. It was the lowest (4.75 t ha^{-1}) in widest (25 cm×15 cm) spacing (Table 1).

It may be concluded that during T. Aman season, for short duration (growth duration 113 to 115 days) rice varieties transplanting date 15 July to 31 July produced statistically identical yield (5.40 to 5.75 t ha^{-1}). The 15 cm×15 cm spacing gave the highest grain yield (5.27 t ha^{-1}) which was statistically identical with the spacing 20cm×15cm.

Experiment of Boro 2020-21

The interaction between transplanting date and spacing was insignificant in all the parameters of yield and yield components (Table 2). Therefore, only the main effect has been described and discussed below:

Effect of transplanting date. Except grain weight, all the parameters were significantly affected by transplanting date (Table 2). Transplanting date 31 December produced the highest number of tiller m^{-2} followed by 15 December, 16 January and the lowest in 1 February. The same trend also observed in number of panicle m^{-2}. The highest number of filled grain panicle^{-1} was found in 15 December followed by 31 December and lowest in 1 September. Transplanting date 31 December produced the highest grain yield (7.85 tha^{-1}) followed by 15 December (7.54 t ha^{-1}) and 16 January (7.35 t ha^{-1}). The lowest grain yield (6.48 t ha^{-1}) was observed in 1 February.

Effect of spacing

The highest number of tiller and panicle was found in closest spacing (20 cm × 15 cm) followed by (25 cm×15 cm) spacing and the lowest in (20 cm×20 cm) spaacing. The tiller and panicle number decreased with increasing spacing. The number of filled grain panicle^{-1} was the highest in (20 cm × 15 cm) spacing but no significant difference with (25 cm×15 cm) and (20 cm ×20 cm) spacing. The lowest number of filled grain panicle^{-1} was observed in spacing (20 cm×20 cm). In case of TWG there was no significant difference observed. In Boro the plants grown in (20 cm× 5 cm) spacing produced the highest grain yield (7.65 t ha^{-1}) which was statistically identical with the yield of (25 cm ×15 cm) spacing. Grain yield obtained from widest spacing (20 cm × 20 cm) decreased significanly (Table 2).

It may be concluded that in Boro season, 15 December to 31 December produced the highest grain yield (7.54 to 7.85 t ha^{-1}) followed by 16 January and lowest in 1 February (6.48 t ha^{-1}). Among the spacing the (20 cm×5 cm) produced the highest grain yield (7.65 t ha^{-1}) which was statistacally similar with the spacing 25 cm×15 cm (7.24 tha^{-1}) and lowest in 20 cm×20 cm spacing.

Integrated nutrient management for yield maximization of rice.

PI: MD. Mamunur Rashid **CI:** S Begum, M S Islam, A Jahan and Dr. M R Islam

This experiment was initiated on a permanent layout at the BRRI farm, Gazipur during T. Aman 2019 to Boro 2020-21 to find out the suitable management practices for yield maximization of rice and soil health. Seven treatments in RCBD with three replications were imposed and each treatment was assigned in 4m×5m sized plot. The treatment combinations were T_1 = Absolute control (No nutrient supply), T_2 = BRRI dose N-P-K-S@83-17-53-12 kg ha^{-1} in T. Aman and 138-21-75-21 kg ha^{-1} in Boro season, T_3 = Soil test based (STB) fertilizer dose N-P-K-S @ 67-10-40-10 kg ha^{-1} in T. Aman And 134-16-75-10 kg ha^{-1} in Boro, T_4 = STB dose + 1 t/ha Cowdung, T_5 = STB dose + 1 t/ha Poultry manure, T_6 = STB dose + 1 t/ha vermicompost and T_7 = STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC. Thirty-day old seedling of BRRI dhan87 in T. Aman and fourty-two day old seedling of BRRI dhan89 in Boro season were transplanted at 20cm ×20cm spacing in both seasons. All manures, soil and plant samples analysis were done by the help of Soil Science Division BRRI, Gazipur. Initial soil (0-15 cm depth) properties were: soil texture, clay loam; pH, 6.94; organic Carbon, 1.59%; Nitrogen, 0.18%; Phosphorus, 21.88 ppm and Potassium, 0.19meq/100g soil. Thirty-day old seedling of BRRI dhan87 in T. Aman and fourty-two day old seedling of BRRI dhan89 in Boro season were transplanted at 20cm×20cm spacing. The flooded water level at 5-7 cm depth was maintained during rice cultivation, and drained out the water 21 days before rice harvesting. Yield and yield component were collected at harvesting time. Collected data were statistically analyzed using a standard statistical procedure (R-software 1).

Grain yield, tiller number, panicle number, plant height and grain number were significantly affected by the different Integrated nutrient management during T. Aman and Boro season. Poultry litter related treatments and BRRI recommended dose performed better than the others in all the parameter except 1000-grain weight. On the other hand, Absolute Control (No nutrient supply) produced the lowest result. The details have been discussed below.

Yield and yield components in T. Aman

Plant height.

In T. Aman (BRRI dhan87), different nutrient management practices have significant effects in rice plant height. The tallest rice plant (129.64 cm) was found in the BRRI recommended dose, which is statistically similar with other nutrient management doses except absolute control. The smallest rice plant (124.87 cm) was found in the absolute control plot (Table 3).

Tiller number.

Tiller production varies significantly among the different nutrient management practices in T. Aman season. STB dose + 1t/ha poultry litter plot produced statistically the highest tiller number followed by other treatments. STB dose + 1t/ha poultry litter produced the highest number of tiller (296 tiller m^{-2}) which was statistically similar with STB dose + 1t/ha vermicompost (285 tiller m^{-2}) whereas control plot produced the lowest number of tiller (204 tiller m^{-2}) among all the treatments. But BRRI dose, STB dose + 1 t/ha cowdung and STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC used plot produced statistically similar tiller number per square meter (Table 3).

Panicle number.

All the nutrient management during T. Aman season significantly affected in panicle production. Here STB dose + 1 t/ha poultry litter, STB dose + 1 t/ha cowdung and STB dose + 1t/ha vermicompost used plot produced statistically highest and similar panicle number. The highest number of panicle (274 panicle m^{-2}) found in STB dose + 1t/ha poultry manure followed by 267 panicle m^{-2} in STB + 1 t/ha cowdung and 266 panicle m^{-2} in STB dose + 1t/ha vermicompost used plot. The lowest number of panicle (180-panicle m^{-2}) among all the treatments was observed in control plot (Table 3).

Grain number and grain weight.

In T. Aman the all-nutrient management plot except control plot produced almost similar number of grain per panicle. STB dose + 1 t/ha Poultry litter and STB dose + 1 t/ha vermicompost plot provide the highest number of grain per panicle (104 grain panicle^{-}1) whereas control plot gave the lowest number of grain (90 grain panicle^{-1}). In addition, there was no significant difference among the treatments in case grain weight (Table 3).

Grain yield.

During T. Aman 2020, Grain yield was significantly affected by different nutrient management practices. STB dose + 1 t/ha poultry manure (6.53 t ha^{-1}) and STB dose + 1 t/ha vermicompost (6.11 t ha^{-1}) produced the highest and statistically similar grain yield followed by BRRI dose (5.89 t ha^{-1}), STB dose + 1 t/ha cowdung (5.75 t ha^{-1}), STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC (5.64 t ha^{-1}), and STB dose (5.46 t ha^{-1}). The lowest yield was observed in control plot (3.40 t ha^{-1}) (Table 3).

Yield and yield components in Boro

Plant height. During Boro season STB dose, BRRI dose, STB dose + 1t/ha Poultry litter, STB dose + 1t/ha cowdung, STB dose + 1t/ha Vermicompost and STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC used plot gave almost similar plant height which was statistically significant from control plot. STB dose with 1 t/ha, poultry litter provides the tallest plant (105.03 cm) whereas control plot gave the smallest plant (96.98 cm) (Table 4).

Tiller number. Tiller production varies significantly among the different nutrient management practices in Boro season. STB dose + 1t/ha poultry litter plot produced statistically highest tiller number followed by others treatment. STB dose + 1t/ha poultry litter produced the highest number of tiller (283 tiller m^{-2}) whereas control plot gave the lowest number of tiller (210 tiller m^{-2}) among all the treatments. However, BRRI dose and STB dose with one t/ha, Vermicompost plot produced statistically similar tiller number per square meter (Table 4).

Panicle number. Panicle production was significantly affected by all the nutrient management during Boro season. Here STB dose + poultry litter used plot produced statistically the highest panicle number. The highest number of panicle (263 panicle m^{-2}) found in STB dose + 1t/ha

poultry manure followed by 258 panicle m^{-2} in BRRI dose and 257 panicle m^{-2} in STB dose + 1 t/ha VC used plot. The lowest number of panicle (190 panicle m^{-2}) among all the treatments was observed in control plot. (Table 4).

Grain number and grain weight:

In Boro season BRRI dose, STB dose + 1 t/ha Poultry litter, STB dose + 1t/ha cowdung STB dose + 1t/ha VC, STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC and STB dose used plot produced almost similar number of grain per panicle which was statistically significant from control plot. STB dose + 1 t/ha Poultry litter provides the highest number of grain per panicle (152 grain panicle^{-}1) whereas control plot produced the lowest number of grain (110 grain panicle^{-1}). On the other hand, there was no significant difference among the treatments in case of grain weight (Table 4).

Grain yield

In Boro season, 2020-21, grain yield was significantly affected by different nutrient management practices. STB dose + 1 t/ha poultry manure (8.90 t ha^{-1}), BRRI dose (8.52 t ha^{-1}) and STB dose + 1 t/ha VC (8.49 t ha^{-1}) produced the highest and statistically similar grain yield followed by STB dose + 1 t/ha cowdung (8.10 t ha^{-1}), STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC (7.95 t ha^{-1}) and STB dose (7.89 t ha^{-1}) where STB dose, STB dose + 1 t/ha cowdung and STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC produced statistically similar grain yield. The lowest yield was observed in control plot (4.48 t ha^{-1}) (Table 4).

Grain yield, tiller number, panicle number, plant height and grain number were significantly affected by the different Integrated nutrient management during both T. Aman and Boro season. Every parameter, poultry litter and vermicompost related treatments performed the best. This study indicates STB dose with one t/ha, poultry litter is better for rice yield. Further research may be needed to find out the suitable integrated fertilizer management.

Monitoring labor wage rate at different locations of Bangladesh

PI: M S Islam **CI:** M M Rashid, Dr. M F Islam and S Begum

A survey was conducted throughout the year to find out the labourers' wage rate at different locations around BRRI HQ such as Joydebpur, Chowrasta, Salna, Board Bazar and Konabari, Tongi area (Table 5). It was observed that the average wage rate per day was Tk. 505-553. The highest wage rate of labourers was in May (Tk. 540-570 per day) due to harvesting and post-harvest operations of Boro rice and transplanting of Aus rice. Another higher rate was during July-August (TK 520-575 per day) due to harvesting and post-harvest operations of Aus rice and transplanting of Aman rice. The third higher wage rate was observed during December-January (Tk 530-575 per day) due to the peak period for harvesting and post-harvest operation of T. Aman rice and transplanting of Boro rice.

The average labour wage rate with food varied between Tk 389-436 and without food Tk 543-614 respectively at different locations surrounding of BRRI regional stations. The working time (8 hrs day^{-1}) of labourers was more or less similar except Satkhira and Gopalganj (Table 6).

Rice Seed Production

PI: M S Islam **CI:** M M Rashid, S Begum and M F Islam

In different rice seasons, Farm Management Division produced about 12,695 kg rice of which 11,095 kg TLS seed, 667 kg non-seed and 933 kg mixed rice (Table 7). All rice has been stored in the BRRI general store.

This division also produced 7,839 kg breeder seed of which 1942 kg, 2817 kg and 3080 kg in Aus, Aman and Boro season respectively (Table 8).

This division has been distributed about 4,760 kg seeds of different rice varieties among the farmers on the eve of the centenary of our national great leader and father of the nation Bangabandhu Sheikh Mujibur Rahman.

Support Services

PI: M S Islam **CI:** M M Rashid, Dr. M F Islam and S Begum

Management of land and labour: Including regional stations, BRRI has 717 labours of which 497 regular and 220 irregular. In BRRI HQ, total numbers is 458 of which 289 regular and 155 irregular labours (Table 9).

Total labour utilization in different divisions was 1,93,147 man days of which 51.12 %, 45.15 % and 3.73 % were utilized for research, support service and holidays, respectively in HQ. It was observed that total labour wages was 10,92,93,485/- of which Tk.5,58,70,830/- and Tk. 4,93,46,008/- and Tk.40,76,647/- were paid to the labourers for research work, support service works, leaves and holidays, respectively.

BRRI has 286.33 ha of land of which 172.64 ha is cultivable. A total of 77.59 ha of land were utilized by different research divisions in different season of which 7.57 ha in Aus, 36.54 ha in T. Aman and 33.48 ha in Boro season. This division manages the BRRI flower garden to maintain the aesthetic view of the campus it has created visible flower garden during summer and winter season.

Table 1. Yield and yield components of rice as affected by Transplanting date and spacing T. Aman 2020.

Treatment	Tiller no m^{-2}	Panicle no m^{-2}	Panicle length (cm)	Filled grain no. $panicle^{-1}$	Unfilled grain no. $panicle^{-1}$	1000 grain wt (gm)	Grain yield (tha^{-1})
Effect of transplanting date							
D_1 (15 Jul)	300	281	22.36	95	24	20.45	5.40
D_2 (31 Jul)	296	279	22.38	99	25	20.52	5.75
D_3 (16 Aug)	275	252	22.41	83	27	20.40	4.30
D_4 (1 Sep)	273	250	22.45	85	26	20.41	4.21
Lsd at 5%	15.20	8.95	ns	6.12	3.52	ns	0.39
Effect of spacing							
15 cm ×15 cm	335	299	22.28	88	26	20.38	5.27
20 cm ×15 cm	296	275	22.45	92	24	20.41	5.09
25 cm ×15 cm	273	256	22.65	93	23	20.42	4.75
	20.04	15.08	0.24	4.25	ns	0.25	0.47

Table 2. Yield and yield components of rice as affected by Transplanting date and Spacing Boro 2020-21.

Treatment	Tiller no m^{-2}	Panicle no m^{-2}	Panicle length (cm)	Filled grain no. $panicle^{-1}$	Unfilled grain no. $panicle^{-1}$	1000 grain wt (gm)	Grain yield (tha-1)
Effect of transplanting date							
D_1 (15 Dec)	295	268	22.17	128	22	21.78	7.54
D_2 (31 Dec)	306	282	22.25	127	26	21.86	7.85
D_3 (16 Jan)	289	266	21.80	127	25	21.83	7.35
D_4 (1 Feb)	274	250	21.75	122	25	21.74	6.48
Lsd at 5%	16.5	15.34	0.27	4.33	3.12	ns	0.44
Effect of spacing							
20cm ×15 cm	298	278	22.10	127	24	21.84	7.65
25cm ×15 cm	292	270	21.98	125	25	21.78	7.24
20cm ×20 cm	277	254	22.03	123	26	21.85	6.71
	15.42	13.47	ns	ns	ns	ns	0.43

Table 3. Yield and yield components of rice in T. Aman 2020.

Treatment	Plant height (cm)	Tiller m^{-2} (no.)	Paniclem^{-2} (no.)	Grain panicle^{-1} (no.)	1000- grain wt. (g)	Grain yield (t ha^{-1})
T_1 = Absolute control	124.87	204	180	90	22.10	3.40
T_2 = BRRI recommended dose N-P-K-S@83-17-53-12 kg/ha	129.64	278	257	102	22.57	5.89
T_3 = Soil test based (STB) fertilizer Dose N-P-K-S@67-10-40-10 kg/ha	126.87	263	246	97	22.34	5.46
T_4 = STB dose + 1 t/ha cowdung	128.30	281	267	96	22.47	5.75
T_5 = STB dose + 1 t/ha poultry manure	129.23	296	274	104	22.52	6.53
T_6 = STB dose + 1 t/ha vermicompost	128.57	285	266	104	22.43	6.11
T_7 = STB dose + 0.33 t/ha CD + 0.33t/ha PM + 0.33 t/ha VC	128.57	278	255	98	22.37	5.64
LSD at 5% level	3.32	13.50	12.23	8.89	0.68	0.48
CV %	3.77	10.12	9.54	9.12	5.09	10.95

Table 4. Yield and yield components in Boro 2020-21.

Treatment	Plant height (cm)	Tiller m^{-2} (no.)	Paniclem^{-2} (no.)	Grain panicle^{-1} (no.)	1000- grain wt. (g)	Grain yield (t ha^{-1})
T_1 = Absolute control	96.98	210	190	110	22.28	4.48
T_2 = BRRI recommended dose N-P-K-S@83-17-53-12 kg/ha	104.53	275	258	148	22.82	8.52
T_3 = Soil Test Based (STB) Fertilizer Dose N-P-K-S@67-10-40-10 kg/ha	104.63	258	242	146	22.83	7.89
T_4 = STB dose + 1 t/ha cowdung	105.03	265	248	145	22.90	8.10
T_5 = STB dose + 1 t/ha poultry manure	104.55	283	263	152	22.88	8.90
T_6 = STB dose + 1 t/ha vermicompost	104.40	269	257	147	22.85	8.49
T_7 = STB dose + 0.33 t/ha CD + 0.33t/ha PM + 0.33 t/ha VC	104.60	260	242	147	22.81	7.95
LSD at 5% level	2.84	7.45	8.92	9.12	0.67	0.46
CV %	3.28	7.98	7.66	7.09	3.32	9.80

Table 5. Labourer's wage rate without stuff at different places around BRRI Gazipur during' 2020-21

Month	Wage rate (Tk)*	Remark
April	460-530	Normal period
May	540-570	Peak period. Harvesting and post-harvest operation of boro rice and transplanting of aus rice.
June	460-550	Normal period
July	520-570	Peak period. Harvesting and post-harvest operation of aus rice and transplanting of aman rice.
August	520-575	
September	510-540	Normal period
October	500-530	
November	510550	
December	530-575	Peak period. Harvesting and post-harvest operation of aman rice and transplanting of boro rice.
January	530-570	
February	500-550	
March	480-530	Normal period
Average	505-553	

* Wage rate of each month is the average rate of different places such as Joydebpur, Chowrasta, salna, Board Bazar, Konabari area.

Table 6. Labourer's wage rate with and without food at different locations of Bangladesh 2020-21.

Location	Average wage rate (Tk) with food	Average wage rate (Tk) without food	Working time
Habiganj	300-350	600-750	6.0 am- 2.0 pm
Rangpur	400-450	600-700	6.30am- 2.30 pm
Rajshahi	350-400	400-500	6.0am- 2.0 pm
Barisal	600-650	700-750	8.0am- 5.0 pm
Sonagazi	450-500	550-600	6.0 am- 2. 0 pm
Cumilla	350-400	650-700	6.0 am- 4.0 pm
Satkhira	350-400	450-500	7.0 am- 12.0 pm
Kushtia	375-400	475-500	6.0 am- 2.0 pm
Bhanga	350-400	600-700	7.0 am- 3.0 pm
Gopalganj	400-450	500-550	7.30am- 1.30 pm
Sirajganj	350-400	450-500	8.0am- 4. 0 pm
Average	389-436	543-614	-

Table 7. Rice seed production of different varieties during 2020-2021.

Variety	Season			Total (kg)
	Aus	Aman	Boro	
BR22	-	350	-	350
BR23	-	290	-	290
BRRI dhan34	-	160	-	160
BRRI dhan46	-	40	-	40
BRRI dhan71	-	175	-	175
BRRI dhan75	-	65	-	65
BRRI dhan87	-	225	-	225
BRRI dhan28	-	-	1060	1060
BRRI dhan29	-	-	810	810
BRRI dhan50			620	620
BRRI dhan58	-	-	385	385
BRRI dhan67			340	340
BRRI dhan81	-	-	965	965
BRRI dhan84		-	610	610
BRRI dhan85	195			195
BRRI dhan88	-	-	630	630
BRRI dhan89	-	-	1155	1155
BRRI dhan91		60	-	60
BRRI dhan92			1830	1830
BRRI dhan96			920	920
BRRI dhan98	210			210
Seed (Total)	**405**	**1365**	**9325**	**11095**
Non seed		667	-	667
Mixed rice	-	933	-	933
Grand total	405	2965	9325	12695

Table 8. Breeder seed production of different varieties during 2020-2021.

Variety	Season			Total (Kg)
	Aus	Aman	Boro	
BR22	-	942	-	942
BRRI dhan48	595	-	-	595
BRRI dhan49	-	1875	-	1875
BRRI dhan58			3080	3080
BRRI dhan82	750	-	-	750
BRRI dhan83	597	-	-	597
Total	1942	2817	3080	7839

Table 9. Land and labor strength of BRRI, 2020-2021.

Station	Total land (ha)	Cultivable land		Labour (no.)		
		Area (ha)	% of total land	Muster Roll		Total
				Regular	Irregular	
HQ at Gazipur	76.83	44.45	57.86	289	155	444
Cumilla	24.68	16.03	64.95	22	13	35
Hobiganj	35.03	25.90	73.94	27	11	38
Sonagazi	45.77	35.90	78.44	35	04	39
Barishal	41.10	10.74	26.13	25	03	28
Rajshahi	13.24	8.92	67.37	25	06	31
Bhanga	11.46	9.55	83.33	16	05	21
Rangpur	6.07	4.05	66.72	29	05	34
Satkhira	20.00	8.10	40.50	19	02	21
Kushtia	4.05	3.0	74.07	10	01	11
Sirajganj	4.05	3.0	74.07	-	9	9
Gopalganj	4.05	3.0	74.07	-	6	6
Total	286.33	172.64	60.29	497	220	717

Farm Machinery and Postharvest Technology (FMPHT) Division

+ Workshop Machinery and Maintenance (WMM) Division

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SUMMARY

An initiative was taken to fabricate a prototype of a whole feed combine harvester in Farm Machinery and Postharvest Technology (FMPHT) divisional workshop, Gazipur which will have an easy fabrication process, low cost, high capacity, and few repair-maintenance obligatory. The first version of the whole feed combine was developed and some problems were identified in this version. Material selection was not good enough and frequent troubles were observed during field operation. Therefore, an initiative was taken to fabricate the second version of the whole feed combine harvester considering the problems which were identified in the previous version of the machine. The introductory performance test was done in different locations. Firstly it was worked satisfyingly but after working few hours the machine stopovers due to the clogging which occurred at the inclined augur/screw. After removing the congested grain from the auger/screw, the machine again worked very courteously. After solving this problem, again the performance test will be organized in the upcoming season.

A head feed thresher was fabricated by using locally available materials in Nayem Engineering workshop, Modan, Netrakona. BRRI provided design, drawing, technical and financial support to develop and manufacture the machine in that workshop. The preliminary test of the machine was done in Aman 2020 season at Modan, Netrakona to find out the mechanical faults of the machine. At that time, it was found that the machine had no major faults. After that, the machine was carried to the FMPHT division for a systematic test. The machine performance test was organized at BRRI threshing yard in Boro 2021season. Few faults were found and modifications were done for eliminating that faults. Machine capacity was not adequate due to the low speed of the feeder chain and feeding mechanism. Some modification was done and methodical test will be organized in the upcoming season. Another prototype is needed to be developed for the upgrading of the capacity and other functions upgradation of the machine.

A research was conducted to design and fabricate a semi-automatic rice transplanter utilizing locally accessible materials at RK Metal in Faridpur. For the development and fabrication of this machine, BRRI offered design, drawing, technical, and financial support by the SFMRA project of BRRI. The study was aimed at design, fabrication, and testing the performance of the prototype. The machine has already been manufactured by the local workshop. A preliminary test of the machine was done at BRRI regional station, Bhanga to find out the mechanical faults of the machine. It was found that the machine has no major faults. Fine-tuning is going on. The performance test of the machine will be done thoroughly in the upcoming season.

A study was conducted to design, fabricate and performance evaluation of BRRI manual seed sower machine in the FMPHT research workshop. The fabrication of the designed machine was completed using AutoCAD tools. Seed hopper, seed metering device and rubber wheel was fabricated using dice. The machine was fabricated using locally available material considering accurate metallurgy. It was calibrated for different grain sizes. The performance of the prototype is tested primarily in research workshop. The result of the primary test was satisfactory.

A research was conducted to mitigate the biotic and abiotic effect on germination and mat type seedling growing during Boro season. Six treatments were taken under two different thickness (0.04 mm and 0.08 mm) of white polythene shed covered day time only (12 hour) and day and night time (24 hour) as abiotic stress control factors. Along with that two fungicide (Atavo and Autostin) and MoP fertilizer were used to control biotic stress on young seedling raised in plastic tray. Plant height, number of leaf, leaf length, stem length, stem thickness, rolling resistance and density was measured in two interval (after 15 and 30 days). The highest temperature (40˚C) was observed inside 8 grade (0.08 mm thickness) polythene shed covered day and night time (24 hour). The combine effect of 0.08 mm thick polythene shed and MoP treatment showed highest value for seedling height (167.3 mm), number of leaf (4), leaf length (99.8

mm), stem length (73.5 mm), stem thickness (1.1 mm), seedling density (18/cm^2). Fungal infection was found lowest in 0.08 mm polythene covered day and night time. Seedling raised plastic trays are much more effective than conventional way in terms of germination and quality. Hence, 0.08 mm thick white polythene was recommended as covering mechanism and MoP as treating mechanism for seedling raising in cold weather.

In order to overcome scarcity of labour in harvesting of paddy and wheat self-propelled reaper has high demand among the farmers. Most of the reapers in our country are imported from China and Korea. Moreover small land size is another problem in Bangladesh for machine operation. A small size battery operated reaper is fabricated at Zomzom workshop, Pabna. In the previous version, the battery operated reaper faced mainly two problems: the harvested paddy was not passed properly through the conveyor section and it was run only three hours. Modification was done to overcome these problems. The machine will be tested at Aman 2021 season.

The experiment on effects of aging was conducted using BRRI dhan50 and higher head rice yield was found in plastic drum after nine month of aging period. The result is promising for premium quality rice. To get more precious result paddy could be stored in temperature control room and air tight storage structure.

The commercial value of rice milling parameter for BRRI dhan90 was evaluated by BRRI modified rubber roll husker and MN-15 polisher. Husking efficiency of modified rubber roll de-husker was around 90.67% for BRRI dhan90. Milling recovery of BRRI dhan90 was 65.7 % polished in MNMP - 15 type polisher. The average head rice recovery based on input paddy was 60.7 %, which is promising for processing of quality rice. Steel engelberg huller may be replaced with one rubber roll de-husker and a polisher for better quality rice. Beside this, rubber roll de-husker separates husk and friction type polisher separates bran. Separately collected husk and bran is suitable for briquette and edible oil production.

Ninety three batches of two day long residential training programme were conducted under financial and technical support from SFMRA project of FMPHT division during the period of 2020-2021. Participants of the training programme were attended from all BRRI RSs and its adjacent area and total 1,865 participants were trained among them1,836 were male and 29 were female. Participants were trained on operation, repair and maintenance of different agricultural machinery and technologies like; transplanter, combine harvester, diesel engine, power weeder, prilled urea applicator, self propelled reaper, power tiller , tractor etc theoretically and practically in the threshing floor and in the main field. At the end of the training, a post-evaluation and trainees reactions regarding the training were collected. Certificates, leaflets and a set of tools were distributed among the participants. Trainees opined that they are now more confident about the use of the agricultural machinery.

Three training programmes on manufacturing, safety and work environment to the workshop personnel of local farm machinery manufacturing industries were conducted in R K Metal, Faridpur; Janata Engineering, Chuadanga and Alim Industries, Sylhet. Three days long hands on training were conducted on machine tools used in the agriculture machinery fabrication workshop, welding, filing, grinding, drilling, power transmission system, operation and maintenance of workshop machinery, safety and work environment of the workshop. The trainees were upgraded to fabricate good quality machine using appropriate tools and accurate measurement through these training.

AGRICULTURAL MACHINERY DEVELOPMENT AND TESTING

Development and fabrication of a whole feed combine harvester

A prototype of whole feed combine harvester was completed using locally available materials taking in consideration of 1st prototype faults in the FMPHT divisional workshop, BRRI, Gazipur (Plate 1). Some parts of the machine such as crawler, gearbox, hydraulic systems, etc. were procured from local markets and local companies.

Plate 1. Fabrication of whole feed combine harvester at FMPHT divisional workshop.

Working principle of the whole feed combine harvester

When the machine moves forward, the divider separates the crop for cutting, the reel picks up the standing or laid crops and pushes them to the cutting mechanism and then pushes them down to the platform after cutting. The platform auger conveys crosswise to there, the retracting fingers throw the crop to the inclined conveyor chain which feeds the crop into the thresher. In the thresher, the cylinder and concave assembly play an important part to separate most of the crop into seed, chaffers that fall directly onto the grain pan or onto a conveyor. The cylinder beater tends to strip the threshed material from the cylinder, aids in further separation at this point, and directs the straw and remaining seed onto the straw carrier (osculating rack or rotary walker). The straw carrier agitates the material to separate out any remaining seed and un-threshed heads as the straw is moved rearward to be discharged from the machine. The material separated from the straw is collected by the grain return conveyor and delivered to the grain pan at the front of the chaffer sieve. The mixture of threshed grain with some chaffer and small debris drops from the concave sieve comes to a vibrating sieve and to be cleaned by the combined operation of a fan and the vibrating sieve. After cleaning, the grain is delivered to the grain tank by a horizontal auger and a lifting auger. After threshing, the straw in the thresher is thrown out through the straw outlet onto the ground. The threshed and clean grain will discharge at Sacking platform through grain delivery spout in the bag or grain tank.

Performance test of the machine

The preliminary performance test was done in three different locations (Tarotpara, Jogitola and BARI farm) during Boro 2021 season (Plate 2). Firstly the machine worked satisfyingly but after working few hours the machine stopovers due to the clogging that occurred at the inclined augur/screw. The auger was clogged due to the dust particle such as cutting leaves and residual straw of the plants, which was generated from threshing drum due to additional moisture content of the paddy. Besides the side clearance of the inclined screw may causes this clogging problem. The inner clearance of the inclined screw was found over then the designed clearance due to poor workmanship. Some modifications were done by changing the chain-sprocket instead of the belt pulley. For this modification, the speed of the horizontal auger/screw has increased more than the previous belt-pulley. After removing the clogged grain from the auger/screw, the machine again worked very nicely. Operation of cutting, conveying, threshing, cleaning was good enough but only clogging problem was found in conveying paddy through the horizontal and inclined screw conveyor. However, it was observed few amounts exhaust gases with lower engine performance, so that engine power needs to increase for obtaining better capacity. The fuel consumption of the machine was 3.78~3.97 l/h and field capacity was 0.318~0.332 ha/h. Table 1 shows the results of the field performance of the machine.

Plate 2. Field trials in different locations (Tarotpara and Jogitola, Gazipur)

Figure 1 presents the travel speed, field capacity and fuel consumption of the machine. The machine was operated in Tarotpara, Jogitola and BARI farm at average speed of 2.19, 2.14, 2.12 km/h respectively. The field capacity of the machine was found 2.46 (0.332 ha/h), 2.40 (0.321ha/h), 2.37 (0.318 ha/h) bigha/h at the location of Tarotpara, Jogitola and BARI farm respectively where the fuel consumption was found 3.97, 3.83, 3.78 l/h during operation in that same locations.

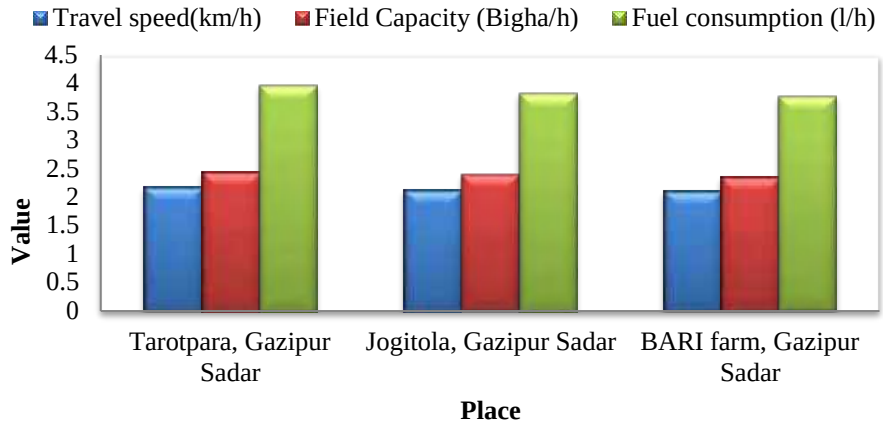


Fig. 1. Travel speed, field capacity and fuel consumption of the machine in different locations.

Table 1. Field performance of BRRI fabricated combine harvester.

Plot section no.	Duration of test (Working hrs.)	Travel speed (km/h)	Area covered (bigha/h)	Area covered (ha/h)	Rate of work: Grain output (kg/h)	Rate of work: Straw output (kg/h)	Fuel consumption l/h
Place: Tarotpara, Gazipur Sadar, Gazipur							
1	1.0	2.20	2.47	0.330	1198.25	978.60	4.20
2	1.5	2.22	2.49	0.343	1256.65	1065.30	3.70
3	1.0	2.15	2.41	0.323	1230.50	1020.50	4.00
Average		2.19	2.46	0.332	1228.47	1021.47	3.97
Place: Jogitola, Gazipur Sadar, Gazipur							
1	1.5	2.00	2.24	0.300	1075.50	950.70	3.90
2	1.0	2.30	2.58	0.345	1150.00	930.60	3.60
3	0.50	2.12	2.38	0.318	1210.50	1040.50	4.00
Average		2.14	2.40	0.321	1145.33	973.93	3.83
Place: BARI farm, Gazipur Sadar, Gazipur							
1	2.0	2.10	2.35	0.315	990.50	920.60	3.50
2	1.0	2.05	2.30	0.308	1010.65	890.40	3.80
3	1.5	2.20	2.47	0.330	1080.50	905.80	4.00
Average		2.12	2.37	0.318	1027.22	905.6	3.78

Figure 2 presents the grain output and straw output of the machine at different locations in Gazipur district. The grain output of the machine during operation was found 1228.47, 1145.33, 1027.22 kg/h at the locations of Tarotpara, Jogitola and BARI farm respectively. On the other hand the straw output of the machine during operation was found 1021.47, 973.93, 905.6 kg/h respectively at that same locations.

Identification of problems

The operators of the machine, present scientist and farmers were interrogated primarily regarding their opinion about the overall performance of the machine during operation in the field. In general they gave satisfactory remarks and opinions about the machine performance in special point of view to the following problems and comments.

- Grain blockage was found in the auger/ screw of the outlet;
- More engine power required;
- More time required to harvest;
- The shuttering loss of grain was observed in the laid down crop during harvesting.

Design and development of a head feed power thresher

BRRI developed Open Drum Thresher (ODT) and Close Drum Thresher (CDT) thresher is very popular all over country. However, the straw remained intact in ODT but there is no cleaning facility in it. So farmers needed more time in cleaning the threshed paddy. On the other hand, CDT has a cleaning facility but straw are crashed away and could not use for their desire purpose. Therefore, an attempt was taken to overcome the existing problem where a cleaning facility will be available and straw remain intact condition.

A prototype of the head feed power thresher was designed and fabricated using locally available materials in the Nayem Engineering workshop, Modan, Netrakona. BRRI provided design, drawing, technical and financial support to develop and manufacturing the machine. The important functional elements are feeding chain, main threshing drum, extra straw outlet, blower, first horizontal screw conveyor/augur of grain discharge, auxiliary threshing drum, reel, grain screw conveyor, second horizontal screw conveyor/augur of grain discharge, gearbox, clean grain outlet, etc. The clean grain discharge mechanism and bagging system are also considerable parameters to design a head feed thresher. The thresher has the provision of threshing, cleaning and straw remain intact after threshing. It has also a whole feed-threshing facility.

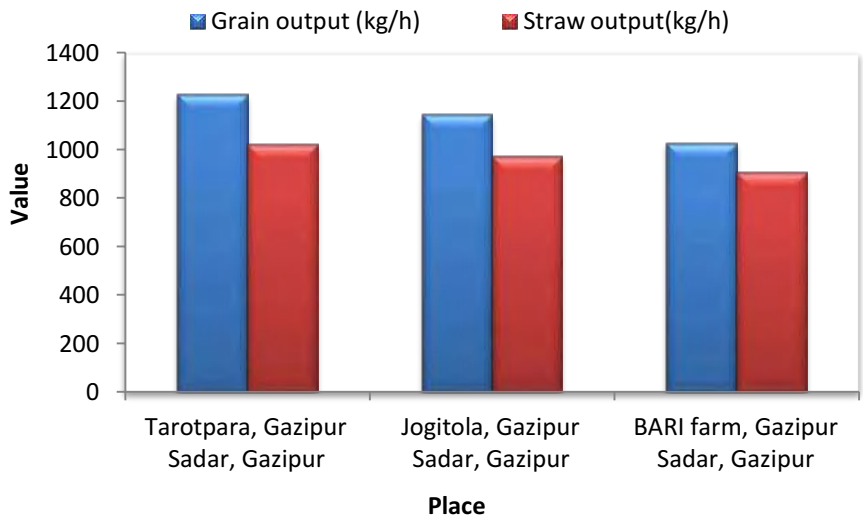


Fig.2. Grain output and straw output of the machine in different locations.

Design consideration

The head feeds combine harvester and a Korean thresher were taken into consideration for designing the head feed thresher. The designed thresher has two functions (a) head feed mechanism for residual straw intact and (b) whole feed mechanism, where straw may be smashed. Also, the thresher has the facility of cleaning, creating less dust, easy handling, and movability mechanism.

The thresher was designed as per the following considerations:

- Both function of head and whole feed mechanism
- Easily threshed small bundled paddy
- Two men can operate
- Higher capacity than open drum thresher
- The thresher should be simple and easy in operation and maintenance
- Locally available materials should be used to fabricate which minimize the fabrication cost
- Capacity should be accepted by the farmers
- Trouble-free operation.

The machine is mainly composed of engine, feeder table and gripper/feeding chain, threshing drum, concaves, oscillating grate, blower/fan and rice outlet (Fig. 3). The working progress of the machine is as follow: the top of the crops is feed into machine for threshing by hand or by gripper chain while the whole straw leaves. The working load is light and the energy consumption is low and it is easy to separate rice and straw because of the mode of half feed.

The power transmission system of the thresher

In the first stage, engine power shifted in the idle pulley. Then the power shifted to the main power transmission shaft. In the second stage, power is transmitted to the main threshing drum, extra straw passage, and blower from the main power transmission shaft. The threshing drum and cleaning blower, extra straw throughout chain get power from idle pulley using different sizes pulley through B-type V belt and chain-sprocket. The power was transmitted to the auxiliary threshing drum from the main power transmission shaft. Then the power was transmitted to the first horizontal augur/screw of grain discharge by chain-sprocket from the auxiliary threshing drum. The power of the gearbox was transmitted from the first horizontal augur of grain discharge by chain-sprocket. From the gearbox, the power was shifted to the feeding chain by a double sprocket. The power was also transmitted to the second horizontal augur/screw of grain discharge from the other side of the auxiliary threshing drum. This power was also transmitted by chain-sprocket. From the second horizontal augur, the power was transmitted to the clean grain outlet by chain-sprocket.

Power transmission/shifting mechanism of the thresher

Engine rpm (Revlution Per Minute) 2200 was used as the prime mover of the machine. Then the engine rpm was reduced to 1435 rpm using a 230 mm diameter pulley. The main power transmission shaft pulley diameter was 210 mm and its calculated rpm was 1039. From the main power transmission shaft, the power was transmitted to the main threshing drum which calculated speed was 607 rpm and its pulley diameter was 260 mm. The pulley diameter of the extra straw outlet was 180 mm and its calculated speed was 924 rpm. The power of this out came from the main power transmission shaft. The power of the blower was transmitted from the main power transmission shaft as well. Its pulley diameter was 75 mm and its calculated speed was 2770 rpm. The pulley diameter of the auxiliary threshing drum was 152 mm and its calculated revolution speed was 1039 rpm. The calculated speed of the first horizontal auger of grain discharge was 393 rpm and its larger sprocket teeth quantity was 37 and the smaller sprocket teeth number was 14. The teeth quantity of the input sprocket of the gearbox was 37 and rpm was 149. The calculated speed of the feeding chain was 110 rpm. The calculated speed of the second horizontal augur was 346 rpm and the number of teeth of the sprocket was 42 (Fig. 4).

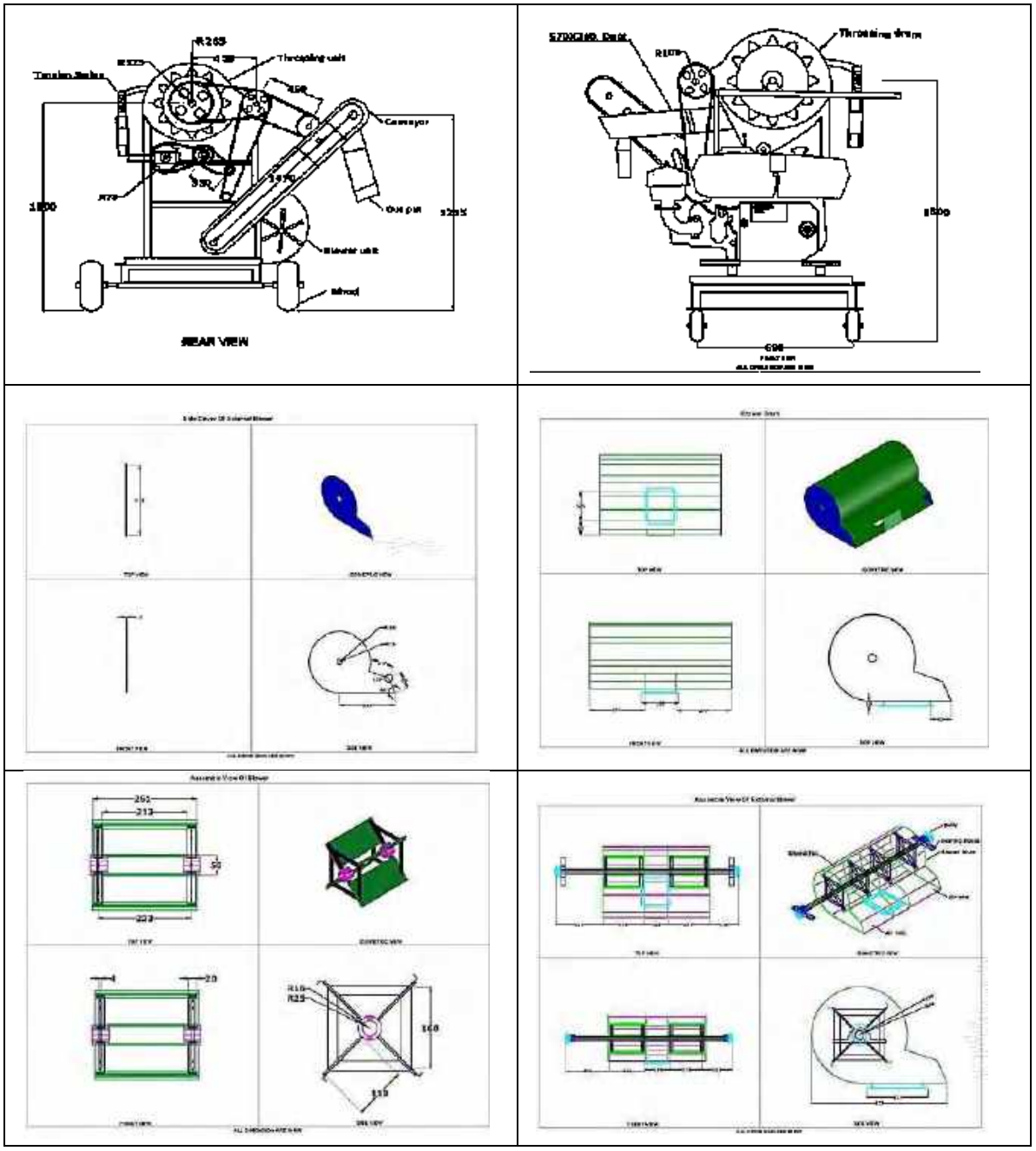


Fig. 3. Some drawing views of the head feed thresher.

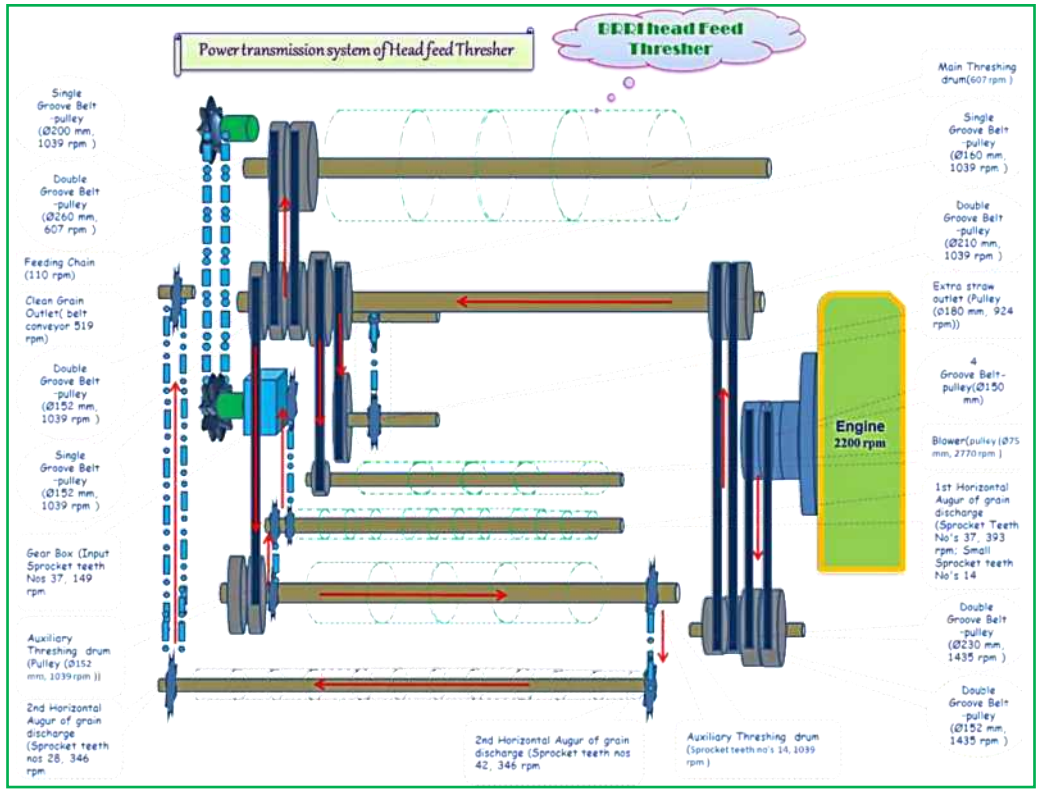


Fig. 4. Schematic illustration of the power transmission system.

Performance test

Tests were conducted on the machine to ascertain its performance (Plate 3). The rice variety was BRRI dhan89. The output from the seed outlet and the chaff outlet were collected and weighed. Generally, the threshing and cleaning efficiencies increased by increasing the drum speed and decreased by increasing both the feed rate and seed moisture content. The increase in the percentage of threshing and cleaning efficiencies by increasing drum speed was attributed to the high stripping and impacting forces applied to the grains, which tend to improve the threshing operation and increase threshing and cleaning efficiencies. The moisture content of the paddy was 26%. Higher moisture content causes lower efficiency in threshing and cleaning. These results were attributed to the high elastic conditions of high moisture content, which results in a little impacting force on the threshing materials.

Plate 3. Performance test of head feed thresher.

Table 2 shows the performance test consequence of the head feed thresher. The thresher has tested both purposes as head feed and whole feed options. The straw length remains untouched after threshing in head feed option. The threshing capacity for head feed and whole feed conditions were observed at 410 kg/h and 450 kg/h, respectively. The cleaning efficiency of the blower was found very well. Un-separation paddy for head feed option was found 3.5 % due to irregular plant height but un-separation paddy for whole feed options was found 1.25 % which was lower than head feed option.

Problems

The speed (rpm) of the feeding chain was not up to the mark. The lower capacity of the machine was found due to the slower speed of the feeding chain. Also, the threshing drum speed, blower speed, auger speed, and delivery grain conveyor belt speed were not perfectly synchronized. The clearance between drum and feeding chain was not perfect therefore un-threshed paddy remained after threshing of the paddy. Cleaning performance and delivery performance of grain of the machine was satisfactory but the overall capacity of the machine was inadequate. Further modification and another prototype development are needed for the upgrading of the capacity and other utilities of the machine.

Semi-automatic rice transplanter

The transplanting machines available in Bangladesh are still being imported. Engine-driven mechanical transplanters are costly and the inter-raw spacing that is not sufficient for the Bangladesh situation is to be set. Previously, several attempts have been taken at home and abroad to developed manually operated rice transplanters. However, manually operated transplanter have been developed that are inefficient. The main reason for the poor acceptance was a low capacity and enormous energy needed to run the machine.

Table 2. Field performance of head feed thresher during Boro 202 season.

Trial no.	Head feed		Whole feed	
	Threshing capacity, kg/hr	Un-separation paddy (%)	Threshing capacity, kg/hr	Un-separation paddy (%)
1	405	3.5	455	1.5
2	415	3	435	1
3	430	4	460	1
4	390	3.5	450	1.5
Average	410	3.5	450	1.25

The general features of head feed thresher

Item	Feature	Item	Feature
Engine type	16 hp Diesel engine	Horizontal augur length	130.0 cm
Operator requirement (labour)	2 nos.	Horizontal auger diameter	13.0 cm
Operation	Head feed and whole feed	Clean grain delivery output length	147.0 cm
Cleaning facility	Blower	Clean grain delivery output width	19.0 cm
Movement of the thresher	Two rubber wheel and two steel wheel	Extra straw outlet length and width	65.0 cm and 19.0 cm
Grain collector	Auger/screw, cup type belt conveyor	Grain delivery belt conveyor length	142.0 cm
Power transmission system	Belt pulley, chain-sprocket, and gearbox	Feeding chain length	390.0 cm
Threshing teeth	loop type	Feeding chain width	6.6 cm
Main threshing drum length	120.0 cm	Teeth per feet	9 nos
Threshing drum dia.	46.0 cm	Feeding height	126.0 cm
2nd threshing drum length	120.0 cm	Machine height	184.0 cm
Blower length	72.0 cm	Machine width	170.0 cm
Blower diameter	28.0 cm	Machine length	280.0 cm

The following materials were used for developing of semi-automatic rice transplanter:

Sprockets. The main function of sprockets is to transmit torque through the chain. There are two sprocket-one drivers and other driven mounted on respective shafts.

Chain. The function of the chain is to transmit torque from driver to driven sprockets. The chain is a simple type.

Tray. This is used to store the rice plant from where the planting fingerpicks the plant and saw it in the ground. This tray has four vertical guide slots.

Planting fork. The planting fork is the main element that is responsible for the plantation of the nursery seed. It has a specific shape that picks the nursery seed and plants in mud. It oscillates at a certain angle and is called a fixed fork mechanism.

Main frame. The main function of a rigid frame is to locate all the different components onto it and held it rigid so the proper function of the operation can be delivered.

Motor and battery. A motor (0.5hp, 12V dc motor) was used as a power transmission system. One battery was used (12V, 24 W) as a power supplier. A charger was used to charge the battery by using electricity.

Design consideration

During design, the following criteria have been considered to develop a manually operated rice transplanter.

- Easy and simple operation and maintenance
- Locally available materials
- Easy manufacturing
- Low manufacturing cost
- Two men can operate in this machine
- The socio-economic condition of Bangladesh.

A floating type rice transplanter concept that uses a DC electric motor powered by Lithium-ion (Li-ion) batteries. The traction DC electric motor and the battery array are fitted in the chassis of the machine. It is a walking type and transplants four rows in a single pass, and can carry more seedlings to replenish the seedling tray intermittently. The transplanting mechanism is driven by sprockets on the rear axle. The DC motor is the solitary source of the torque to drive the machine forward while also driving the transplanting mechanism. The general mechanism that is going to be adopted is the use of the transplanting arm. A conceptual design of different parts of the machine has been done using AutoCAD software (Fig. 5).

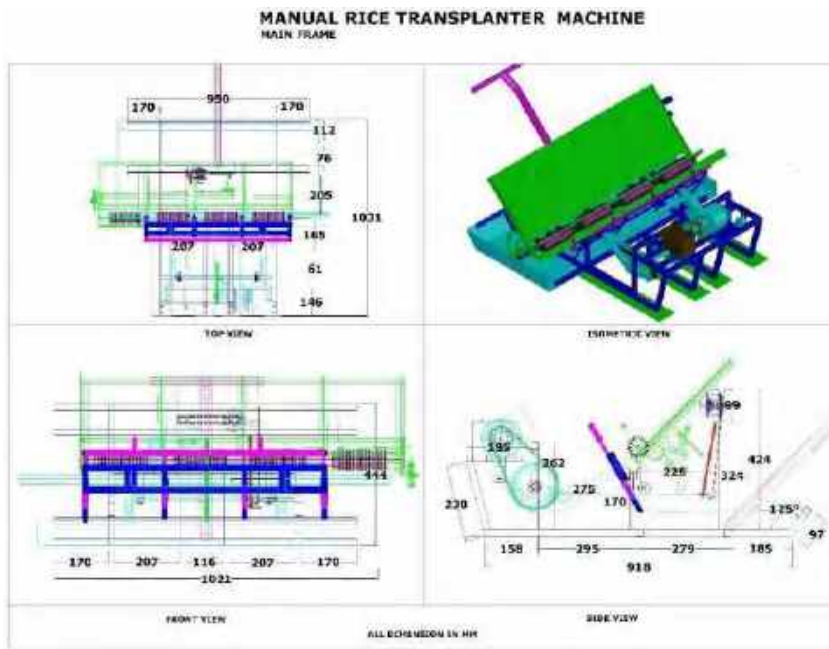


Fig.5. Seismic view of the proposed semi-automatic rice transplanter.

Main Frame

It is made up of an MS square bar on which other components like hopper, disk, shaft, etc are mounted. The mainframe of the machine will be made by 20×20×10 mm MS square bar (Fig. 6).

Tray movement mechanism

The tray is to carry the seedling mat and to direct the plants to the planting arm. Basic factors (width, length, angle, speed of movement) were considered in designing the tray mechanism (Fig. 7). As two plant rows were planted at once, the tray width was twice as plant space. The movement of the tray per one planting of the arm was decided by the volume taken away from the planting finger at a time. The volume taken by the finger depends on the space of the finger jaw. Tray movement is decided by the forward speed of the machine. To make constant feeding of the seedling mat to the planting arm it should come down to the end of the tray by gravity. Higher angles reduce the energy required to feed the seedling mat to the transplanting arm while too much angle effect on falling and compaction of nursery at end of the tray making it difficult to take out the plants from the nursery by transplanting arm. Length is decided by the power given to the machine. Higher the length of the mat makes higher the power required to carry the weight of the mat. So, to reduce the weight of the machine tray length was reduced to have an optimum weight (Fig. 8).

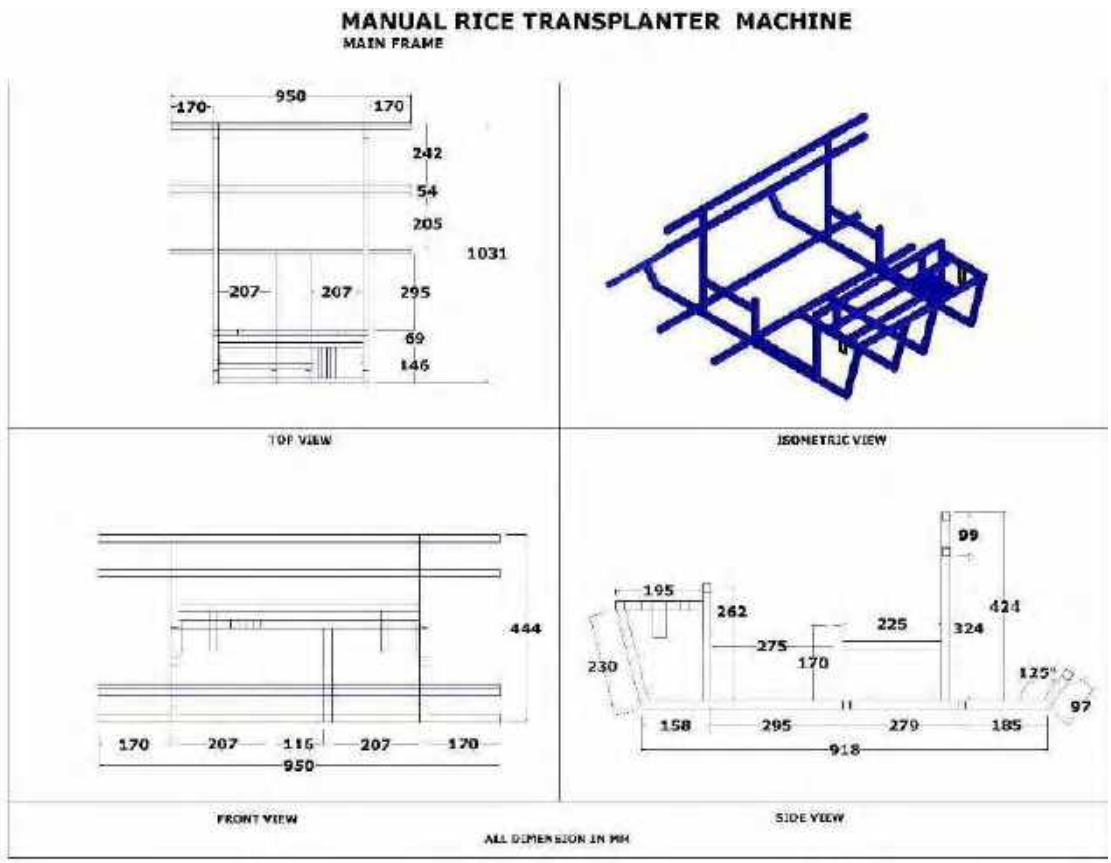
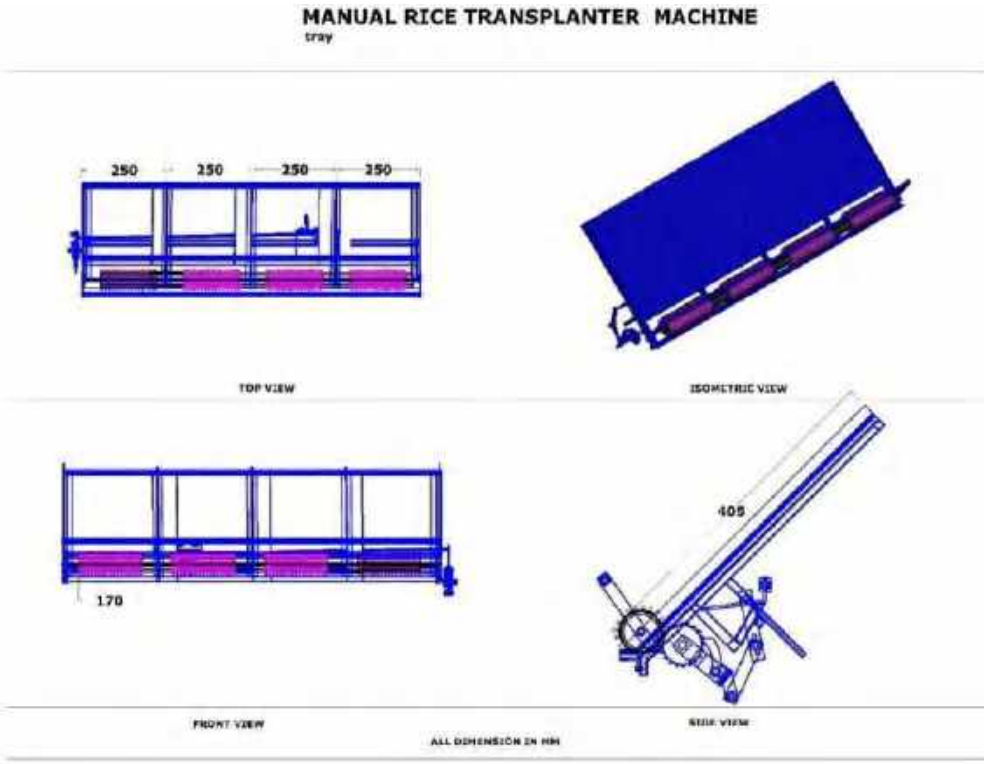


Fig. 6. Mainframe of the transplanter.



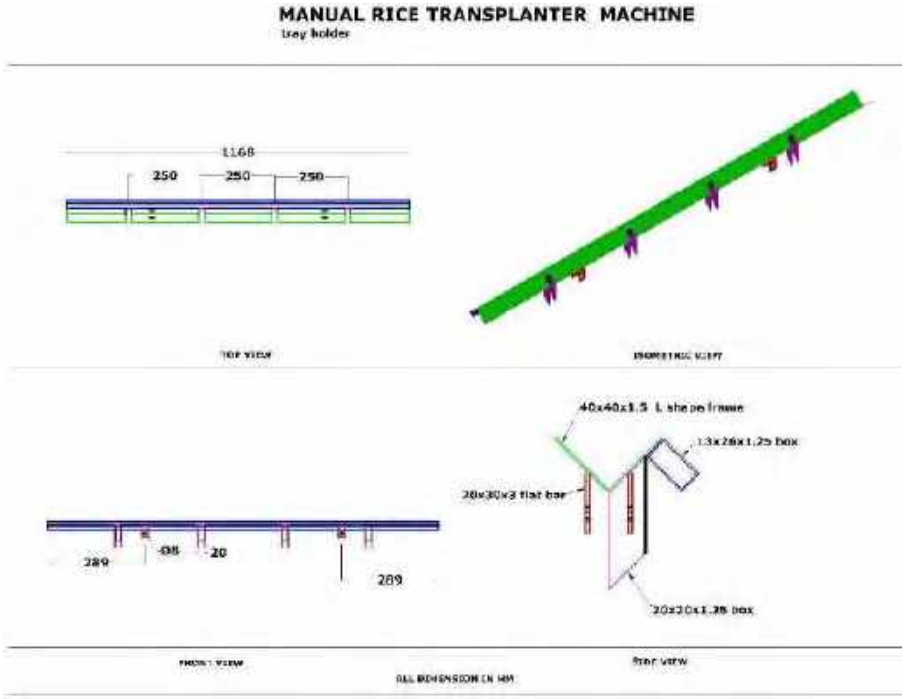


Fig.7. Different view of tray holder.

Power Transmission

The chain box is mainly responsible for the transmission of power from the planting arms to the tray moving mechanism. The chain box house is made up of cast iron material. Inner construction of the chain box consists of two sprockets of equal teeth connected by a chain. There are two sprockets externally connected to the chain box. The teeth sprocket from the one end of the chain box is connected to the planting arm through the chain. The teeth will be fixed by calculating the rpm of the motor (Fig.9).

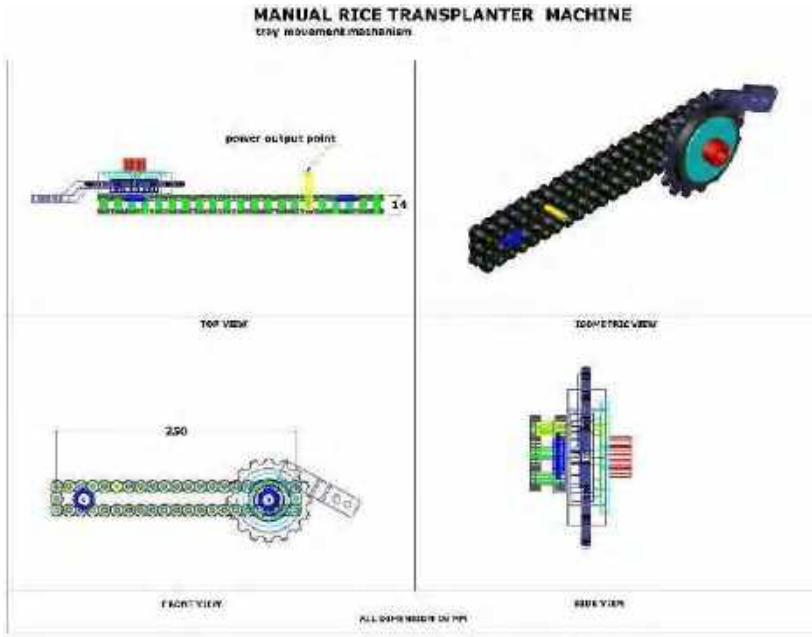


Fig. 8. Try movement mechanism.

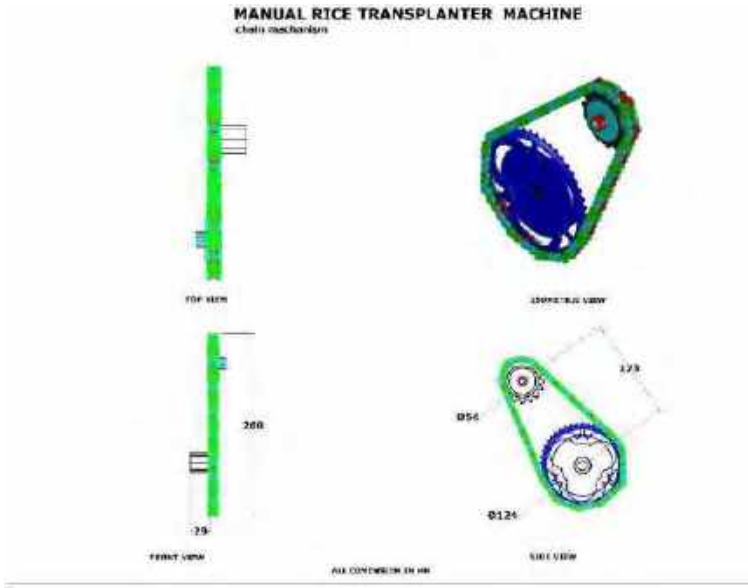


Fig. 9. Power transmission mechanism.

Floating device

The machine must be able to float in order to avoid sinking deep into the soil while working in a wet field. The floating device is screwed to the machine at the bottom and is rectangular in shape, matching the machine's base measurements (Fig. 10). It is mostly made of lightweight material.

Planting unit moving pathway

The moving pathway consists of a four-bar linkage mechanism which can be treated as a planting arm for the planting unit. This four-bar linkage mechanism provides the basic pick and place movement. Other parameters include speed of traveling, plant catching mechanism, depth of pathway. A four-bar linkage mechanism is used. In the catching mechanism place of catching should be designed and calculated accurately so that plant shouldn't be harmed or damaged while catching or releasing executed by the transplanting arm.

Motor selection

All power to propel the machine forward and drive the machine is supplied by the electric motor. A chain and sprocket mechanism is used to transmit power to the planting unit. A double shafted D.C. War P9 motor was selected because it does not need an inverter as compared to the A.C. induction motor which decreases the overall cost of the machine.

Manufacturing progress

The prototype has been constructing according to the conceptual design and drawing in FMPHT Divisional workshop and RK metal, Faridpur. Plate 5 shows some pictorial views.

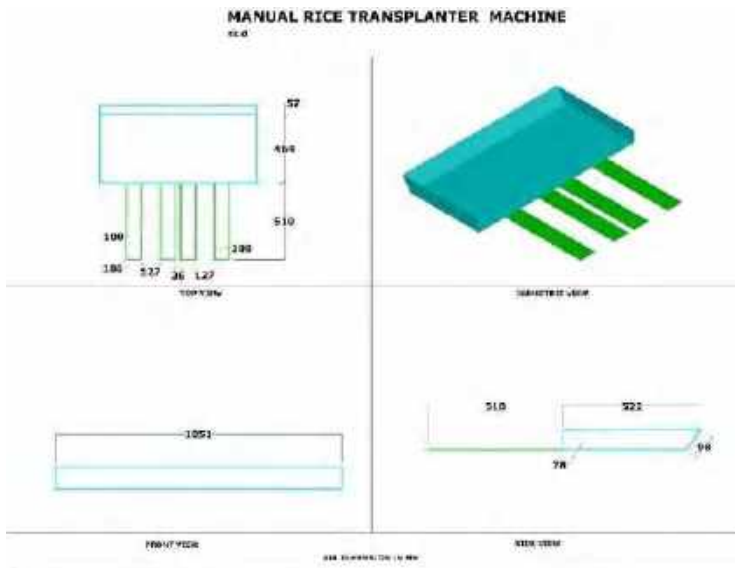


Fig.10. Floating device of manual rice transplanter.

Plate 5. Pictorial view of the manufacturing process.

Observational trial

An observational trial was done in the experimental field of BRRI RS, Bhanga, Faridpur (plate 6). The following observation are made during field trial:

- The overall performance of the machine is good, especially the transplanting mechanism.
- Some mechanical faults were identified during the field operation.
- The machine weight seems too high.

12-volt motor is not available in the local market. The power supply unit should be modified. A small petrol engine might be used by replacing Battery. The power-driven wheel can be attached to the easy movement of the machine.

Design and development of a manual seed sower machine for raising mat type seedling

Uniform seedling density is essential for a mechanical rice transplanting system. Manual seed distribution system is labourious and time-consuming operation. In this case, mechanical seed sower can spread out uniformly and neatly in seedling tray. Therefore, it is high time to introduce a community based seedling-raising approach and develop entrepreneurs at the village level. To address this issue, it is utmost need to utilize machine technology to do the work faster and precisely. Hence this study was undertaken to calibrate a seed sower machine developed in BRRI for uniform seed dispensing and evaluated its overall performances using different rice varieties of different grain sizes.

Design consideration

The design of the manual seed sower machine was done with the help of AutoCAD engineering tools (software). The prototype of the machine was fabricated in the FMPHT research workshop according to the design. A laboratory test was done in the FMPHT divisional workshop.

- Ease of sowing
- Easy and simple of operation and maintenance
- Locally available materials were used to fabricate the machine
- Capable of dispensing various sizes of seed
- Ensure the uniformity of seed distribution
- Avoid the spilled seed on the tray (Aero dynamics-falling rate-height of the seed meter)
- Light weight
- Hopper capacity
- Avoid seed damage during rotation of the seed meter
- Avoid skidding while moving on the plain.

The machine has five main components that have to be designed and be fabricated accurately for its efficient working. These are a seed metering device, drive wheels, a shutter lever, brush and brush adjustment meter. Figures 11 and 12 show the design of all parts of manual seed sower machine.

Seed metering device. It is the most integral part where dispose seed from the hopper takes place (Fig. 11a). Seeding rate and seed rate depend on the diameter, the number of grooves, and depth of the grooves of the seed meter. For maximum efficiency of the machine, this part requires the proper and accurate design of the components will be 40mm diameter, 4.2 mm depth of 14 no of grooves. It is comprised of the following components.

Plate 6. Field trial of the semi-automatic rice transplanter.

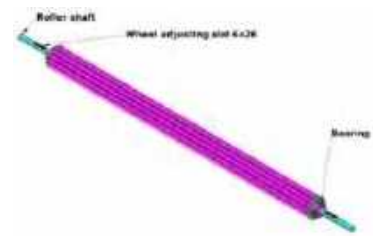


Fig. 11a. Seed metering device.

Fig. 11b. Drive wheel

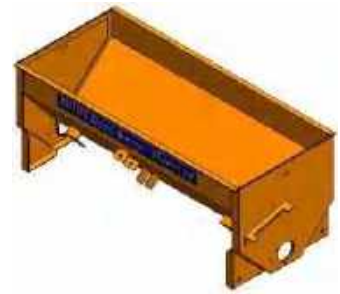


Fig. 11c. Hopper.

Drive wheels. This is the component that provides power to the moving seed metering unit (Fig. 11b). Higher RPM will damage the sprouted seeds where the RPM of the seed meter depends on drive wheel diameter. For optimum result wheel, dia considered 100mm. The following design consideration must adhere to the wheel should be strong enough to carry the overall weight of this machine should also be favorable to facilitate the powering of the machine through manpower.

Hopper. This is the part where the seed is being fed into the seed meter (Fig. 11c). The design/orientation of this component should ensure that there is no seed escaping from it during seeding time. Machine structure will be based on hopper.

Brush. It is a very sensitive part of the machine (Fig. 12a). Sprouted seed smoothly handles by this brush so the brush should be soft and flexible. For efficient functioning of this component, the following design considerations were made; be made from hair to smoothly disposal of seed, its length 598 mm width 32mm were chosen.

Brush adjustment meter. This is a controlling unit of seed by the variable opening size of seed meter for different varieties of seeds (Fig. 12b). 20mm stroke length was chosen for seeding rate and soil delivery controlled for coverage of the spread seeds.

Design of all parts of the machine, fabrication procedure, power requirement, data analysis of performance test, farmer's feedback and economic analysis of the machine has been completed. Complete report of the machine will be submitted in the annual research review workshop.

Mitigation of biotic and abiotic stress in mat type seedlings

An experiment was conducted to find out the biotic and abiotic stresses on germination and mat type seedling growing during Boro season at Sylhet sadar, Sylhet during 2020 -21. The treatments and design factor which are used to conduct the experiment described as follows:

Seedling covering mechanism used as main factor

P_1=Covering by 0.04 mm thickness polythene (day and night time)

P_2=Covering by 0.04 mm thickness polythene (day time only)

Fig. 12a. Brush

Fig. 12b. Brush adjustment meter

Treatments and design

P_3=Covering by 0.08 mm thickness polythene (day and night time)

P_4=Covering by 0.08 mm thickness polythene (day time only)

P_5=Control (uncovered)

Seeds and seedling treating mechanism used as sub-factor

F_1= Seeds treated by fungicide-1

F_2= Seeds treated by fungicide-2

F_3= Fungicide-1spraying on infant seedling

F_4= Fungicide-2 spraying on infant seedling

F_5= MoP @ 8-10g/tray

F_6= Control

Seeds were treated using the fungicide (F_1 and F_2) before 10-12 hours of germination. Fungicide was spread on young seedling immediate after seedling emergence (F_3 to F_4). Seedling trays of treatments P_1 (0.04 mm thickness polythene) and P_3 (0.08 mm thickness polythene) were kept day and night time under the polythene shed during the growing periods while P_2 (0.04 mm thickness polythene) and P_4 (0.08 mm thickness polythene) were kept day time only under the polythene shed. Other management were same for all treatments. The agronomic and mechanical parameters of the raised seedling were assessed at 15 and 30 days after sowing. Sprinkler irrigation was used to irrigate regularly throughout the seedling growing period. Description of the fungicide applied as biotic stress control agent is presented in Table 3.

Seedling quality. Seedling height, number of leaf, leaf length, stem length, stem thickness, seedling density and disease incidence were measured at 15 and 30 days after sowing to assess the seedling quality. All physical data are collected through digital slide calipers. The height of plants was measured in mm from collar region to the tip of the seedling. Stem length was also measured in mm from the bottom of the first leaf to the bottom of the stem. Digital slide caliper was used to measure the stem thickness. A metal sheet box of (200×100 mm^2 size) was used to determine the seedling density from each tray as well as other seedling quality parameters. Fungal infection on seedling are measured which is roughly visible in terms of percentage affected. Pathogenic test or other parameter are not taken in this study.

Characteristics of seedling mat. Rolling quality of the seedling mat was measured to assess the mat quality. Rolling quality of the seedling mat were measured in terms of scored 10 for excellent (no crack during rolling), 8 for good (single and minor crack), 6 for medium (more than one crack but possible to roll up: medium crack), 4 for bad (more than one crack and difficult to roll up: major crack), 2 for very bad (more than one and large size crack and very difficult to roll up: extreme crack) and 1 for not possible to roll up in any way.

Ambient temperature and relative humidity. Temperature is an important factor for the growth of rice seedling raised in plastic tray. Figure 13 presents the ambient temperature during seedling raising period. The highest atmospheric temperature was observed 34^0C and the lowest temperature was 7^0C during seedling growing period. Figure 14 presents the relative humidity during growing period collected from local weather station.

Table 3. Description of the fungicide applied as biotic stress control agent.

Fungicide Treatment	Brand name	Group	Active ingredient (AI)	Recommended dose	Manufacturer
F_1	Atavo 75 WDG(Water Dispersible Granule)	Carbendazim	Imidacloprid 250 gm+ Carbendazim 250 gm + thriam 250 per kg	5 g per 10 liter water	Annodata Limited
F_2	Autostin 50 WDG	Carbendazim	Carbendazim 500 per kg	2-3 g. per liter of water	Auto crop care limited

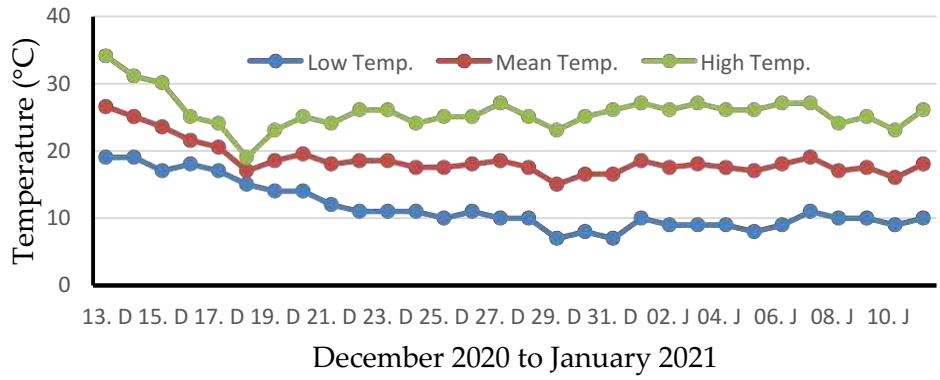


Fig. 13. Ambient temperature during study period (December 2020 to January 2021).

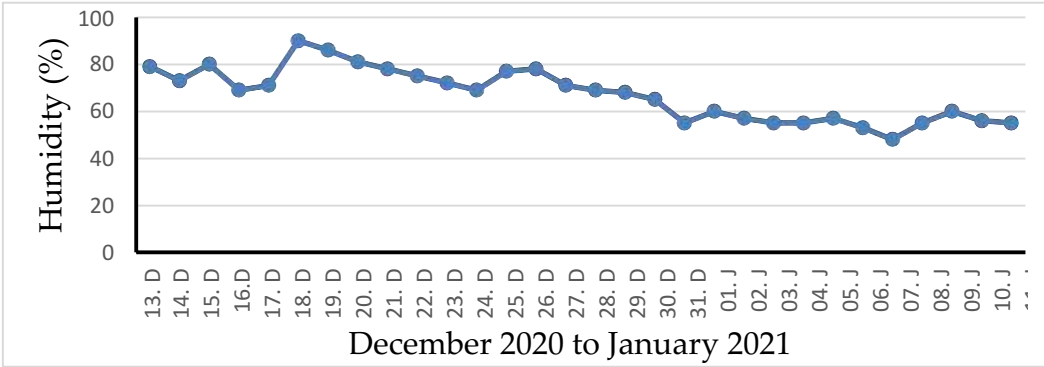


Fig. 14. Ambient air humidity during seedling growing period.

Inside temperature of the polythene shed. For protecting the seedling from low temperature, seedling trays were covered by two different thickness (0.04 and 0.08 mm) of white polythene sheet. Figures 15 and 16 provide the information regarding inside temperature of the two different thickness of polythene shed. As for abiotic stress control, the seedling trays which are covered by polythene 0.08 mm thickness showed significantly better performance than uncovered trays. In different study, it was proved that the effect of genotype, temperature and their interactions on germination characteristics is significant and significant reductions in the germination of rice at temperature less than 16^{0}C and upper than 30^{0}C. Fungal infection and seedling density were high in covered trays than uncovered trays.

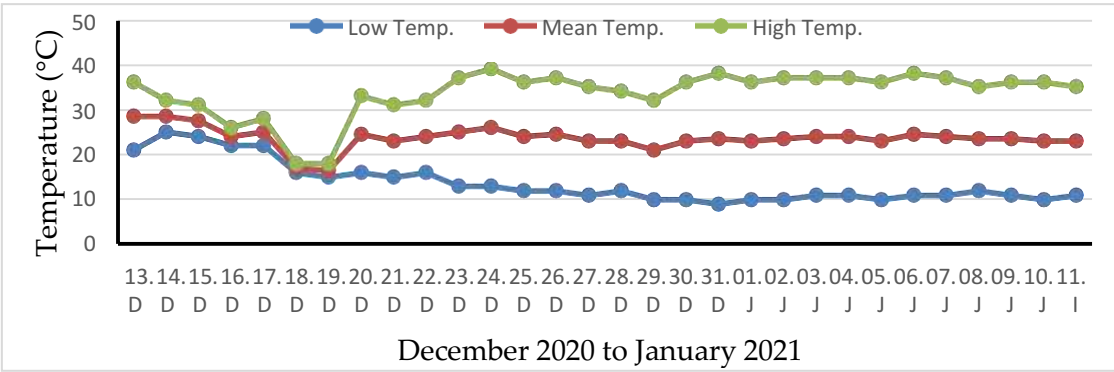


Fig. 15. Inside temperature of 4 grade (0.04 mm thickness) polythene.

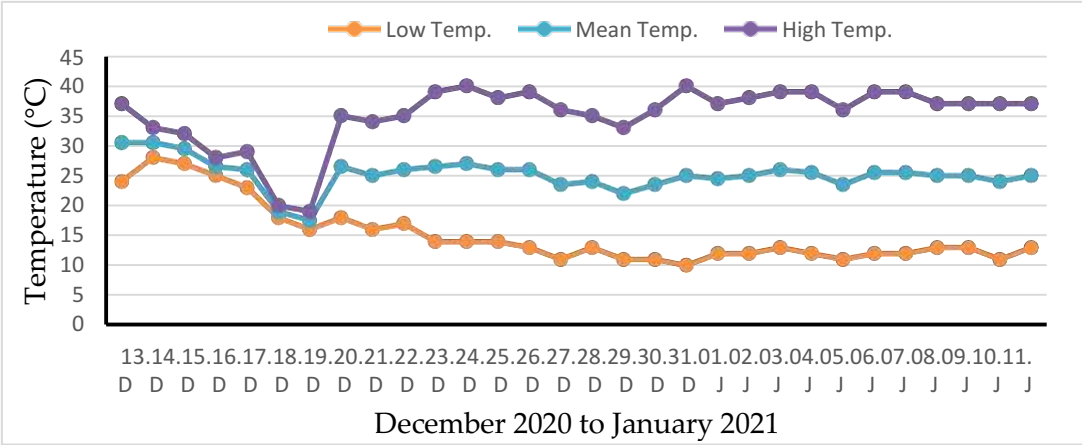


Fig. 16. Inside temperature of 8 grade (0.08 mm thickness) polythene.

Field demonstration on seedling quality. Observation values of the observers on seedling quality varied significantly with the interaction effect of abiotic stress factor (mode and method of covering) and biotic stress factor (seeds and seedling treatment) as were varied significantly with the single effect of abiotic as well as biotic stress factor (Table 4 and Figs. 17 and 18). Significantly higher values were observed for the interaction of F_3 to F_6 with P_1 (8.9 to 9.4), F_1 to F_6 with P_2 (9.2 to 9.6), F_3 to F_5 with P_3 (9.0 to 9.1) and F_1 to F_6 with P_4 (9.3 to 9.6) whereas significantly lower values were observed for the interaction of F_1 to F_2 with P_1 (8.6 to 8.8), F_1, F_2 and F_6 with P_3 (7.8 to 8.7), F_1 to F_6 with P_5 (3.7 to 7.9). However, only day time coverage by both thickness of polythene produced poor quality of seedling when seeds were treated by two different fungicides of F_1 and F_2.

Seedling quality varied significantly with the covering of polythene sheet while uncovered trays produced poor quality of seedling (Table 4). Among the abiotic stress factor (mode and method of covering) P_4 (9.3) and P_2 (9.5) scored significantly higher values while significantly lower value was observed for P_5 (6.6) (Table 4 and Fig. 17). On the other hand, significantly higher and similar values were observed among the biotic treatments of F_3 to F_6 whereas significantly lower value was observed for F_1 (Table 4 and Fig. 18). Note: NS-Not significant, **-significant at 5 %, *-significant at 1 %, LoS-Level of significance, A-Abiotic stress factor, B-Biotic stress factor, P_1 = 0.04mm polythene 24 hr cover (day and night time), P_2= 0.04mm polythene 12 hr cover(night time only), P_3= 0.08mm polythene 24 hr cover (day and night time), P_4= 0.08mm polythene 12 hr

Table 4. Seedling quality based on observation values of the observers during demonstration.

Biotic stress control factors (Seeds and seedling treatment)	Abiotic stress control factors (Mode and method of covering)					Mean
	P_1	P_2	P_3	P_4	P_5	
F_1	8.8	9.2	8.3	9.5	3.7	7.9
F_2	8.6	9.4	7.8	9.4	6.4	8.3
F_3	9.4	9.2	9.0	9.6	6.8	8.8
F_4	9.3	9.4	9.1	9.6	7.5	9.0
F_5	9.1	9.6	9.1	9.6	7.5	9.0
F_6	8.9	9.3	8.7	9.3	7.9	8.8
Mean	9.0	9.3	8.7	9.5	6.6	-
% of cv	5.78					
LoS	A= *, B= * and A× B = *					
LSD $_{0.05}$	A= 0.33, B= 0.36 and A× B= 0.81					

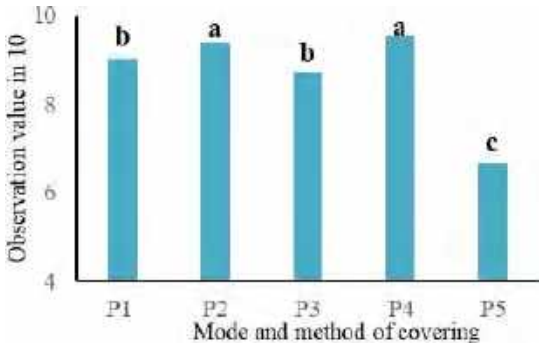


Fig. 17. Effect of abiotic stress control factors on observation values of seedling quality.

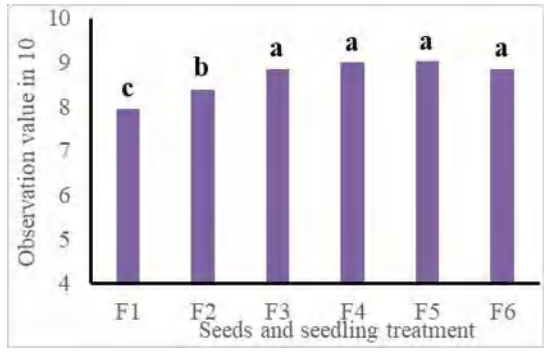


Fig. 18. Effect of biotic stress control factor on observation values of seedling quality.

cover(night time only), P_5= no cover(uncovered), F_1= seed treatment by fungicide 1 (Atavo 75), F_2= seed treatment by fungicide 2 (Autostin 50), F_3= spray by fungicide 1 (Atavo 75), F_4= spray by fungicide 2 (Autostin 50), F_5= spray of MoP, F_6= no action.

Seedling height. Interaction effect of abiotic (mode and method of covering) and biotic stress control factors (seeds and seedling treatment) showed significant effect on seedling height as were single effect of abiotic stress factor and biotic stress factor (Table 5 and Figs. 19 and 20). Significantly higher values was observed for the interaction of F_5 with P_4 (142.87 to 196.63). On the other hand significantly lower values were observed in case of interaction of F_1 to F_6 with P_1 (112.08 to 143.27), F_1 to F_6 with P_2 (128.92 to 162.36), F_1 to F_6 with P_3 (99.4 to 123.11), F_1 to F_6 with P_5 (92.79 to 103.87). After 30 days, seedling height showed remarkable value with 0.08 mm thickness polythene shed covered 24 hours (day and night) which was treated with MOP spray. Whereas other treatments did not show desired result at all.

Among the abiotic stress control factors (mode and method of covering), P_4 scored significantly higher value where significantly lower value was observed for P_5 (Table 5 and Fig. 19). F_5 showed significantly higher values followed by all others treatment as biotic stress control factor (Table 5 and Fig. 20).

Stem thickness. Effect of abiotic stress control factor (mode and method of covering) and biotic stress factor (seed and seedling treatment) did not show significant effect on stem thickness along with the single effect of biotic stress control. Although the single effect of abiotic stress showed significant effect. (Table 6 and Figs. 21 and 22). Significantly higher values were observed for F_6 with P_1 (1.1), F_1, F_3 and F_6 with P_5 (1 to 1.25). Whereas lower values were observed for F_1 to F_5 with P_1 (0.78 to 0.94), F_1 to F_6 with P_2 (0.82 to 0.97), F_1 to F_6 with P_3 (0.68 to 0.94), F_1 to F_6 with P_4 (0.75 to 0.90), F_2, F_4 to F_5 (0.95 to 1.0). After 30 days uncovered seedlings showed significant performance in stem thickness when seed treated with fungicide 1 (Atavo).

Table 5. Effect of abiotic and biotic stress control factors on seedling height (mm).

Biotic stress control factor	Abiotic stress control factors (mode and method of covering)					Mean (mm)
	P_1	P_2	P_3	P_4	P_5	
F_1	134.91	140.55	123.11	142.87	90.24	126.34
F_2	115.96	162.36	112.42	147.05	94.77	126.51
F_3	112.08	152.66	117.16	158.81	85.61	125.27
F_4	126.79	148.18	114.33	155.96	95.55	128.16
F_5	143.27	162.01	122.66	196.63	103.87	145.69
F_6	129.64	128.92	99.4	151.68	92.79 op	120.49
Mean (mm)	127.11	149.12	114.85	158.84	93.81	
% of cv	9.22					
LoS	A= *, B= * and A× B = *					
LSD $_{0.05}$	A= 7.9161, B= 8.6716 and A× B= 19.39					

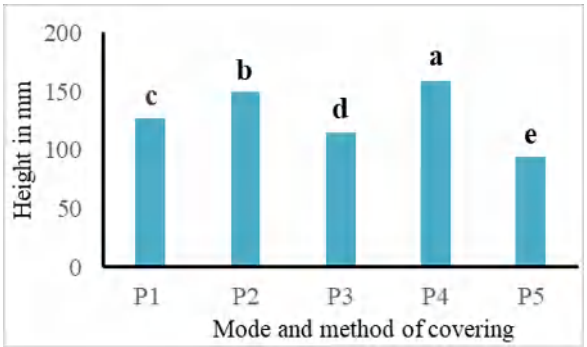


Fig. 20. Effect of biotic stress control factors on seedlings height.

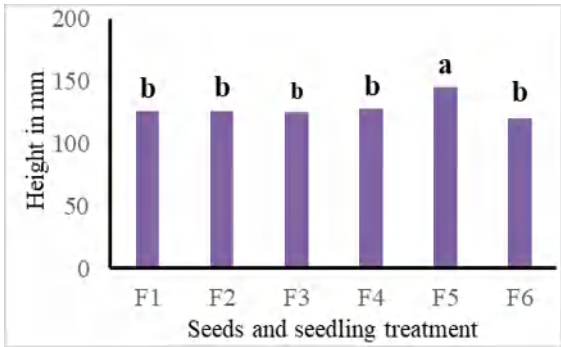


Fig. 19. Effect of abiotic stress control factors on seedlings height.

Table 6. Effect of abiotic and biotic stress control factors on stem thickness in mm at 30 days after seeds sowing.

Biotic stress control factor	Abiotic stress control factor (mode and method of covering)					Mean (mm)
	P_1	P_2	P_3	P_4	P_5	
F_1	0.94	0.91	0.94	0.78	1.25	0.96
F_2	0.91	0.94	0.87	0.77	0.95	0.89
F_3	0.88	0.82	0.68	0.90	1.10	0.87
F_4	0.78	0.97	0.94	0.75	0.98	0.88
F_5	0.91	0.87	0.86	0.86	1.00	0.90
F_6	1.1	0.84	0.68	0.84	1.00	0.91
Mean (mm)	0.93	0.89	0.83	0.82	1.05	
% of cv	16.27					
$LSD_{0.05}$	A= 0.098					

Note: NS-Not significant, **-significant at 5 %, *-significant at 1 %, LoS-Level of significance, A-Abiotic stress factor, B-Biotic stress factor, P_1 = 0.04mm polythene 24 hr cover (day and night time), P_2= 0.04mm polythene 12 hr cover(night time only), P_3= 0.08mm polythene 24 hr cover (day and night time), P_4= 0.08mm polythene 12 hr cover(night time only), P_5= no cover(uncovered), F_1= seed treatment by fungicide 1 (Atavo 75), F_2= seed treatment by fungicide 2 (Autostin 50), F_3= spray by fungicide 1 (Atavo 75), F_4= spray by fungicide 2 (Autostin 50), F_5= spray of MoP, F_6= no action.

Among the abiotic stress control factors (mode and method of covering), P_5 (1.05) scored significantly higher value and P_4 (0.82) scored significantly lower value (Table 6 and Fig. 21). In case of biotic stress control factor (seed and seedling treated) F_1 to F_6 scored significantly higher value (Table 6 and Fig. 22). K. Zaman et al. (2014) found that he highest and the lowest temperatures were observed at 0.04 mm thick black polythene shed during day-night and 0.08 mm thick black polythene shed during day-night respectively. They also observed that the highest stem thickness was found where seedling trays were put in 0.04 mm thick white polythene shed during night.

Seedling density. Two way interaction effect of abiotic and biotic stress control factor did not show significant effect on seedling density (seedling/cm^2) accompanied by the single effect of biotic stress factor. However the single effect of abiotic stress showed significant effect on seedling density (Table 7 and Figs. 23 and 24). Mathematically higher values was observed for F_1 to F_4 with P_1 (14 to 15), F_3 to F_4 with P_3 (14.3 to 15.3), F_1 to F_5 with P_4 (14.3 to 18). On the other hand mathematically lower value was scored for F_5 to F_6 with P_1 (a2.6 to 13), F_1 to F_6 with P_2 (10 to 13), F_1 to F_2, F_5 to F_6 with P_3 (12 to 13.6 and 11 to 13.3), F_6 with P_5 (12.6), F_1 to F_6 with (9 to 13.6). Seedling density showed better performance when seedling were covered 24 hour by 0.08 mm thickness polythene shed and sprayed by MoP. In case of seedling in uncovered trays showed poor growth.

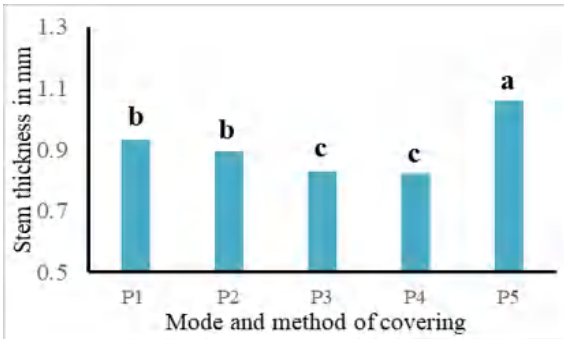


Fig. 21. Effect of abiotic stress control factors on stem thickness in mm at 30 days after seeds sowing.

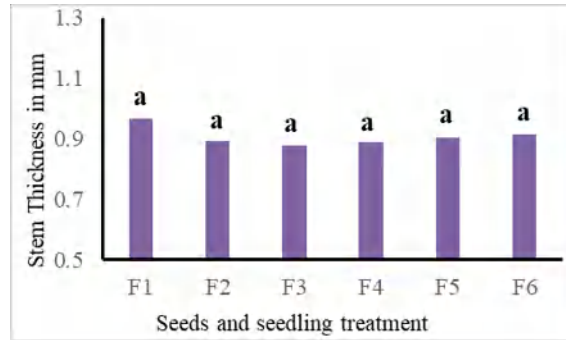


Fig. 22. Effect of biotic stress control factors on stem thickness at 30 days after seeds sowing.

Among the abiotic stress control factors (mode and method of covering), P_4 (15.5) scored significantly higher value followed by P_1 (14.11). Meanwhile, P_5 (11.2) and P_2 (11.2) scored significantly lower value (Table 7 and Fig. 23). F_3 (14.06) as biotic stress control factors (seeds and seedling treatment) scored significantly higher value followed by F_1 to F_2 (12.6 to 13.66) and F_4 to F_5 (13.0 to 13.4). Significantly lower value was observed for F_6 (12) (Table 7 and Fig. 24).

Table 7. Interaction effect of abiotic and biotic stress control factors on seedling density (Number/cm^2).

Biotic stress control factor	Abiotic stress control factors (mode and method of covering)					Mean (No./cm^2)
	P_1	P_2	P_3	P_4	P_5	
F_1	15.0	10.0	12.0	16.3	9.6	12.6
F_2	14.0	11.0	13.6	16.0	13.6	13.6
F_3	15.3	13.0	14.3	14.3	13.3	14.0
F_4	14.6	12.3	15.3	15.6	9.0	13.4
F_5	13.0	11.6	13.3	18.0	9.3	13.0
F_6	12.6	11.0	11.0	12.6	12.6	12.0
Mean (No./cm^2)	14.1	11.5	13.2	15.5	11.2	
% of cv	18.98					
LoS	A=* , B=NS and A× B=NS					
LSD $_{0.05}$	A=1.66					

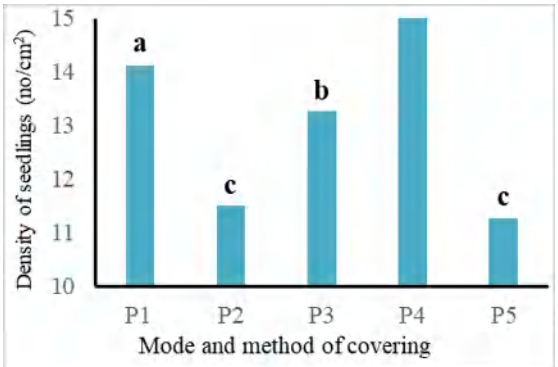


Fig. 23. Effect of abiotic stress control factors on seedling density at 30 days after seeds sowing.

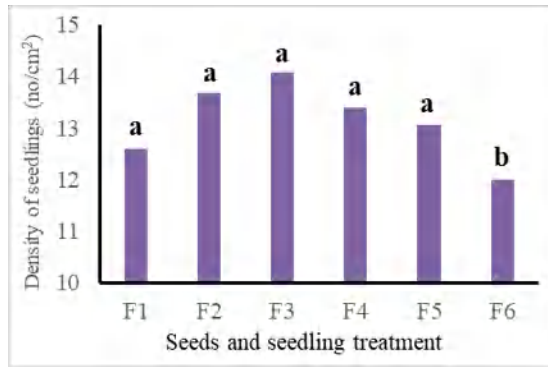


Fig. 24. Effect of biotic stress control factors on seedling density at 30 days after seeds sowing.

Fungal infection. Interaction effect of abiotic stress factor (mode and method of covering) and biotic stress factor (seed and seedling covering) did not show significant effect on seedling density. On the contrary the single effect of abiotic stress and biotic stress factor showed significant effect on fungal infection (Table 8 and Figs. 25 and 26). Significantly higher value was observed for F_6 with P_5 (28.3). Significantly lower value was scored for F_1 to F_6 with P_1 (1.6 to 8.3), F_1 to F_6 with P_2 (0 to 6.6), F_1 to F_6 for P_3 (3.3 to 16.6), F_1 to F_6 with P_4 (0 to 5), F_1 to F_5 with P_5 (10 to 18.3). Fungal infection was severe in uncovered tray where no treatment was provided. On the other hand, seedling covered both thickness (0.04 mm and 0.08 mm) of polythene and pretreated seed with both fungicide (Atavo and Autostin) showed noticeable result against fungal attack.

Among the abiotic stress control factors (mode and method of covering), P_5 (16.6) scored significantly higher percentage of infection. Meanwhile P_4 (3.0) scored significantly lower percentage followed by P_1 (4.4) and P_2 (3.0) (Table 8 and Fig. 25). Significantly higher and lower percentage of plants were infected for biotic stress control factors F_6 and F_1 to F_6, respectively. On the other hand F_6 (13) biotic stress factor (seed and seedling treated) scored significantly higher value. Significantly lower value was observed for biotic stress F_1 to F_5 (3.33 to 8.33) (Table 8 and Fig. 26).

Table 8. Effect of abiotic and biotic stress control factors on fungal infection on seedling.

Biotic stress control factors	Abiotic stress control factors (mode and method of covering)					Mean
	P_1	P_2	P_3	P_4	P_5	
F_1	1.6	1.6	5	0	10	3.6
F_2	1.6	0	3.3	1.6	10	3.3
F_3	5	3.3	5	3.3	18.3	7
F_4	5	1.6	8.3	3.3	16.6	7
F_5	5	5	10	5	16.6	8.3
F_6	8.3	6.6	16.6	5	28.3	13
Mean	4.4	3.0	8.0	3.0	16.6	
% of cv	48.63					
$LSD_{0.05}$	A= 2.28 and B= 2.50					

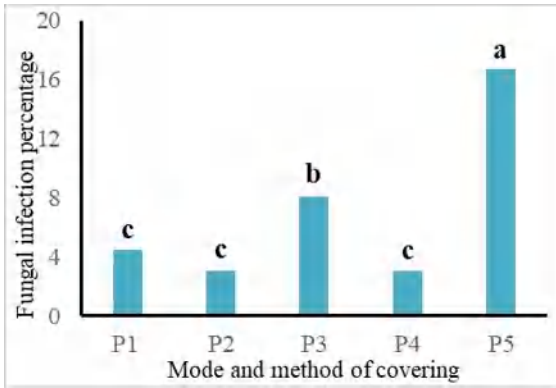


Fig. 25. Effect of abiotic stress control factors on fungal infection at 30 days after seeds sowing.

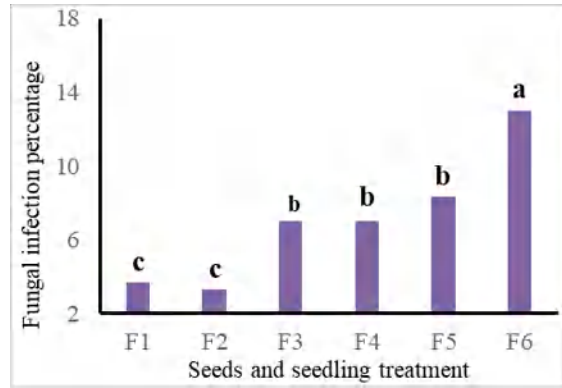


Fig. 26. Effect of biotic stress control factors on fungal infection at 30 days after seeds sowing.

Note: NS-Not significant, **-significant at 5 %, *-significant at 1 %, LoS-Level of significance, A-Abiotic stress factor, B-Biotic stress factor, P_1 = 0.04mm polythene 24 hr cover (day and night time), P_2= 0.04mm polythene 12 hr cover(night time only), P_3= 0.08mm polythene 24 hr cover (day and night time), P_4= 0.08mm polythene 12 hr cover(night time only), P_5= no cover(uncovered), F_1= seed treatment by fungicide 1 (Atavo 75), F_2= seed treatment by fungicide 2 (Autostin 50), F_3=

spray by fungicide 1 (Atavo 75), F_4= spray by fungicide 2 (Autostin 50), F_5= spray of MoP, F_6= no action.

Performance of rice transplanter greatly depends on mat type seedling quality. In Boro season, farmers faced a major problem to raise seedling quality due to low temperature and fungal infection. On the basis of seedling quality (seedling height, leaf length, stem length, stem thickness, number of leaf), combine treatments effect of abiotic and biotic stress control factor MoP and 0.08 mm polythene shed covered trays showed better performance.

Design and development of battery operated small size reaper

Most of the farmers of our county are using traditional method for harvesting paddy such as kachi. In this condition a motor operated reaper is necessary for the small and medium scale farmers to overcome the situation of labour shortage at harvesting period. This research work focused on ease of harvesting operation to the small and medium land holders for harvesting crop in less time and at low cost by considering different factors as cost of equipment, ease of operation, field condition, time of operation and climatological conditions. The operating, adjusting and maintaining principle of this reaper is simple for effective handling of unskilled operators.

A battery operated small size reaper was modified in Zomzom workshop, Pabna. In the previous version the cutting part of this reaper was worked well but there was a problem in the convey system. The harvested paddy was not passed properly through the convey section. The problem was occurred because the rpm of convey belt and cutting blade was same where the recommended ratio was not followed to reduce the machine weight. In the modified version, the rpm of convey belt and cutting blade were set properly. In the previous version, the battery size was small (96W, 48V) by which the reaper can be operated 3 hours continuously by the fully charged battery. In the modified version, battery was changed by 48V, 240W to operate this machine in 8 hours. The machine consists of main body, power transmission system and cutter bar. The wide of the cutter car was 40 cm. A motor (1 hr, 48V) was used as power source. A charger was used to charge the battery by using electricity. A controller was used to control the forward and backward speed and goes to the neutral position. Flat bar, angle bar, SS rod, chain and sprocket were the common materials to manufacture the machine. Plate 7 shows the fabrication of battery operated reaper.The machine will be tested at Aman 2021 season.

Plate 7. Battery operated reaper.

MILLING AND PROCESSING TECHNOLOGY

Effect of ageing on milling performance of premium quality rice

Aging of rice is one of the typical steps between harvest and consumption. During aging of rice, a number of physiochemical propertices changes that causes impact on rice cooking and eating quality. The aging experiment was conducted using BRRI dhan50 as unparboiled condition and milling was done in semi-auto rice mill at FMPHT division in BRRI head quarter, Gazipur. BRRI dhan50 was stored in the three different types of storage structure at 11.00% moisture content (wb). These are painted motka**,** hermetic bag and plastic drum. Milling quality was assessed at every 3 month interval up to 1 year from the time of storage. Five treatments with three replications were taken for every storage structure. The treatments were T_1 = Milling after immediate of harvesting, T_2 = Milling

after 3 months, T_3 = Milling after 6 months, T_4 = Milling after 9 months and T_5= Milling after 12 months. The paddy was stored at 11% moisture content (wb) in different storage structure. The ultimate goal of milling is to achieve maximum head rice yield (HRY).

After immediate of harvesting, the initial moisture content of BRRI dhan50 was 11.00% (wb), milling yield was 62.40%, head rice recovery was 70.40 % (based on milled rice) and whiteness index was 42.

In painted motka from three month to ninth month the milling yield of BRRI dhan50 was ranged from 61.50% to 62.10%. In the hermetic bag from three month to ninth month the milling yield of BRRI dhan50 was ranged from 53.66% to 62.65%. In the plastic drum from three month to ninth month the milling yield of BRRI dhan50 was ranged from 63.10% to 63.84%. Whiteness index was decreased for all storage structure after different month of ageing (Table 9).

In painted motka, the head rice recoveries were 70.55% after three month, 71.55% after six month and 64.20% after ninth month of aging period. Due to porous behavior moisture uptake was observed in motka which reduce the quality of paddy and head rice recovery.

In the hermatic bag, the head rice recoveries were 70.60% after three month, 77.33% after six month and 66.51% after ninth month of aging period. After ninth month there was possibility of moisture uptake into the hermetic bag through zipper joint that attributed to reduce the quality of paddy and head rice recovery.

In plastic drum, the head rice recoveries were 71.10% after three month, 77.78% after six month and 80.34% after ninth month of aging period. The head rice recovery was increased simultaneously with the month of ageing period increased.

Figure 27 presents the results of head rice yield during aging period in the different storage structure. The head rice yield increased in the plastic drum storage with the increase aging period. However, painted motka and hermetic bag storage structure showed the confusing results with the increase of aging period due to adsorption of moisture from environment.

Table 9. Milling parameter of BRRI dhan50 after different month of ageing.

Milling parameter	Painted motka	Hermetic bag	Plastic drum
After three month of ageing			
Moisture content	11.50	11.20	11.20
Milling yield %	62.10	62.65	63.10
Milling degree %	11.10	10.98	10.65
Head rice % (Based on total milled rice)	70.55	70.60	71.10
Broken rice % (Based on total milled rice)	29.45	29.40	28.90
Whiteness Index	41.34	41.10	41.93
After six month of ageing			
Moisture content	11.70	11.40	11.25
Milling yield %	61.95	60.71	63.84
Milling degree %	11.46	11.20	9.33
Head rice %(Based on total milled rice)	71.55	77.33	77.78
Broken rice % (Based on total milled rice)	28.22	22.67	22.44
Whiteness Index	41.13	42.36	43.43
After ninth month of ageing			
Moisture content	12.70	12.30	11.53
Milling yield %	61.50	53.66	63.50
Milling degree %	11.96	10.58	10.24
Head rice % (Based on total milled rice)	64.20	66.51	80.34
Broken rice % (Based on total milled rice)	35.80	33.49	19.66
Whiteness Index	38.5	32.07	41.13

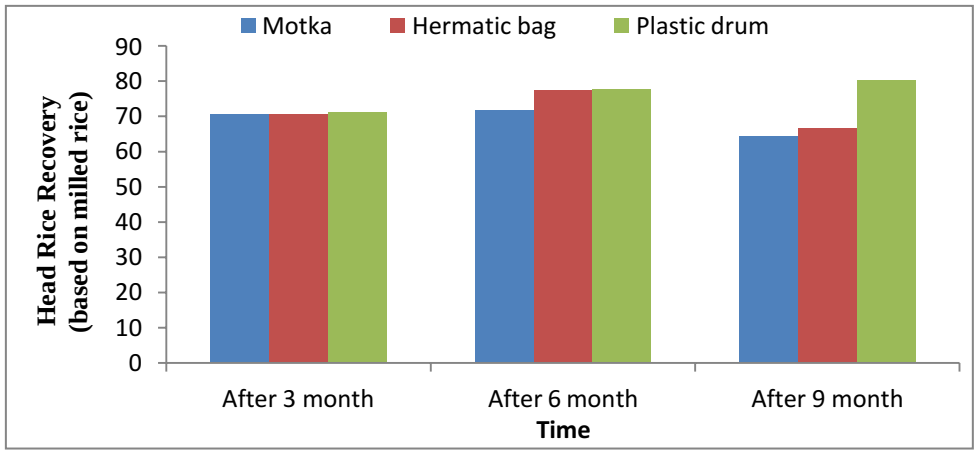


Fig. 27. Relationship between head rice recovery and ageing period of different storage structure.

From this study, higher head rice recovery was found in plastic drum after ninth month of ageing period which is promising for premium quality rice. To get more precious result paddy could be stored in temperature control room.

Evaluation of milling parameter of BRRI dhan90 processed in BRRI modified De-husker and friction type polisher

An experiment was conducted with the BRRI developed de-husker and friction type polisher using BRRI dhan90 (un-parboiled). The moisture content was 11.15% (wb.) and each sample size was 20 kg. De-husked paddy was processed in MNMP-15 model friction type polisher to evaluate the commercial value of milling parameter of newly released BRRI dhan90.

The average de-husking capacity of the husker was 643 kg/h and husking efficiency was about 90.67% (Table 10). Husking efficiency can be increased by closing the adjustable roller which increases the broken rice (brown rice). The average brown rice percentage was found 78.70% and the rest was husk and embryo. Average fixed and adjustable rubber roll rpm was found 1,048 and 788 respectively.

Adjustable rubber roll rotate 24.80 % less rpm than the fixed rubber roll. The difference in peripheral speed subjects the paddy grain falling between the rolls to a shearing action that strips off the husk. The clearance between the rolls is adjustable and it should be less than the thickness of the grain.

Brown rice of BRRI dhan90 from rubber roll de-husker was polished in friction type polisher. The average capacity of the polisher was 632 kg/h and the average milling recovery was 65.7 %. The average head rice recovery (based on input paddy) was 60.7 % and head rice recovery (based on total milled rice) was 92.33% (Table 11).

The broken rice percentage was 5.0 % (based on input paddy) and 7.7% (based on total milled rice). Husking efficiency and milling recovery was found around 90.67% and 65.7 % repectively of BRRI dhan90 polished in friction type polisher followed by de-husking. The average head rice recovery based on input paddy was 60.7 %,

Table 10. Performance of developed husker for BRRI dhan90.

Capacity (one pass) Kg/h	Husking Efficiency (one pass) %	Brown Rice, % (based on input paddy)	Adjustable roll speed (rpm)	Fixed roll speed (rpm)	Ratio of fixed and adjustable roller
646	90.00	79.0	786	1046	24.86
642	91.00	78.0	790	1048	24.69
640	91.00	79.0	789	1050	24.85
643	90.67	78.70	788	1048	24.80

Table 11. Milling parameter of BRRI dhan90 processed in friction type polisher.

Capacity of Polisher Kg/h	Milling yield %	Head rice % (Based on input paddy)	Head rice % (Based on total milled rice)	Broken rice % (Based on input paddy)	Broken rice % (Based on total milled rice)
628.0	66.0	60.4	91.5	5.6	8.5
630.0	66.3	61.7	93.0	4.6	7.0
635.0	65.0	60.1	92.5	4.9	7.5
632.0	65.7	60.7	92.33	5.0	7.7

which is promising for processing of quality rice. Steel engelberg huller may replace with one rubber roll de-husker and a polisher for better quality rice. De-husker also separates husk and polisher separates bran. Separately collected husk and bran is suitable for briquette and edible oil production.

INDUSTRIAL AND FARM LEVEL EXTENSION OF BRRI MACHINERY

Training on Operation and Maintenance of Farm Machinery to the Machinery Operators and Mechanic

Training is an effective tool to develop technical and efficient manpower for effective use, repair and maintenance of agricultural machinery in the farm yard. Proper operation and maintenance increase the life time of a machine and as a result more income generating activities (IGA) were observed, that increased the productivity of the machine. In order to build up trained manpower on farm machinery in the rural areas by financial support "Strengthening Farm Machinery Research Activity for Mechanized Rice Cultivation (SFMRA)" project of Farm Machinery and Postharvest Technology(FMPHT) Division of BRRI conducted two-day long residential training programme at BRRI head quarter and 11 RSs of BRRI.

Two-day long residential training

Two-day long residential training was conducted under the financial and technical support by SFMRA project of FMPHT Division in order to introduce BRRI developed and other agricultural machines at farmers levels; to develop skilled operators on agricultural machinery at farm levels and to build up awareness about the use and benefit of using agricultural machines. A total of 20 participants attended in each training program. Priorities were given to select the participants on the basis of having experience on operating agricultural machinery. Lecture and practical session were arranged by BRRI scientists, DAE personnel (AD, DD, UAO and Agriculture Engg.) and Academicians (University professors). Knowledge was shared to the participants on the operation and maintenance of BRRI developed machinery and technologies and other agricultural machinery. During practical session machinery were operated by the participants for gathering experience on agricultural machinery operations in no load condition in the drying yard/road. After successful operation in the drying yard/ road participants were taken to the main field for practical operation of agricultural machinery.

Major activities done by the participants of the training programme

The following BRRI developed machinery; technologies and other agricultural machinery were introduced and practically operated to the trainees during thetraining programme.

- Demonstration on seedling raising technique for mechanical rice transplanter
- Operation and maintenance on mechanical rice transplanter
- Operation and maintenance on BRRI prilled urea applicator
- Operation and maintenance on BRRI manual and power weeder
- Operation and maintenance on whole feed combine harvester
- Operation and maintenance on self-propelled rice/wheat reaper
- Operation and maintenance on BRRI open drum thresher
- Operation and maintenance on BRRI closed drum thresher

- Operation and maintenance on BRRI winnower
- Hands on repair and maintenance on diesel engine
- Practical field operation of agricultural machinery in the farm level
- Developed the operators cum entrepreneur of the agricultural machinery for sustainable mechanization.

Ninety-three batches of residential training programme was conducted and 1,865 numbers participants were trained in the programme among them1,836 were male and 29 were female. Participants of the training programme attended from BRRI RS and its adjacent area. An inaugural session was held at the 1st day of the training programme and after that a pre-evaluation of the trainees was done. Lecture and mostly practical session were arranged in all the locations. Step by step procedure to raise seedling in tray was shown practically to the participants. After this machine like Mechanical Rice Transplanter, Combine Harvester, Self-propelled Reaper, BRRI Open Drum Thresher, BRRI Closed Drum thresher, BRRI Prilled Urea Applicator, BRRI Power and Manual Weeder, BRRI Winnower, Tractor and Power Tiller were operated preliminary in no load condition in threshing floor/road and after that these machines were operated by the trainees in the field one after one (Plate 8). At the end of the training, a post-evaluation and trainees reactions regarding the training were collected. Certificates, leaflets and a set of tools were distributed among the participants.

Formal training was very effective tool as they were isolated from their home and were able to concentrate fully in the class room. The trainees wanted to have one week instead of two days training to improve their skill in farm machinery. Trainees opined that they are now more confident about the use of the machinery and the hand tools will be useful for their work.

Training on manufacturing, safety and work environment to the workshop personnel

The Government of Bangladesh encourages production and manufacturing of appropriate agricultural machinery in socio-economic context of the country and provides support to the manufacturing workshops and industries to make them more productive and self-sufficient. The demand for quality agricultural machinery is increasing day by day, including harvesting, planting, processing of crops, packaging, and application of fertilizers in the land. As a result, small and large agricultural machinery factories have jumped up. But demand lead agricultural machinery are not fabricated due to lack of skilled technicians and basic knowledge on operation, repair and maintenance of the mechanics. In these cases, appropriate training on quality machine fabrication, safety and work environment of workshop personnel is needed to survive in the international competitive market.

Plate 8a. Practical session on diesel engine.

Plate 8b. Mat type seedling tray preparation.

Plate 8c. Field operation of rice transplanter.

Plate 8d. Distribution of certificates

Three-day long three trainings were conducted with the financial and technical support by SFMRA project of BRRI. The trainings were conducted at the selected local manufacturing workshop. A total of 20 participants were attended in each training programme. Participants were selected by direct consultation with the chairman of related engineering workshop. Professor, Bangladesh Agricultural University; senior scientists of BARI and FMPHT division of BRRI conducted the training programmes as expert member.

Steps of training programme

Theoretical session

Theoretical session of the training program was arranged with the help of multimedia presentation and training tools in the workshop (Plate 9). Lecture was given by the expert member following a pre-scheduled training curriculum. The training curriculum is presented below-

Introducing and utility of machine tools, measuring tools, marking or layout tools, cutting tools and supporting hand tools used in the agricultural machinery workshop. File and Filing methods, safety and care of files in Mechanical Workshop.

- Welding and welding process
- Drilling and utility of drilling machine
- Grinding and function of grinding machine
- Power transmission system of different types of engine
- Utility of belt and pulley to transmit power from engine
- Utility of chain and sprocket to transmit power from engine
- Introducing and utility of different types gear
- Utility of different types of shaft
- Operation and maintenance of lathe machine
- Operation and maintenance of shaper machine
- Operation and maintenance of milling machine
- Operation and maintenance of power press machine
- Operation and maintenance of share machine
- Maintenance of agricultural machinery workshop
- Work environment of agricultural machinery workshop
- Safety and precaution measures to protect accident in agricultural machinery workshop

Group formation. Trainees were divided into four groups in each batch to make the training programme effective and successful.

Practical session. Practical session was arranged to fabricate a selected job. Step by step procedure to fabricate the selected job was shown practically to the participants. Participants gained knowledge to prepare the job according to specification.

Feedback session. At the end of the training, feedback session was arranged to get feedback from the participants about the training. Trainees opinion/suggestion were collected for further application in research field. Skilled manpower in the local manufacturing workshop was developed which will be helpful to fabricate qualified agricultural machinery and adopted in the farmer's field.

Plate 9. Pictorial view of practical and closing session of training program.

MAINTENANCE WORK OF WMM DIVISION

Repair and maintenance works of transports/ vehicles and different farm machinery

BRRI has different kinds of transport/vehicles and farm machinery. WMM Division of BRRI does the repair and maintenance works of different kinds of transport/vehicles and farm machinery. There were 43 vehicles (4-wheeler), 110 motor cycles, 12 tractors with accessories (one scrapper, three harrows, five rotaries, three discs and three scissors), 21 power tillers, 13 hydro-tillers, one reaper, four BRRI field mower, 22 pumps, 13 closed drum threshers, eight open drum threshers, two engines, and other farm machinery were repaired and changed of spare parts under major and moderate/minor repair and maintenance work.

The repair and maintenance works have been divided into two groups such as:

- Moderate/minor repair and maintenance work and
- Major repair and maintenance work

Moderate/minor repair and maintenance work

Moderate/minor repair and maintenance works have been classified into three groups:

- Moderate/minor spare parts change and repair
- Minor CNG related trouble shooting and electrical works of vehicles
- Transport/vehicles/machinery cleaning and servicing

Moderate/minor spare parts change and repair works of all the vehicles and different farm machinery were done day to day in BRRI except CNG related trouble shootings of these vehicles, because there was no trained manpower in BRRI regarding CNG related trouble shootings. As a result, major/moderate/minor/or any kind of CNG related trouble shootings of these vehicles were totally done outside BRRI. A total of 43 vehicles (4-wheeler) in 1,363 times, 110 motor cycles and other farm machineries in 39 times were repaired and changed of spare parts under moderate/minor repair and maintenance work.

Major repair and maintenance work

WMM division does seven types of major repair and maintenance works:

- Major spare parts change and repair
- Overhauling
- CNG conversion
- Denting-painting
- Tyre-tube
- Battery
- Major CNG related trouble shooting

Major repair and maintenance works have been done in BRRI workshop and outside BRRI. Some of the major spare parts change, overhauling and repair works have been done in BRRI workshop but major works were done outside BRRI due to fund limitation and some of the major works have been done by direct contracting through Vehicle Solution, Ferajitola, Vatara, Dhaka; NAVANA Toyota 3S center, Tejgaon, Dhaka and also in local workshops. On the other hand, most of the CNG related works (CNG conversion, any

kinds of CNG related trouble shooting) have been done by direct contracting through Rupantorito Prakritic Gas Co. Ltd., Joar Sahara, Dhaka, a government workshop but denting-painting works have totally been done outside BRRI. At present electrical works have been done in BRRI workshop. Purchasing the battery and tyre–tube or taking the tyre–tube from BRRI store (if available) through requisition were attached to the vehicles/transports in BRRI workshop. A total of 43 vehicles (4-wheeler) in 1363 times, 12 tractor in 75 times, 21 power tillers in 147 times, 13 hydro tillers in 64 times and others were repaired and changed of spare parts in BRRI workshop and outside of BRRI under major repair and maintenance work.

Total cost of major and moderate/minor repair and maintenance was Tk 53,73,625.00 from July 2020 to June 2021. Major repair and maintenance cost was Tk 42,60,051.00 and moderate/minor repair and maintenance cost was Tk 11,13,574.00.

Adaptive Research Division

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SUMMARY

In the reporting period (2020-2021), 28 advanced breeding lines along with 24 check varieties were evaluated under advanced line adaptive research trials (ALARTs) at 120 farmers' field in different agro ecological regions of Bangladesh. Considering the important characteristics and farmers' opinion, two advanced breeding lines were recommended for proposed variety trial (PVT). During Aus 2020, the entry BR9006-40-2-3-1 was found suitable for T. Aus ecosystem in favorable environment and recommended for PVT. In non-saline tidal environment (NSTE) for T. Aus season, the entry BR8781-16-1-3-P2 may be recommended for PVT, if the irregularities of flowering is corrected by any means. No advanced line was recommended for PVT during Aman 2020 and Boro 2021. But the ALART (PQR) in T. Aman 2020 may be conducted for further observation and recommended as re-ALART.

Seed Production and Dissemination Programmes (SPDP) were conducted by using different BRRI varieties (BRRI dhan43, 48, 49, 58, 65, 67, 71, 73, 74, 75, 79, 80, 81, 82, 83, 84, 85, 87, 88, 89, 90, 91, 93, 94 and 95) under GoB and different projects. About 700 demonstrations were conducted in 200 upazilas of almost all districts of the country, from which about 370 tons of paddy were produced and 86 tons were retained as seeds by the farmers for next year cultivation. About 35 thousand farmers gained awareness and knowledge about BRRI varieties through demonstrations.

A total of 400 head to head adaptive trial (HHAT) were conducted through Public Private Partnership (PPP) during Aman 2020 and Boro 2021 under TRB project. From the interaction of genotypes and rice growing eco-system, BRRI dhan87 was found the most suitable variety for Aman season and varietal preferences were BRRI dhan87> BRRI dhan71> BRRI dhan75> BRRI dhan79> BRRI dhan49> BRRI dhan78> BRRI dhan80> BRRI dhan76> and BRRI dhan73. In Boro 2021, BRRI dhan88 was found as the highest yielder (6.48 t ha^{-1}) having growth duration 141 days in SD. In LD, BRRI dhan92 produced the highest grain yield (7.26 t ha^{-1}). A recent salt tolerant rice variety BRRI dhan99 produced the grain yield 6.14 t ha^{-1} and performed best compared to the others. Single Boro areas in Haor areas, the average yield of BRRI dhan96 was recorded 6.47 t ha^{-1} followed by BRRI dhan88.

ARD conducted 103 farmers' training at different locations of the country, in which 3,140 trainees participated on modern rice production technologies. Sixty eight field days were arranged where around 5,000 farmers, local leaders and DAE personnel participated. In BRRI farm, 6052 kg quality seeds of recently released BRRI varieties were produced which were used to conduct research activities and dissemination programme.

TECHNOLOGY VALIDATION

Advanced line adaptive research trial (ALART)

T. Aus 2020, ALART, Favourable environment (FE). Two advanced lines i.e. BR9005-53-1-1 and BR9006-40-2-3-1 were evaluated against BRRI Dhan48 and BRRI Dhan82 as checks at farmers' field in ten locations under T. Aus ecosystem. The plots were severely affected in three locations i.e, Rajshahi, Rangpur and Mymensingh by birds. Therefore, the results of these three locations were excluded and the rest results (seven locations) were analyzed for decision making. On an average of seven locations, the tested line BR9006-40-2-3-1 produced significantly higher grain yield (5.28 t ha^{-1}) compared to the other entries including checks. The line BR9006-40-2-3-1 yielded the highest followed by BRRI dhan48, tested line BR9005-53-1-1 and BRRI dhan82 (Table 1). The highest yielder BR9006-40-2-3-1 showed earlier growth duration (106 days) than the check variety BRRI dhan48 (110 days). Most of the farmers showed their interest about the entry BR9006-40-2-3-1 due to its good yield, tall and strong plant, long panicle and phenotypic acceptance. Considering all necessary attributes, the entry BR9006-40-2-3-1 was recommended for PVT.

Table 1. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART, T. Aus for favorable environment (FE), 2020.

Genotype	Location								G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})										
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
BR9005-53-1-1	5.02	4.60	4.92	5.07	5.20	4.75	4.01	4.80	107	21.1	94
BR9006-40-2-3-1	5.65	5.30	5.13	5.43	5.90	5.33	4.23	5.28	106	23.2	106
BRRI dhan48(Ck)	5.48	4.40	4.68	5.32	5.88	4.67	4.42	4.98	110	23.2	102
BRRI dhan82(Ck)	5.55	4.50	4.65	5.03	5.03	4.39	4.16	4.76	104	22.6	110
$LSD_{0.05}$	0.53							0.2	1	0.9	2

L1-Barishal, L2-Cumilla, L3-Habiganj, L4-Chattogram, L5-Kushtia, L6-Faridpur, L7-BRRI, Gazipur

T. Aus 2020, ALART non-saline tidal environment (NSTE) T. Aus, 2020. Two advanced line i.e., BR8784-4-1-2-P2 and BR8781-16-1-3-P2 along with BRRI dhan27 and BRRI dhan48 as checks were tested at farmers' field in ten locations under non-saline tidal environment. The plots in three locations such as Barguna (Amtali), Jhalokathi (Nalchiti) and Feni (Sonagazi) were damaged by torrential rain just after transplanting. The tested entry BR8781-16-1-3-P2 produced similar yield (4.85 tha^{-1}) with the popular check variety BRRI dhan48 (4.80 t/ha) but the plant height of the entry (114 cm) was longer than BRRI dhan48 (108 cm) (Table 2) and it was lodging resistant. In southern area of Bangladesh, we need more T. Aus variety which can satisfy farmers' demand in terms of grain yield and long plant height but lodging resistant. Considering all attributes, the above entry BR8781-16-1-3-P2 may be recommended for proposed variety trial (PVT), if the irregularity of flowering is corrected by any means.

B. Aman 2020, ALART deep water rice (DWR), deep flooded (1 to 2 meters). Four advanced lines bred for deep flooded (1 to 2 meters water depth) condition i.e., BR9390-6-2-2B, BR9376-6-2-2B, BR10260-5-15-21-6B, BR9390-6-2-1B along with Khoia-motor and Lalmohon as checks were established in ten different representative locations. The plots were selected in representative deep water rice area where flood water depth was expected to be around 1 to 2 meters. But all the advanced lines and check varieties were damaged and not suitable for data collection in nine locations. The result obtained from only one location i.e., Cumilla (Homna). The maximum water depth in Cumilla was 90 cm on 26-07-2020 (at 66 DAS) i.e. water depth didn't exceed 1 m. And water depth was around 0.5 m in most of the time of growing season. The yield of all advanced lines ranged from 0.47 to 0.93 t ha^{-1} (Table 3). Yield of all the advanced lines was significantly lower than the check variety Khoia-motor (1.12 t ha^{-1}). Among the advanced lines entry no. 2 produced the highest grain yield (0.93 t ha^{-1}), whereas entry no. 4 produced the lowest grain yield (0.47 t ha^{-1}). Elongation capacity of advanced lines was low and failed to survive under 1 to 2 meters water depth condition in 9 out of 10 locations. Farmers were not interested on those low yielding advanced lines. So, none of the advanced lines was recommended for PVT.

Table 2. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART, T. Aus for Non-saline tidal environment (NSTE), 2020.

Genotype	Location								G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})										
	L1	L2	L3	L4	L5	L6	L7	Mean	Mean	Mean	Mean
BR8784-4-1-2-P2	3.03	4.58	4.23	5.46	4.47	4.65	4.02	4.35	123	20.9	119
BR8781-16-1-3-P2	3.84	5.53	5.00	5.43	4.72	5.51	3.94	4.85	121	23.5	114
BRRI dhan27 (ck)	3.21	4.02	3.88	4.79	3.77	4.12	4.09	3.98	118	27.9	137
BRRI dhan48 (ck)	3.09	5.47	4.86	5.36	4.86	5.49	4.49	4.80	114	22.7	108
$LSD_{0.05}$	0.46							0.18	0.44	0.68	1.33

L1-Barguna (Nilganj, Amtati), L2- Barguna (Ghotkhali, Amtati), L3-Patuakhali (Kalapara), L4-Barguna (Taltoli), L5-Pirojpur (Kaukhali), L6-Mirsori (Chattogram), L7-BRRI, Gazipur

Table 3. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART, deep water rice (DWR) Deep flooded (1 to 2 meter) during B. Aman 2020 at Homna, Cumilla.

Genotype	Grain yield (t ha^{-1})	Duration (day)	Plant jeight (cm)	TGW (gm)
BR9390-6-2-2B	0.69	162	205	24.8
BR9376-6-2-2B	0.93	163	198	22.4
BR10260-5-15-21-6B	0.53	160	229	22.9
BR9390-6-2-1B	0.47	164	201	22.9
Khoia-motor (ck)	1.12	164	210	26.7
Lalmohon (ck)	0.47	166	181	25.2
$LSD_{0.05}$	0.37	1.52	12.61	1.01
CV%	28.87	0.51	3.40	2.31

Early T. Aman 2020, ALART, stagnant water rice (SWR), shallow flooded (50 to 100 cm). Three advanced lines for shallow flooded (50 to 100 cm water depth) condition i.e., BR10230-7-19-B, BR10247-14-18-7-3-3B, BR10238-5-1-9-3B along with BR23 as check were established in ten different locations. But the trials were severely damaged in seven locations and were not suitable for data collection. Partial results were obtained from two locations e.g. Sadar, Munsiganj and Deep Water Tank BRRI, Gazipur. However, full result was obtained from only one location i.e. Assasuni, Satkhira. The plots were selected in representative shallow flooded rice area where water depth was expected to be around 50 to 100 cm. Statistical analysis of data has not been done because data was not available from seven locations and partial results obtained from two locations. Still from the mean data, we can get an idea about the performance of tested entries. Water depth of the trial sites of Assasuni, Satkhira and Sadar, Munshiganj was lower than our target water depth (50 cm to 100 cm) for proper validation of the advanced lines. Yield of all the advanced lines was lower than the check variety BR23 which yielded 3.71 t ha^{-1}. The yield of all advanced lines ranged from 3.18 to 3.40 t ha^{-1} (Table 4). Elongation capacity of the advanced lines was lower and failed to survive under 50 to 100 cm water depth condition in seven trial sites. Farmers were not interested on those low yielding advanced lines compared to the check variety BR23. So, none of the advanced lines was recommended for PVT.

T. Aman 2020, ALART, Rainfed lowland rice (RLR): Two advanced lines: BR9571-13-1-9-1-1 and BR9574-9-5-3-1-1 along with BRRI dhan49 (ck) and BRRI dhan87 (ck) as checks were tested at farmers' field in ten locations. Averaged yield performances (3.69-3.85 t ha^{-1}) of the tested advanced lines were significantly lower than the check variety BRRI dhan87 (4.41 t ha^{-1}) and BRRI dhan49 (4.10 t ha^{-1}) (Table 5). Moreover the phenotypic acceptance of the tested lines was poor. Considering the above results and phenotypic acceptance, grain type, insect infections, and farmers' opinion, BRRI dhan87 was found to be the best among all the tested entries followed by BRRI dhan49. Therefore, none of tested line was recommended for PVT.

Table 4. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART, Stagnant Water Rice, (SWR; 50 to 100 cm water depth), during Early T. Aman 2020.

Genotype	Location				G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})						
	L1	L2	L3	Mean	Mean	Mean	Mean
BR10230-7-19-B	2.75 (1 Rep)	3.16 (2 Rep)	3.64 (3 Rep)	3.18	184	25.34	120
BR10247-14-18-7-3-3B	3.02 (1Rep)	3.7 (2 Rep)	3.49 (3 Rep)	3.40	183	24.12	125
BR10238-5-1-9-3B	1.94 (1Rep)	3.54 (3 Rep)	4.39 (3 Rep)	3.29	182	27.36	115
BR23 (Ck)	2.59 (3 Rep)	4.06 (3 Rep)	4.48(3 Rep)	3.71	193	25.57	125

L1- Sadar Munshiganj, L2- BRRI Deep water Tank, Shibbari, Gazipur, L3- Assasuni, Satkhira

Table 5. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (RLR) during T. Aman 2020.

Genotype	Location											G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
BR9571-13-1-9-1-1	4.36	4.07	3.07	4.37	2.48	3.37	3.42	3.79	3.46	4.53	3.69	136	17.32	124
BR9574-9-5-3-1-1	2.39	5.10	3.81	5.33	2.44	4.47	3.20	3.83	3.30	4.62	3.85	131	21.43	110
BRRI dhan49 (Ck)	3.55	4.93	5.03	5.73	3.17	4.23	3.94	4.49	4.48	4.57	4.41	135	19.59	104
BRRI dhan87 (Ck)	3.07	5.16	5.16	6.33	1.94	3.83	2.43	4.12	4.47	4.51	4.10	128	22.46	119
$LSD_{0.05}$	0.42										0.13	0.3	0.91	2

L1- Pirojpur, L2- Faridpur, L3- Satkhira, L4- Kushtia, L5- Rajshahi, L6- Rangpur, L7- Habiganj, L8- Cumilla, L9- Feni, L10- BRRI, Gazipur

T. Aman 2020, ALART, zinc enriched rice (ZER). One zinc enriched advanced rice genotypes BR10001-94-2-B along with BRRI dhan72 and BRRI dhan87 as checks were tested at farmers' field in ten locations. On average, the tested genotype BR10001-94-2-B produced statistically similar yield (4.03 t ha^{-1}) to the check varieties BRRI dhan72 (4.07 t ha^{-1}) and BRRI dhan87 (4.18 t ha^{-1}) (Table 6). Mean growth duration of the advance line was two days longer than check varieties. Grain shape and size of the genotype was bold and small awn was present. Farmers didn't prefer BR10001-94-2-B entry compared to the check varieties BRRI dhan72 and BRRI dhan87. Therefore, the tested entry was not recommended for PVT.

T. Aman 2020, ALART insect resistant rice-brown plant hopper (IRR-BPH). Four advanced lines BR9880-40-1-3-34, BR9881-24-2-2-25, BR9880-27-4-1-18 and BR9880-2-2-2-1 along with the check varieties BRRI dhan93 and T27A (R. ck) were tested at farmers' field in ten locations. But the trials of Naogaon (Shaphahar) and Sirajganj (Tarash) were damaged due to heavy rain and inundation. Three tested lines BR9881-24-2-2-25, BR9880-40-1-3-34 and BR9880-27-4-1-18 gave similar average yield (4.12 t ha^{-1}, 4.10 tha^{-1} and 4.09 t ha^{-1} respectively) and it was also similar to the check variety BRRI dhan93 (Table 7). Brown plant hopper (BPH) infestation was observed in two locations. None of the tested lines was preferred by farmers due to BPH infestation and lower yield. Considering grain yield and other characteristics, none of the tested lines was recommended for PVT.

T. Aman 2020, ALART premium quality rice (PQR). Three advanced lines for premium quality rice such as BR9178-7-2-4-4, BR8528-2-2-3-HR2 and BR8882-30-2-5-2 along with BRRI dhan37 as standard check and Dinajpur Kataribhog as local check were tested at 10 different agro ecological conditions of the country. The trial conducted at Sadar upazila of Dinajpur district was damaged due to severe infestation of sheath blight and Brown Plant Hopper at reproductive stage. Farmers did not prefer any of the tested entries due to lower yield (Table 8), irregular flowering, disease susceptibility and lodging tendency. All entries including checks were fully lodged

Table 6. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (ZER) during T. Aman 2020.

Genotype	Location											G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
BR10001-94-2-B	4.66	4.10	4.43	4.79	3.23	2.37	6.09	3.46	2.99	4.19	4.03	130	30.2	120
BRRI dhan72(Ck)	4.87	4.59	3.42	5.14	3.07	2.38	6.40	3.15	3.51	4.13	4.07	128	27.6	114
BRRI dhan87(Ck)	5.01	4.43	3.36	4.94	4.03	2.06	6.06	4.23	4.05	3.66	4.18	128	23.0	120
$LSD_{0.05}$	0.56										0.18	0.25	0.83	1.48

L1- Gazipur, L2- Cumilla, L3- Pirojpur, L4- Faridpur, L5- Rangpur, L6- Rajshahi, L7- Kushtia, L8- Feni, L9- Satkhira, L10- Habiganj

Table 7. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of the rice genotypes under ALART (IRR-BPH) during T. Aman 2020.

Genotype	Location									G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR9880-40-1-3-34	4.15	4.80	3.84	4.26	2.89	5.36	3.69	3.80	4.10	130	19.7	110
BR9881-24-2-2-25	3.55	4.90	4.18	4.21	3.60	5.55	3.27	3.72	4.12	132	20.6	109
BR9880-27-4-1-18	4.90	4.83	3.56	4.43	2.51	5.30	3.36	3.79	4.09	130	24.5	118
BR9880-2-2-2-1	3.89	5.17	4.04	4.37	2.69	5.21	2.62	3.58	3.95	130	24.3	116
BRRI dhan93 (Ck)	4.42	5.20	4.44	4.69	3.05	4.57	3.12	4.43	4.24	135	21.0	121
T27A (R. Ck)	3.28	2.17	3.12	2.86	0.57	1.04	2.06	1.23	2.04	148	21.5	145
$LSD_{0.05}$	0.59								0.21	0.36	0.81	2.05

L1-Cumilla, L2-Dinajpur, L3-Feni, L4-Gazipur, L5-Habiganj, L6-Kushtia, L7-Rajshahi, L8-Satkhira

at experimental field of BRRI, Gazipur due to stormy wind at reproductive stage. Grain size and shape were needed to be evaluated again. Considering all necessary attributes, this ALART (PQR) may be conducted for further observation and recommended as re-ALART.

Boro 2021, ALART premium quality rice (PQR). Two advanced lines of premium Quality Rice (PQR) such as BR8526-38-2-1-HR1 and Lata Balam along with BRRI dhan50, BRRI dhan63 and BRRI dhan81 as standard checkes were tested at 10 different locations of the country. On average, both the tested entries produced statistically similar yield to that of check varieties (Table 9), whereas growth duration of the entries was 10-12 days longer than the check varieties at different locations. Flowering and maturity of the tested genotype Lata Balam was irregular. Phenotypic acceptance of Lata Balam at vegetative and reproductive stage was not better than check varieties. Farmers and extension personnel didn't choose both the advanced lines for its yield and long duration in comparisons with the check varieties. Considering all the necessary attributes, none of the two advanced lines was recommended for PVT.

Table 8. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (PQR) during T. Aman 2020.

Genotype	Location										G. duration (day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean	Mean	Mean	Mean
BR9178-7-2-4-4	3.53	3. 24	3.30	2.53	3.30	3.40	2.23	3.23	3.43	3.13	151	16.20	138
BR8528-2-2-3-HR2	3.47	3.03	3.20	4.30	3.30	4.50	3.00	5.33	5.45	3.95	136	21.30	117
BR8882-30-2-5-2	2.23	2.99	3.13	2.90	2.70	2.80	2.37	3.81	3.90	2.98	149	14.50	131
Dinajpur K.bhog(Ck.)	2.63	2.89	3.37	2.50	2.57	2.87	2.07	3.33	3.43	2.85	150	15.20	145
BRRI dhan37 (Ck.)	4.43	2.78	3.30	3.57	3.10	3.07	3.00	3.37	3.41	3.34	155	16.10	133
$LSD_{0.05}$	0.27									0.09	0.45	0.58	2.11

L1-Bogra, L2-BRRI Gazipur, L3-Naoga, L4-Rangpur (Birgonj), L5-Dinajpur (Kaharol), L6-Dinajpur (Chirirbandar), L7-Rangpur (Pirganj), L8-Rangpur (Taraganj), L9-Naoga (Manda)

Table 9. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (PQR) during Boro 2021.

Genotype	Location											(day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
BR8526-38-2-1-HR1	5.22	6.60	8.30	8.09	5.48	6.82	5.57	6.36	6.70	6.28	6.54	159	18.38	104
Lata Balam	6.31	6.97	7.66	8.15	6.51	5.52	5.72	5.85	6.06	6.51	6.53	154	23.63	103
BRRI dhan50 (Ck)	5.44	6.03	8.37	6.91	5.74	6.96	6.41	6.16	5.91	5.69	6.36	152	19.03	87
BRRI dhan63 (Ck)	5.17	4.29	7.56	8.23	6.97	7.44	6.68	6.23	5.27	4.95	6.28	149	21.47	87
BRRI dhan81 (Ck)	5.30	6.60	7.74	7.15	6.30	6.46	6.07	6.67	5.42	5.48	6.32	147	21.39	97
$LSD_{0.05}$	0.77										0.30	0.21	0.53	1.24

L1- Dinajpur (Chirirbandar), L2- Rangpur (Mithapukur), L3- Bogra (Dhunat), L4- Rajshahi (Poba), L5-Rajshahi (Godagari), L6-Kushtia (Sadar), L7- Satkhira (Sadar), L8- Feni (Fulgazi), L9- Gazipur (Kapasia), L10- BRRI, Gazipur

Boro 2021, ALART Zinc enriched rice (ZER). Two zinc enriched advanced rice genotypes (BR8912-12-6-1-1-1-1 and IR105837-8-95-2-1) developed by Plant Breeding Division were evaluated against the check varieties BRRI dhan74 and BRRI dhan89 in 10 different locations of the country. The results from Faridpur (Nagarkanda) were out-lier. Therefore, the results from Faridpur (Nagarkanda) for analysis and reports were not included here. Farmers and extension personnel didn't choose both the advanced lines for its lower yield and long duration in comparisons with the check varieties (Table 10), beside both the advanced lines having lodging tendency. Considering all the necessary attributes, none of the two advanced line was recommended for PVT.

Boro 2021, ALART bacterial blight resistant rice (BBRR-Bio). Two advanced lines developed by Biotechnology division BR (Bio) 11447-1-28-14-3 and BR (Bio) 11447-3-10-7-1 for BLB resistant rice were evaluated against check variety BRRI dhan28 in different 10 locations of the country. The result from Bagura was excluded from the analysis due to outlier. Both the advanced lines gave slightly higher mean yield than the check variety BRRI dhan28 but the duration of the lines was 2-3 days longer than the check (Table 11). Both the tested lines were prone to Bacterial Blight disease as well as other diseases. Grains of both tested lines were medium bold type and mean thousand grains weight was also higher compare to checks BRRI dhan28. In most of the cases, scientist, extension personnel and farmer choose the variety BRRI dhan28 for its phenotype and slender grain. Some also preferred the tested line BR (Bio)11447-1-28-14-3. However, they did not like the phenotypic stature and grain size of both tested lines. Considering all the above characteristics, none of the tested line was recommended for PVT.

Boro 2021, ALART Favourable Boro Rice-Bhanga (FBR-Bhanga). Two advanced lines developed by BRRI, regional station Bhanga (SVIN063-Boro-18-Bhanga and SVIN076-Boro-18-Bhanga) were evaluated against two check varieties (BRRI dhan29 and BRRI dhan89) in ten different locations of the country. No advanced line showed yield advantage compared to the standard check BRRI dhan89 (Table 12). Though both the advanced lines produced little higher yields than the check BRRI dhan29, but were much less than another check variety BRRI dhan89. Insect and disease attack was same as the checks indicating no advantage against pest attack. In most cases, farmers, scientists and SA/SAAO chose the entry BRRI dhan89 as their first choice. Considering all the above characteristics, one of the entry was recommended for PVT.

Table 10. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (ZER) during Boro 2021.

Genotype	Location										(day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean	Mean	Mean	Mean
BR8912-12-6-1-1-1-1	7.64	6.35	6.97	7.15	7.53	6.93	7.10	7.20	7.23	7.12	157	22.49	103
IR105837-8-95-2-1	6.65	6.20	6.65	7.37	6.51	6.47	6.66	7.33	7.20	6.78	151	27.75	112
BRRI dha74 Ck)	6.32	7.65	7.51	8.04	6.70	7.14	6.90	7.43	7.47	7.24	147	30.03	96
BRRI dha89 Ck)	7.61	7.90	7.97	8.97	7.68	7.65	7.80	5.43	8.12	7.68	157	23.14	109
$LSD_{0.05}$	0.76									0.25	0.26	0.70	1.63

L1-Jhalokathi, L2-Satkhira, L3-Habigonj, L4-Kushtia, L5-BRRI Gazipur, L6-Gazipur (Kapasia), L7-Rajshahi, L8-Rangpur, L9- Feni

Table 11. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (BBRR-Bio) during Boro 2021.

Genotype	Location										(day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean	Mean	Mean	Mean
BR(Bio)11447-1-28-14-3	5.50	6.64	7.57	6.31	6.65	6.77	6.11	7.79	6.29	6.33	145	24.96	103
BR(Bio)11447-3-10-7-1	5.68	6.42	7.51	6.96	7.78	6.70	5.43	7.69	6.96	6.44	144	24.24	105
BRRI dhan28 (Ck)	5.40	6.52	7.37	6.23	6.62	6.70	3.62	6.84	6.38	6.01	142	22.48	101
$LSD_{0.05}$	0.71									0.24	0.30	0.49	1.43

L1-Jhalokathi, L2-Feni, L3-Cumilla, L4-BRRI Gazipur, L5-Habiganj, L6-Rajshahi, L7-Rangpur, L8-Satkhira, L9-Gazipur (Kapasia)

Table 12. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (FBR-Bhanga) during Boro 2021.

Genotype	Location											(day)	TGW (g)	Plant height (cm)
	Grain yield (tha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
SVIN063-Boro-18-Bhanga	8.06	7.21	8.99	6.46	7.64	6.91	7.58	7.35	7.76	6.74	7.47	156	23.8	108
SVIN076-Boro-18-Bhanga	8.11	7.43	8.48	7.03	7.67	7.31	7.76	7.61	6.49	7.23	7.51	156	22.4	106
BRRI dhan29 (Ck)	7.87	7.54	8.14	7.41	7.60	7.14	7.93	6.84	6.07	7.53	7.41	158	21.7	102
BRRI dhan89 (Ck)	7.77	7.61	8.19	7.57	7.75	7.43	7.84	7.88	6.32	7.90	7.63	156	23.3	110
$LSD_{0.05}$	0.76										NS	1	0.5	1

L1- Jhalokathi, L2- Feni, L3- Faridpur, L4- BRRI Gazipur, L5-Habiganj, L6- Kushtia, L7- Rajshahi, L8- Rangpur, L9-Satkhira, L-10-Gazipur (Kapasia),

TECHNOLOGY DISSEMINATION

Seed production and dissemination programme (SPDP)

Scientists of ARD conducted different demonstration trials and involved in different promotional activities for rapid dissemination of BRRI developed technologies. Among them, SPDP was very important activity where BRRI developed different promising rice varieties were demonstrated at farmers' field in different seasons for rapid dissemination. SPDPs were conducted in collaboration with DAE using different sources of funds such as GoB, SPIRA, TRB, and TTFP.

SPDP during B. Aus 2020 under GoB. SPDP were conducted at five upazilas (Bhola Sadar,Borhanuddin, Doulatkhan, Lalmohon and Tazumuddin) of Bhola districts. Three modern rice varieties (BRRI dhan43, BRRI dhan65 and BRRI dhan83) were used as cultivar. BRRI dhan83 produced the highest mean grain yield 4.38 t ha^{-1} followed by BRRI dhan65 (3.8 t ha^{-1}) and the lowest yield (3.47 t ha^{-1}) was in BRRI dhan43. A total of 6,275 kg grains were produced from all demonstrated plots and 1,540 kg quality seeds were retained by the farmers for the next year use. About 565 farmers acquired awareness and knowledge about the varieties through field visits, discussion and knowledge sharing. A total of 363 farmers were motivated and showed their interest to cultivate these varieties in the next year.

SPDP during T. Aus, 2020 under GoB. SPDPs were conducted at 15 upazilas of seven districts (Tangail, Patuakhali, Bhola, B. Baria, Sylhet, Borguna and Gaibandha). Four modern rice varieties (BRRI dhan48, BRRI dhan82, BRRI dhan85 and BRRI hybrid dhan7) were used as cultivar. Demonstration size of each variety was one bigha and three varieties were demonstrated in three bighas of land in a cluster at each upazila. BRRI hybrid dhan7 produced the highest mean grain yield (4.98 t ha^{-1}) followed by BRRI dhan82 (4.60 t ha^{-1}), BRRI dhan48 (4.05 t ha^{-1}) and the lowest yield was in BRRI dhan85 (4.01 t ha^{-1}). A total of 2,4291kg grains were produced from all demonstrated plots and 2,630 kg quality seeds were retained by the farmers for the next year cultivation. About 2,884 farmers acquired awareness and gained knowledge about the varieties. A total of 1,199 farmers were motivated and showed their interest to cultivate these varieties in the next year.

SPDP in Jhum cultivation during Aus 2020. SPDPs were conducted in Jhum cultivation at four upazilas (Sadar, Dighinala, Ramgarh and Matiranga) in Khagrachari districts. Each SPDP consists of two varieties cultivated in two bighas of land (one variety in one bigha land). Three varieties (BRRI dhan48, BRRI dhan65 and BRRI dhan83) were selected for SPDP in Jhum cultivation system. BRRI dhan48 (3.60 t ha^{-1}) yielded the highest among the demonstrated varieties. BRRI dhan83 yielded 3.1 t ha^{-1} followed by BR20 (2.9 t ha^{-1}) and BRRI dhan65 (2.1 tha^{-1}). Farmers retained 340 kg seeds of different varieties for next Jhum

cultivation. A total of 310 farmers were gained knowledge from these SPDPs and 60 farmers were motivated to grow BRRI varieties in next year. Considering all the traits BRRI dhan48 would be a very good variety for Jhum cultivation.

SPDP in Valley of hills during T. Aus, 2020. The SPDPs were conducted at the valley of hill at farmers' field in eight upzilas of Khagrachari, Rangamati and Bandarban districts. BRRI dhan48, BRRI dhan82 and BRRI dhan85 were selected for this programme. Two varieties were selected for each SPDP sites. Yield of BRRI dhan82 and BRRI dhan85 was more or less similar (4.4 and 4.25 t ha^{-1}) and they have higher potentiality to grow in these areas. There was only one demonstration site of BRRI dhan48 at Kaptai upazila of Rangamati District and it produced 5.37 t ha^{-1}. A total of 9,383 kg seed was produced from these demonstrations and farmers retained 631 kg seeds of different varieties for the next year cultivation. A total of 658 farmers were gained knowledge from these SPDPs and 193 farmers were motivated to grow BRRI varieties in next year.

SPDP during T. Aman, 2020 under GoB. SPDPs were conducted in different agro-ecological regions of the country covering in 27 upazilas of 13 districts (Tangail, Munshiganj, Netrakona, Mymensingh, Sherpur, B. Baria, Chattogram, Patuakhali, Gaibandha, Dinajpur, Jashore, Sunamganj and Nilphamari). Twelve modern rice varieties (BRRI dhan70, BRRI dhan71, BRRI dhan73, BRRI dhan75, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI dhan90, BRRI dhan91, BRRI dhan93 BRRI dhan94 and BRRI dhan95) were used in this programme. Plot size of each variety was one bigha and three varieties were demonstrated in three bighas area in a cluster in each upazila. Among the varieties, BRRI dhan87 produced the highest mean grain yield 5.73 t ha^{-1} followed by BRRI dhan95 (5.37 t ha^{-1}) and BRRI dhan71 (5.19 t ha^{-1}). The lowest mean grain yield (2.72 tha^{-1}) was found in BRRI dhan91. A total of 53,221 kg rice grains were produced from all demonstrated plots from which farmers retained 6,141 kg quality seeds for the next year use. About 6,037 farmers acquired awareness and knowledge about the varieties. A total of 1,877 farmers were motivated and showed their interest to cultivate these varieties next year. BRRI dhan87, BRRI dhan95, BRRI dhan71 and BRRI dhan75 were highly preferred by the farmers for its good taste, quality grain and shorter life cycle that create opportunity to timely establishment of rabi crops.

SPDP during T. Aman, 2020 under SPIRA. SPDPs were conducted at 10 upazilas of six districts (Dinajpur, Gaibandha, Nilphamari, Jashore, Gazipur and Manikganj). One modern rice variety (BRRI dhan87) was used as cultivar. Demonstration size of this variety was six bighas in a cluster in each demonstration site. BRRI dhan87 produced the highest grain yield of 6.89 tha^{-1} in Dinajpur sadar upazila followed by Chririrbandar upazila (6.5 tha^{-1}) and the lowest yield (4.75 tha^{-1}) was observed in Gobindaganj upazila of Gaibandha district. A total of 50.12 ton grains were produced from all demonstrated sites and farmers retained 4,640 kg quality seeds for the next year use. About 2,260 farmers acquired awareness and knowledge about the variety. A total of 818 farmers were motivated and showed their interest to cultivate BRRI dhan87 next year. BRRI dhan87 was highly preferred by the farmers for its quality grain, lower sterility and long panicle length where some farmers complained about the lodging, sheath blight and BLB problem of this variety.

Dissemination of BRRI hybrid dhan4 and BRRI hybrid dhan6 in T. Aman 2020. Dissemination of BRRI developed hybrid varieties for T.Aman season were conducted in 15 upazilas of 11 districts (Tangail, Khagrachari, Rangamati, Bandarban, Mymensingh, Dinajpur, Nilphamari, Jashore, Sunamganj, Netrakona and Sherpur). Two hybrid rice varieties (BRRI Hybrid dhan4 and BRRI Hybrid dhan6) were used in the program. Plot size of each variety was one bigha and two varieties were demonstrated in two bighas area in a cluster in each upazila. BRRI hybrid dhan6 produced higher mean grain yield (5.9 t ha^{-1}) compared to that of BRRI hybrid dhan4 (5.46 t ha^{-1}). A total of 22,822 kg grains were produced from all demonstrated plots. About 2,257 farmers acquired awareness and knowledge about the varieties. A total of 398 farmers were motivated

and showed their interest to cultivate these varieties in the next year.

Performance of BRRI dhan71 and BRRI dhan75 in T. Aman-potato-Boro cropping pattern during T. Aman 2020. SPDPs were conducted in potato growing areas of northern part of Bangladesh to introduce short duration T. Aman rice varieties during T. Aman 2020. Two modern rice varieties, BRRI dhan71 and BRRI dhan75 having the growth duration less than 120 days, were cultivated in nine upazilas of five districts (Nilphamari, Thakurgaon, Gaibandha, Joypurhat and Bogura) under GoB. The average yield of BRRI dhan71 and BRRI dhan75 was 4.48 t ha^{-1} and 4.25 t ha^{-1} respectively. About 10 ton grains were produced from all demonstration plots and farmers retained 1,735 kg quality seeds for the next year cultivation. About 1,339 farmers acquired awareness and knowledge about the varieties. In total 368 and 405 farmers were motivated to grow BRRI dhan71 and BRRI dhan75, respectively during the next season.

SPDPs in Aman 2020 under TRB project. A total of 25 SPDPs were conducted in 19 upazilas of 16 districts (Netrakona, Mymensingh, Kishoreganj, Gazipur, Chuadanga, Jhenidah, Khulna, Bhola, Naogaon, Bogura, Chapai Nawabganj, Gaibandha, Lalmonirhat, Sylhet, Bandarban and Cox'sbazar). BRRI dhan71, BRRI dhan73, BRRI dhan75, BRRI dhan79, BRRI dhan80 and BRRI dhan87 were demonstrated in the SPDPs. Area of each SPDP was three bigha and total area of SPDP was 72 bigha. Irrespective of varieties and locations, BRRI dhan87 gave the highest mean grain yield (5.47 t ha^{-1}) followed by BRRI dhan73 (5.24 t ha^{-1}) and the lowest mean grain yield was found in BRRI dhan80 (4.76 t ha^{-1}). Total production of all the varieties was 43,778 kg from which 6,280 kg was retained as seeds by the farmers for next season cultivation. About 4,610 farmers gained awareness and knowledge about the varieties and 730 farmers were motivated to cultivate the varieties.

Head to head adaptive trial (HHAT) in Aman 2020 under TRB project. A total of 200 head to head adaptive trials (HHAT) were conducted throughout the country under TRB project. One bigha of land was divided in equal parts according to tested varieties, where a variety was treated as a treatment. The programme was executed at 47 districts of the country with the active collaboration of nine different BRRI regional stations, Department of Agricultural Extension (DAE) and 17 private organizations. The trial was set up following RCB design where every farmer (1 trial) was considered as one replication. The following four categories of HHAT having some modern rice varieties were conducted at concerned rice growing eco-system.

a. Rainfed low land rice ecosystem having short growth duration rice variety (RLR-SD). The tested varieties having growth duration, less than 120 days were BRRI dhan57, BRRI dhan71, BRRI dhan75, BINA dhan16, BINA dhan17 and BINA dhan22. In the trial RLR-SD, both of BRRI dhan75 and BRRI dhan71 performed better than BRRI dhan57 and BINA dhan16. BRRI dhan75 produced the highest grain yield (5.32 tha^{-1}) followed by BRRI dhan71 (5.19 tha^{-1}). BINA dhan16 showed the earliest variety having 108 days growth duration.

b. Rainfed low land rice ecosystem having long growth duration rice variety (RLR-LD). The tested varieties having growth duration, more than 120 days were BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan94 and BRRI dhan95. In RLR-LD rice growing eco-system, BRRI dhan87 performed as the best among the others and produced average grain yield 5.58 t ha^{-1} in all over the Bangladesh. The second highest yielders were BRRI dhan93 and BRRI dhan94 produced grain yield 5.17 t ha^{-1} and very much close to BRRI dhan87 having 133 days growth durations. BRRI dhan93, BRRI dhan94 and BRRI dhan95 which were released in 2019, performed well in all over the Bangladesh and mean grain yields were 5.17, 5.17 and 5.11 tha^{-1} respectively. Among them, BRRI dhan95 was one week earlier than BRRI dhan93 and BRRI dhan94.

c. Coastal ecosystem (CE). The areas considering coastal part of the country. The rice varieties were BRRI dhan72, BRRI dhan73, BRRI dhan78 and BRRI dhan79. BRRI dhan72 was the highest yielder (5.00 t ha^{-1}) in the trial coastal

ecosystem and the nearest second yielder was BRRI dhan79 (4.96 t ha^{-1}). Among the coastal ecosystem, the tested variety BRRI dhan72 had 5t/ha average grain yield and mean maturity was 127 days which shows significant better performance in all over the coastal region of Bangladesh. BRRI dhan79 which is multi stress tolerant variety produced also average grain yield 4.96 t ha^{-1} and its mean maturity was 136 days. BRRI dhan73 and BRRI dhan78 had better performance over the check or farmers' variety in that region.

d. Flash flood submergence (FFS). The areas which are flash flood prone during rainy season and the rice varieties were BRRI dhan51, BRRI dhan52, BRRI dhan79, IR13F441 and BINA dhan11. BRRI dhan52 produced the highest grain yield (4.77 t ha^{-1}) followed by BRRI dhan79 (4.75 t ha^{-1}) in the trial FFS. The mean growth duration of BRRI dhan52 and BRRI dhan79 were 142 and 141 days respectively, which were very much close to each other. Although the yield and growth duration of those varieties were very similar farmers preferred more BRRI dhan52 than BRRI dhan79 because of more survival capacity in flooded condition and grain quality of BRRI dhan52. The lowest yielder (4.31 tha^{-1}) was BINA dhan11 and it was the earliest among all other varieties. This variety was nearly three weeks earlier than BRRI dhan52 and also than BRRI dhan79.

SPDP during T. Aman, 2020 under TTFP. Block demonstration was done with the latest BRRI developed rice varieties such as BRRI dhan70, BRRI dhan71, BRRI dhan75, BRRI dhan79, BRRI dhan80 and BRRI dhan87 by selected farmers at Valona and Muztagata upzillas of Mymensingh and Sadar and Sarishabari upzilas of Jamalpur. Six farmers were selected in each location. Land area of each location was six bighas (2 acare) having one bigha of land for each farmer. So, total no. of farmers was 24. The average yield of BRRI dhan70, BRRI dhan71, BRRI dhan75, BRRI dhan79, BRRI dhan80 and BRRI dhan87 was 4.48, 4.50, 4.62, 4.94, 4.49 and 5.77 tha^{-1} respectively. Among the rice varieties, BRRI dhan87 produced the highest grain yield 5.77 t ha^{-1} followed by BRRI dhan79 (4.94 t ha^{-1}), BRRI dhan75 (4.62 t ha^{-1}) and BRRI dhan71 (4.50 t ha^{-1}). Very similar grain yield was found in the three rice varieties e.g. BRRI dhan70, BRRI dhan71 and BRRI dhan80. However, the lowest grain yield (4.48 t ha^{-1}) was found in BRRI dhan70 and the 2nd lowest grain yield (4.49 t ha^{-1}) was found in BRRI dhan80. Grand total of six rice varieties regarding grain production was 15,440 kg from where farmers retained 2,392 kg as seed for the next year cultivation. 595 farmers were motivated by the varieties for the next year cultivation. Plastic drums having capacity of 75-80 kg were supplied to each farmer of the project plots to preserve paddy for the next year cultivation.

New model demonstration by 4-stakeholders for rapid dissemination of rice variety in T. Aman 2020 under GoB. A new method of demonstration was initiated where four stakeholders (researcher, extension agent, seed producer/ dealer and farmer) are linked in a demonstration and play a significant role through participatory approach. The model demonstration was done in three different locations (in three villages) of a upazila in two different districts. The piloting was carried out in Assasuni of Satkhira and Dakshin Surma of Sylhet. In each demonstration, one seed producer/dealer was linked with DAE to select suitable farmer and land. Five suitable varieties and other associated technologies were demonstrated in these demonstrations. Field day was arranged too. Yield, collected seed amount, seed distribution and other data were collected from these demonstrations. BRRI dhan87 yielded the highest (5.03-5.39 t ha^{-1}) followed by the check variety BRRI dhan49 (4.72-4.94 t ha^{-1}). Here farmers chose BRRI dhan87 as their first choice and BRRI dhan49 as second choice. Only 900 kg seeds of different varieties chosen by farmers could be collected by the seed producer avoiding storm effect (lodging area). On the other hand, 2,550 kg TLS were collected by the local seed producer (Ahmed seed agency) from three demonstrations. In Dakshin Surma of Sylhet, BRRI dhan93 produced higher yield and was chosen be the farmers as first choice. Near about three tons of TLS were collected here and demand of seeds are high due to farmers' interest in growing of these varieties.

SPDP in Boro 2021 under GoB. SPDPs were conducted in 36 upazilas of 18 districts (Khulna,

Chittagong, Cox's Bazar, Manikganj, Munsiganj, Lalmonirhat, Thakurgaon, Tangail, Mymensingh, Khulna, Sherpur, Gaibandha, Nilphamari, Kisoreganj, Netrakona, Khagrachari, Rangamati, Bandarban). BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88, BRRI dhan89 and BRRI dhan92 were used in the programme. Plot size of each variety was one bigha and three varieties were demonstrated in three bighas area in a cluster in each upazila. BRRI dhan92 produced the highest mean grain yield 7.53 t ha^{-1} followed by BRRI dhan89 (7.49 t ha^{-1}) and BRRI dhan88 (6.66 t ha^{-1}). The lowest mean rice grain yield was 6.02 t ha^{-1} in BRRI dhan84 followed by 6.11 and 6.33 t ha^{-1} in BRRI dhan74 BRRI dhan81 respectively. A total of 148,162 kg grains were produced from all demonstrated plots and 17,521 kg quality seeds were retained by the farmers as seed for the next year cultivation.

Introducing BRRI dhan81 and 88 in T Aman-Potato-Boro Cropping pattern during Boro 2021. Two short duration Boro varieties, BRRI dhan81 and BRRI dhan88 were introduced in T. Aman-Potato-Boro cropping pattern of northern districts. A total of 22 SPDPs were conducted in 11 upazilas of five districts namely Nilphamari, Gaibandha, Bagura, Thakurgaon and Joypurhat. Irrespective locations, BRRI dhan88 produced the highest mean grain yield (6.45 t ha^{-1}) followed by BRRI dhan81 (6.14 t ha^{-1}) and the lowest grain yield was found in BRRI dhan81 (5.3 t ha^{-1}) at Jaldhaka, Nilphamari. A total of 15 tons of seeds were produced from those varieties and 1,485 kg seeds were retained for next year cultivation. About 1,187 farmers gained awareness and knowledge about the varieties and 276 farmers were motivated to cultivate the varieties. Mean growth duration BRRI dhan81 and BRRI dhan88 was 140 days which is five days earlier than BRRI dhan28. So farmers can easily cultivate these two varieties after harvesting potato in the T. Aman-Potato-Boro Cropping Pattern.

Introducing double transplanting method in Potato/Mustard-Boro-Fellow cropping pattern under GOB during Boro 2021. Four Boro varieties, BRRI dhan88, BRRI dhan89, BRRI dhan92 and BRRI dhan96 were introduced in Potato/Mustard-Boro-Fellow cropping pattern of Dhaka Division through double transplanting method. All the seedlings were transplanted (both single and double) after the harvesting of mustard/potato crop. A total of 16 SPDPs were conducted in two upazilas of Manikganj districts (Singair, Harirampur) and Sirajdikhan of Munshiganj district. For seedling growing, dry seed bed covered with transparent polythene was practiced in all locations of Manikganj. Whereas, in Munshiganj, the normal BRRI practice (wet seedbed) was followed for seed bed preparation and other cultural practices. Area of each SPDP was four bigha and total area of SPDP was 16 bighas. A total of 9.4 tons of grains were produced from those varieties and 1440 kg seeds were retained for next year cultivation. About 2,475 farmers were gained awareness and knowledge about the varieties and 475 farmers were motivated to cultivate the varieties. However, farmers did not preferred double transplanting for its higher cost and longer growth duration.

SPDP during Boro 2021 uder TRB. A total of 35 SPDPs were conducted in 21 upazilas of 15 districts (Netrakona, Mymensingh, Kishoreganj, Gaibandha, Lalmonirhat, Bagura, Joypurhat, Naogaon, Chapai Nawabganj, Khulna, Jashore, Jhenaidah, Chuadanga, Magura and Sylhet). Seven modern rice varieties BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88, and BRRI dhan89 were demonstrated in the SPDPs. Area of each SPDP was three bigha and total area of SPDP was 112 bigha. Irrespective of varieties and locations, BRRI dhan89 produced the highest mean grain yield (7.67 t ha^{-1}) followed by BRRI dhan74 (7.06 t ha^{-1}) and the lowest grain yield was found in BRRI dhan84 (6.11 t ha^{-1}). Total produced grains of all the varieties were 1,01,568 kg from which 9,535 kg was retained as seeds by the farmers for next season cultivation. About 5,046 farmers were gained knowledge about the varieties and 1,005 farmers were motivated to cultivate the varieties.

Adaptive trial of BRRI varieties during Boro 2021 under GoB. Five promising short duration Boro varieties (BRRI dhan67, BRRI dhan74, BRRI dhan84, BRRI dhan88 and BRRI

dhan96) were selected to test their adaptability over different locations of the country covering three hilly districts and four districts in the plain land (Kishoreganj, Manikganj, Munshiganj and Narsingdi). Irrespective of location, BRRI dhan74 (6.61 t ha^{-1}) and BRRI dhan88 (6.60 t ha^{-1}) yielded higher than the other varieties. BRRI dhan74 was better yielder especially in hilly areas and farmers of these areas are very much interested to grow it. In plain land area, BRRI dhan88 was better performer and specially it showed higher yield in Manikganj and Munshiganj, where it was grown after sharisha and potato respectively.

Head to head adaptive trial (HHAT) during Boro 2021 under TRB. A total of 200 head to head adaptive trials (HHAT) with five categories according to rice ecosystem were conducted throughout the country through public and private partnership (PPP). The trials were categorized in five different groups considering the agro-ecology and used rice variety. The followings were the major groups

a. Short growth duration rice variety (<150 days). Tested varieties BRRI dhan28, BRRI dhan67, BRRI dhan81, BRRI dhan84 and BRRI dhan88 was found as the highest yielder (6.48 t ha^{-1}) having growth duration of 141 days. Whereas BRRI dhan84 produced the lowest yield (6.21 tha^{-1}). BRRI dhan67 and BRRI dhan81 produced similar yield and the growth duration were 142 and 141 days respectively.

b. Long growth duration rice variety (>150 days): Tested varieties were BRRI dhan29, BRRI dhan58, BRRI dhan89 and BRRI dhan92. BRRI dhan92 produced the highest grain yield (7.26 t ha^{-1}) followed by BRRI dhan89 (7.01 t ha^{-1}). BRRI dhan58 produced the lowest yield (6.78 t ha^{-1}) having also the lowest growth duration 151 days only. The growth duration of BRRI dhan29 was the highest (156 days) among all the tested varieties and BRRI dhan58 was the lowest (151 days).

c. Saline ecosystem (SE). Tested varieties were Bina dhan10, BRRI dhan28, BRRI dhan67, BRRI dhan97 and BRRI dhan99. A recent salt tolerance rice variety BRRI dhan99 produced the grain yield of 6.14 tha^{-1} and performed the best among varieties. BRRI dhan28 produced only 5.16 t ha^{-1} having only growth duration of 132 days.

d. Haor ecosystem (HE). Tested varieties were BRRI dhan28, BRRI dhan67, BRRI dhan84, BRRI dhan88 and BRRI dhan96. In Haor areas, the average yield of BRRI dhan96 was 6.47 t ha^{-1} followed by BRRI dhan88 (6.22 t ha^{-1}). BRRI dhan84 also performed well in Haor eco-system, which produced grain yield 6.17 t ha^{-1} having only 139 days growth duration. BRRI dhan96 was found as the most suitable cultivar with lowest growth duration (139 days), which can overcome early flash flood.

e. Hilly ecosystem (HE). Tested varieties were BRRI dhan28, BRRI dhan67 and BRRI dhan74. BRRI dhan67 was the highest yielder (7.37 t ha^{-1}) in hilly rice ecosystem followed by BRRI dhan74 (7.18 tha^{-1}). BRRI dhan28 was affected by neck blast and that is why, yield was affected. Irrigation water was scarce at hilly areas, and very often surface water was used for irrigation. The growth duration of BRRI dhan67 was at par of BRRI dhan28 and could be cultivated with minimum irrigation, whereas BRRI dhan67 produced significantly higher yield than the old variety BRRI dhan28.

New model demonstration by four stakeholders for rapid dissemination of rice variety in Boro 2020 under GoB. A new method of demonstration was initiated where four stakeholders (researcher, extension, seed producer/ dealer and farmer) is linked in a demonstration and play a significant role through participatory approach. The model demonstration was done in three different locations (in three villages) of a upazila in two different districts. The piloting was carried out in Assasuni of Satkhira and Dakshin Surma of Sylhet. In each demonstration, one seed producer/dealer was linked with DAE to select suitable farmer and land. Five suitable varieties and other associated technologies were demonstrated in these demonstrations. In Boro 2021, all the demonstrations of Satkhira were set up in salinity affected areas where salinity ranges between 3.05 to 8.885 ds/m. BRRI dhan67 produced higher yield in all the three locations. Though BRRI dhan97 and BRRI dhan99 showed more tolerance against

salinity but due to higher salinity and water shortage at later stage (maturity stage) the yield was affected. On the other hand BRRI dhan67 could escape the situation due to its shorter growth duration. Most of the farmers chose BRRI dhan67 due to some of its advantages. In the demonstrations of Dakshin Surma, Sylhet, farmers chose BRRI dhan89 and BRRI dhan92 due to their higher yield though they showed longer growth duration.

FARMERS TRAINING AND PROMOTIONAL ACTIVITIES

Farmers' training. During the reporting period ARD conducted 103 farmers' training at different locations of the country in which 3,140 trainees (2,859 farmers and 281 SAAOs of DAE) participated during the reporting period of 2020-21.

Field day/farmers' rally. ARD conducted 68 field days at different locations in different seasons of the country under GoB and two projects (SPIRA and TRB). Around 4,935 participants including farmers, local leaders and DAE personnel participated in the field days.

Seed production at BRRI farm. A total of 6052 kg quality seeds of different BRRI varieties were produced at BRRI farms during the reporting period. In total 1,020 kg seeds of 13 varieties were produced during T. Aman 2020, whereas 5,032 kg TLS of 15 BRRI developed and one BINA developed rice varieties were produced during Boro 2021 season.

Distribution of plastic drum under GoB during Boro 2021. Thirty-six plastic drums were provided in 12 seed centers of seven districts. Around 80 kg seeds were preserved in each drum.

Seed support to farmers and stakeholders under TRB project. Adaptive Research Division distributed 1.50 and 3.80 tons of truthfully labeled seeds (TLS) of 29 modern rice varieties to farmers and stakeholders in Aman 2020 and Boro 2021 respectively among the farmers.

Training Division

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Effectiveness of imparted rice production training

SUMMARY

Training Division has conducted 36 training programmes in the reporting year with course during from one day to ten days. Total number was 454 participants. Need based course curriculum was developed for these courses based on training need assessment. The participants were sub-assistant agriculture officer (SAAO) of the Department of Agriculture Extension (DAE), scientists, scientific assistants and farm manager of BRRI. Among the training programmes an evaluation was done on scientific report writing (SRW) training course to evaluate the strength and weakness of the training programmes. The Kirkpatric evaluation approach was used to evaluate the training programmes under four levels namely; reaction, learning, behaviour and results guided by 18 evaluation questions. The findings showed that the most of the participants were highly satisfied with the SRW training course. They also suggested to organizing such training programme in a regular basis especially for the young scientists. Speaker evaluation also reveals most of the BRRI's speakers' performance was excellent.

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

Training on modern rice production technologies

Fifteen training courses on modern rice production technologies were conducted during the reporting period. The main objective of the course was to train the Sub-Assistant Agriculture Officers (SAAO) of DAE. So that they can (i) be able to use and disseminate modern rice production technologies and (ii) identify and solved the field problems of rice cultivation and help the farmers to increase rice productivity. The course curriculum was designed based on the priority of field problems related to rice production and rice based technologies. Among the different approaches in this training course, lectures and hands-on practices were the leading methods. Duration of the course was one day. A total of 381 SAAOs were trained. Among the participants 300 and 81 were male and female respectively (Table 1).

Training on scientific report writing

The responsibility of a scientist does not end when their laboratory and field investigation is complete. They must also communicate their results to the scientific community, donor organizations, policy makers and potential users of the knowledge generated. Only then scientists can claim to have made a real contribution to their existing body of scientific knowledge. Scientists must have the relevant skills that enable them to make effective written presentations that communicate information clearly and concisely. Therefore, this five-day long training on scientific report writing was organized for the senior scientific officers and scientific officers of Bangladesh Rice Research Institute during 2020-21. A total of 78 participants split up into five batches were trained through this course. Particulars of the trainings are given in table 2.

Evaluation of scientific report writing training course

Evaluation involves the assessment of the effectiveness of the training programmes and methods in which it can be improved. This assessment is done by collecting data on whether the participants were satisfied with the deliverables of the training programmes, whether they learned something from the training and are able to apply those skills at their workplace. There are different tools for assessment of a training programme. In this study we used Krikpatrk's four level model and the levels are: reaction, learning, behavior, and results.

Reaction

For this study, individual responses of all the participants were collected regarding the course. Result showed that 10 participants mentioned the training met their expectations. When the participants were asked whether the training objectives for each topic were identified and followed. Participants answered it was very good and one participant marks it excellent. All the participants said that the curriculum content was organized. Among the 14 participants seven

participants expressed their opinion that they will apply the course materials to their daily work situation very effectively (table 3).

Four survey questions such as how knowledgeable was the facilitator on the subject matter? Did the facilitator explain the concepts clearly and in an understandable way? How did the facilitator handle questions that were asked? And how would you rate their facilitation skills on the whole? were asked and all the responses were collected and analyzed. Among the 14 participants seven participants said that knowledge of the facilitators on the subject matter was very good. Although one facilitator was categorized in an average group. Eleven participants mentioned that the facilitators explain the concepts clearly and in an understandable way. While 10 participants express that the question handling ability of the facilitator was very excellent. When the participants were asked how they would rate their facilitation skills on the whole, nine participants rate it very good and only one participant expressed in excellent category (table 4).

Learning:

Knowledge improvement. The improvement of knowledge was remarkable in scientific report writing training course (Table 5). The participants got average 6.42 marks among the total 18 marks in pre-test evaluation in the scientific report writing related question. Which rose to 12.9 in the post-test evaluation and the improvement was 36%. Considering statistics related question having 10 marks, the pre-test evaluation marks was 0.88. After post-test evaluation of the same question the participants got 6.82 marks and the 59.4% improvement was recorded.

Skill improvement. Skill improvement of the participants was measured based on the experience of the participants. Considering 1-5 year work experience, skill improvement of 18 participants ranged from very good to excellent category. Highest 18 participants showed better skill improvement and that ranged from very good to excellent while the service experience was 11-15 years. Least skill improvement took place in the experience ranging from 6-10 years (Table 6).

Three questions such as how do you rate the training overall?, will the training help you do your job better? is this training worthwhile and should it be conducted on a regular basis? were asked to the participants about the overall status of the scientific report writing training course. In response to these three questions, 12 participants opined that the training programme was very good to excellent and it should be regularly arranged for the young and mid level scientists (Table 7).

Training on laboratory accreditation for BRRI scientists

Five training programmes on Hands on Training in AAS, HPLC, LCMS and ICPOES for BRRI Scientists under the project of Accreditation of BRRI Central Laboratory Programme were conducted in the year 2020-2021. Among the five batches, durations of the three batches were five days and the rest two batches were ten days. Participants of these training courses were SO, SSO and PSO of different divisions of BRRI and the same trainees repeatedly participated in each batch. So that they become more efficient in handling and operating the machineries of BRRI central laboratory. Because these selected trainees will take the responsibility to operate the central accreditation laboratory of BRRI in future. Particulars of the trainings are given in table 8.

Hands on training for using high throughput phenotypic system for C_4 Rice research

Five training programmes for using high throughput phenotypic system for C_4 Rice research were conducted during the reporting period for the BRRI Scientific Officers and Senior Scientific Officers. These training were funded by the new generation rice (C_4 Rice) research strengthening programme of BRRI. Duration of the course was two days. 74 participants were trained through this course. Table 9 presents particulars of the trainings.

Training on transforming rice breeding

Four training programmes on Transforming Rice Breeding (SA), (SSA) and Farm manager of BRRI were conducted during the reporting period. Duration of the course was one week. A total of 79

participants were trained through this course. Table 10 presents the particulars of the trainings.

Training on integrated rice disease management

In the year 2020-21, one day training programme on Integrated Rice Disease Management was conducted for the SA/SSA of BRRI. The training was funded by National Agricultural Technology Project (NATP) of Plant Pathology Division. A total of 51 SA/SSA of BRRI were trained through this course. Table 11 presents the summaries of the tainings.

Training Information of Training Division

During the reporting period, 36 training programmes have been conducted by the Training Division. Through this training a total of 545 participants were trained. Table 12 presents the summaries of the trainings.

Table 1. Particulars of one day modern rice production training for SAAO of DAE.

Batch	Duration	No. of participants		
		Total	Male	Female
	01 Feb 2021	33	17	16
	02 Feb 2021	26	16	10
	09 Feb 2021	28	25	3
	16 Mar 2021	21	14	7
	5 Apr 2021	16	12	4
	6 Apr 2021	15	10	5
	7 Apr 2021	10	8	2
	27 Apr 2021	30	23	7
	25 May 2021	25	21	4
	26 May 2021	35	30	5
	01 Jun 2021	46	41	5
	03 Jun 2021	17	13	4
	08 Jun 2021	26	22	4
	16 Jun 2021	20	18	2
	23 June, 2021	33	30	3
	Total	381	300	81

Table 2 . Particulars of scientific report writing training for BRRI scientists.

Batch No.	Duration	No. of participants		
		Total	Male	Female
	04-08 Oct 2020	16	13	3
	11-15 Oct 2020	16	11	5
	18-22 Oct 2020	15	10	5
	01-05 Nov 2020	15	10	5
	15-19 Nov 2020	16	9	7
	Total	78	53	25

Table 3. Expression of the participants on the course of scientific report writing.

Survey question	Good	Very good	Excellent
The training met my expectations	4	10	o
The training objectives for each topic were identified and followed	4	9	1
The curriculum content was organized and easy to follow	7	3	3
Can you practically apply the course material to your daily work situation?	7	6	1
How will the course affect your ability to perform your job now on?	8	5	1

Table 4. Expression of the participants on the facilitators of scientific report writing course.

Survey question	Average	Good	Very good	Excellent
How knowledgeable was the facilitator on the subject matter?	1	6	6	1
Did the facilitator explain the concepts clearly and in an understandable way?	1	1	8	3
How did the facilitator handle questions that were asked?	1	4	8	2
How would you rate their facilitation skills on the whole	2	2	9	1

Table 5. Improvement of knowledge of the participant in the subject matter in scientific report writing training course.

Subject matter	Marks	Pre-test	Post-test	Improvement
Scientific report writing related	18	6.42	12.9	36
Statistical related	10	0.88	6.82	59.4

Table 6. Skill improvement of the participants in scientific report writing training course.

Experience (Year)	Excellent	Very good	Good	Fair
1-5	7	11	13	2
6-10	2	5	6	3
11-15	14	4	4	-
>15	3	0	1	-

Table 7. Overall expression of the participants in scientific report writing training course.

Training Specific question	Good	Very good	Excellent
How do you rate the training overall?	4	8	2
The training will help me do my job better	4	8	2
This training is worthwhile and should conducted on a regular basis	2	5	7

Table 8. Particulars of training for BRRI scientists on laboratory accreditation.

Batch	Duration	No. of participants		
		Total	Male	Female
	13-17 Sep 2020	10	6	4
	13-17 Sep 2020	10	4	6
	08-12 Nov 2020	11	2	9
	21 Dec 20-01 Jan 21	14	9	5
	06-17 Jun 2021	14	5	9
	Total	59	26	33

Table 9. Hands on training for using high throughput phenotypic system for C_4 rice research for BRRI scientists.

Batch	Duration	No. of participants		
		Total	Male	Female
	31 Mar-01 Apr 2021	15	11	4
	18-19 Apr 2021	15	12	3
	20-21 Apr 2021	15	10	5
	25-26 Apr 2021	14	6	8
	06-07 Jun 2021	15	11	4
	Total	74	50	24

Table 10. Particulars of one week training for BRRI SA/SSA on transforming rice breeding.

Batch	Duration	No. of participants		
		Total	Male	Female
	27 Feb-4 Mar 2021	19	17	2
	06-11 Mar 2021	19	18	1
	20-25 Mar 2021	24	23	1
	27 Mar-01 Apr 2021	17	13	4
	Total	79	71	8

Table 11. Particulars of one day training for BRRI SA/SSA on integrated rice disease management.

Batch	Duration	No. of participants		
		Total	Male	Female
	27 January, 2021	26	23	3
	28 January, 2021	25	22	3
	Total	51	45	6

Table 12. Total training conducted by training division during 2020-21.

Title	No. of training	Duration	No. of participants			Designation
			M	F	Total	
Modern rice production technology training	15	1 day	300	81	381	SAAO,DAE
Training on scientific report writing	5	5 days	53	25	78	SO,SSO,BRRI
Hands on training for using high throughput phenotypic system for C_4 rice research	5	2 days	50	24	74	SO,SSO,BRRI
Transforming rice breeding	4	1-week	71	8	79	SA/SSA,BRRI
Training on laboratory accreditation	5	7-10 days	26	33	59	SO,SSO,BRRI
Training on integrated rice disease management	2	1-day	45	6	51	SA/SSA,BRRI
Total	36		545	177	722	

EFFECTIVENESS OF IMPARTED RICE PRODUCTION TRAINING

It is important to determine the impact of different aspects of imparted rice production training for its better planning and execution in future. This study was conducted at the end of each batch to collect the relevant information. After the completion of data collection, information was compiled and analyzed. This study reveals that all the training programmes on modern rice production were very much helpful for the trainees to build up their capacity for modern rice production activities.

Performance of BRRI speakers

Five batches of scientific report writing training course for BRRI scientists and four batches on transforming rice breeding training course were considered for this evaluation. At first, batch wise analysis was done on the basis of five criteria for each speaker. The criteria were: a. presentation style; b. question handling; c. use of training materials; d. time management and e. quality and relevance of handout and its timely supply. Average of five criteria was used to determine the performance of individual speaker in each batch. The overall performances of BRRI's speakers' were very good to excellent.

BRRI RS, Barishal

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315 Variety development
316 Yield trial 2020-2021
321 International network for genetic evaluation of rice (inger), boro 2020-21
321 Development and validation of high iron and zinc rice in confined field trial(cft), boro 2020-21
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330 Demonstration, seed production and scaling up of brri rice varieties

SUMMARY

BRRI RS, Barishal is operating a strong breeding programme to develop suitable high yielding varieties for tidal submergence in T. Aman and favoulrable Boro seasons. To achieve the goal, forty new crosses were made, and seventy-one crosses were confirmed. A total of 887 and 657 plants were selected from five F_3 and twienty-one F_5 populations respectively during T. Aman 2020. Besides, a total of 672 plant progenies were selected from 44 F_2 population, and 582 plant progenies were selected from five F_4 generation during Boro 2020-21. In a special programme to develop New Generation Rice (NGR) dense and erect panicles, 2,579 plant progenies were selected from the F_4 generation, and 125 advanced breeding lines were bulked from the F_6 generation during T. Aman 2020 and 626 plant progenies were selected from five F_5 generation during Boro 2020-21. To explore the attributes of NGR in exotic cross populations, 936 plant progenies were selected from F_3 generation during T. Aman 2020 and 847 plant progenies from the F_4 generation during Boro 2020-21.

Two observational yield trials (OYTs) were conducted during T. Aman 2020 one for tidal submergence consisting 101 advanced breeding entries and out of then 46 lines were selected for theit better performances. The other OYT for dense and erect panicle comprising 145 entries and out of those 37 lines were selected. Two more OYTs consisting 104 and 194 entries were conducted and out of then 29 and 63 entries were selected respectively based on their performances during Boro 2020-21.

Two preliminary yield trials (PYTs) were conducted during Boro 2020-21. In PYT-1 thirty-five advanced breeding lines along with four checks were evaluated and better performing thirteen entries were selected for further trials . In PYT-2, eleven advanced breeding lines along with four checks were evaluated but none of the tested lines out yielded the checks.

A total of sixteen regional yield trials (RYTs) were conducted during 2020-21. Out of then, one RYT for the tidal non-saline ecosystem was conducted in three locations of Barishal region during T. Aus 2020. Four RYTs, two for insect resistence rice (IRR) and two for salt tolerance (STR) were conducted during T. Aman 2020. Eleven RYTs were conducted during Boro 2020-2021 including two RYTs from BRRI RS, Barishal and two from BRRI RS, Cumilla and the rest seven from BRRI HQ, Gazipur.

A total of eight advanced yield trials (AYTs) were conducted with the poptential breeding lines selected from different trials. Seventeen entries along with the four checks were evaluated in AYT during T. Aman 2020 and seven AYTs were conducted during Boro, 2020-21 and out of then five included the NGR lines.

One hundred and twenty-five entries along with the five checks were evaluated in a**n** International Network for Genetic Evaluation of Rice (INGER) trials during Boro 2020-21. Forteen lines were selected based on phenotypic acceptability and grain yield for further evaluation in AYT.

A confined field trial (CFT) was conducted with eleven transgenic lines of high iron and zinc rice development programme along with non-transgenic check variety BRRI dhan28 during Boro 2020-21.

A total of 369 local Aman germplasm were grown in six-line plots for characterization, utilization and maintenance during T. Aman 2020.

Zero insecticide technology was practiced to reduce insecticide uses in BRRI RS, Barishal Charbadna and Shagordi farms for seed production during Boro 2020-21. For this purpose, about 100 perch per hectare of land were placed to help birds sit on it. Furthermore, random sweeping at every seven days interval was done all over the field, and harmful insects were destroyed. Then complete 20 sweeping were done in the infested plots, and thus, insect pests were controlled. Insect pests and natural enemy populations were monitored in the light trap throughout the year. Insects were recorded higher in T. Aman season than in Boro season. In 2020-21 the highest insect pest incidence was found for brown planthopper (8,562 counts), followed by yellow stem borer (8442 counts) and green leafhopper (7,546 counts). In case of natural

enemies, the highest counts were recorded for staphylinid beetle (14,526 counts), followed by green mirid bug (9,415 counts) and carabid beetle (1,228 counts). Survey of insect pests and natural enemies in seedbeds of Charbadna farm with yellow sticky traps resulted in a higher number of thrips counts in the seedbed of most varieties under observation. A survey of insect pests and natural enemies in the selected block of Kolapara upazila at the maximum tillering stage suggested that T. Aman HYV and local cultivars were mostly infested by brown planthoppers. Green mirid bug was found higher in HYV compared to local varieties. In contrast, higher numbers of spiders were found in local cultivars compared to HYV.

Screening of nine available pesticides for controlling blast disease of rice was conducted in Aman 2020. Difa and Nativo significantly reduced neck blast (NB) disease. Reduction of neck blast disease incidence by these chemicals was ranged from 90% over untreated control (plain water). Another screening of ten available pesticides for controlling blast disease of rice was conducted in Boro 2020-21. Nativo significantly reduced neck blast disease. The reduction of neck blast disease incidence by these chemicals was 76% over untreated control (plain water). Survey and monitoring of rice diseases in selected areas were conducted during Aman 2020 and Boro 2020-21 brown spot and bacterial leaf blight were recorded as major diseases.

From the results of ALART, in Aus 2020: BR8781-16-1-3-P2 for non saline tidal ecosystem (NSTE) and BR9006-40-2-3-1 for favourable environment (FE) may be selected for the proposed variety trial. BR9571-13-1-9-1-1 for rainfed lowland rice (RLR) and BR10001-94-2-B for zinc enriched rice (ZER) may be selected in T. Aman for the proposed variety trial. SVIN063-Boro-18-Bhanga and SVIN076-Boro-18-Bhanga for favourable Boro Rice-Bhanga (FBR-Bhanga), BR8912-12-6-1-1-1-1 for zinc enriched rice (ZER) and BR (Bio)11447-3-10-7-1 and BR (Bio)11447-1-28-14-3 for Bacterial Blight Resistant Rice-Biotechnology (BBRR-Bio) may be selected for proposed variety trial in Boro season.

During the reporting year, BRRI RS, Barishal has conducted three demonstrations in Aman season and four demonstrations in Boro season which covered 14 acres of land. Furthermore, about 1212 acres of fallow lands were brought under Boro cultivation, establishing 126 seed supported block demonstrations by BRRI RS, Barishal in six districts of the Barishal region. From the demonstrations and field days, farmers expressed their preferences to cultivate BRRI dhan74 in the next Boro season.

Head to head trial for Boro varieties under TRB project in the Barishal region suggests that BRRI dhan84 and BRRI dhan67 could be popular and be disseminated among the farmers as newly released varieties.

A total of 11,825 kg breeder seed and 8,230 kg TLS during T. Aman 2020 and 31,440 kg breeder seed and 15,053 kg TLS during Boro 2020-21 season were produced.

VARIETY DEVELOPMENT

Hybridization and pedigree nursery.

Development of varieties for tidal submergence. Fourteen new crosses were made, and 375 F_1 seeds were collected to develop tidal submergence tolerant rice varieties (Table 1). Twenty four crosses were confirmed and registered in the BRRI cross-list with station code BRBa125 to BRBa148. A total of 657 plants were selected from Twentyone F_5 population during T. Aman 2020.

Table 1. List of F_1 seeds produced in T. Aman 2020.

Cross combination	No. of seeds	Cross combination	No. of seeds
Lalpaika/BRRI dhan76	8	Sada Chikon/BRRI dhan52	13
Moulata/BRRI dhan41	21	Sada Chikon/BRRI dhan76	13
Moulata/BRRI dhan52	17	Sada Pajam/BR8442-12-1-3-1-B5	50
Nakuchimota/BRRI dhan76	29	Sada Pajam/BRRI dhan52	25
Sahi Balam/BR 23	11	Sada Pajam/BRRI dhan76	25
Sahi Balam/BRRI dhan76	15	Sada Pajam/BRRI dhan77	28
Sahi Balam/BRRI dhan77	61	Sada Pajam/BRRI dhan87	59

Breeding for favourable ecosystem

A total of 26 crosses were done and 1953 F_1 seeds were obtained to develop high yielding Boro rice varieties during Boro 2020-21(Table 2). Besides, 47 crosses were confirmed and registered in BRRI RS, Barishal, code BRBa78 to BRBa124 out of 50 crosses done in T. Aman 2020. A total of 672 plant progenies from 44 F_2 population, 887 plant progenies from five F_3 population., and 582 plant progenies from 5 F_4 generation were selected during Boro 2020-21.

Breeding for new generation rice (NGR)

To develop improved varieties with dense and erect panicles. 2,579 plant progenies were selected from the 21 F_4 Population, and 125 homozenious lines were bulked from the F_6 generation during T. Aman 2020. A total of 1626 plants were selected from five F_5 population during Boro 2020-21. To explore the attributes of new generation rice (NGR) in exotic populations 936 plant progenies were selected from 47 F_3 population during T. Aman 2020 and out of then 847 plant progenies were selected from susequent F_4 generation planted during Boro 2020-21.

YIELD TRIAL 2020-2021

Observational trial (OT), 2020-2021. Two (OTs) were conducted during T. Aman 2020. One for tidal submergence consisting 101 advanced breeding lines along with five checks BR 23, BRRI dhan52, BRRI dhan76, BRRI dhan77 and BRRI dhan87 were grown in BRRI Sagardi farm, Barishal. Based on plant height, growth duration and phenotypic acceptability, 46 genotypes were selected from 101 entries for evaluation in preliminary yield trial. The other OT for dense and erect panicle comprising 145 entries along with five checks BR 23, BRRI dhan52, BRRI dhan76, BRRI dhan77 and BRRI dhan87 were grown in Charbadna farm of BRRI RS, Barishal. A total of 37 advanced breeding lines were selected for preliminary yield trial based on phenotypic attributes viz. plant height, growth duration and phenotypic acceptability.

Observational yield trial (OYT) Boro 2020-21. Two OYTs were conducted in Charbadna farm during Boro 2020-21. The OYT#1 consisting 104 entries along with four checks BRRI dhan58, BRRI dhan74, BRRI dhan88 and BRRI dhan92 were grown. Based on phenotypic acceptability(4-5) and grain yield performance (5.12-6.95t/ha) twenty-nine genotypes were selected for further evaluation. The OYT#2 comprising 194 entries along with five checks BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan88 and BRRI dhan92 were grown. Among the tested materials, the highest grain yield was oftained in the BRBa23-2-3-1-2-B-P1 (8.91 t/ha) followed by BRBa23-9-1-1-2-B-P1 (8.3 t/ha), BRBa23-2-2-1-1 (7.51 t/ha BRBa23-8-B-P1 (7.00

Table 2. List of F_1 seeds produced in Boro 2020-21.

Cross combination	No. of Seeds	Cross combination	No. of Seeds
BR 8912-12-6-1-1-1-1/AKT6	30	BRBa 3-2-4/BRRI dhan83	93
BR 8912-12-6-1-1-1-1/BRRI dhan67	55	BRBa 3-2-4/BRRI dhan92	101
BR 8912-12-6-1-1-1-1/BRRI dhan83	45	BRH 13-2-4-6-4B/AKT6	133
BR 8912-12-6-1-1-1-1/BRRI dhan92	40	BRH 13-2-4-6-4B/BRRI dhan48	90
BRBa 1-4-9/AKT6	11	NGR 1167-2/BRRI dhan74	22
BRBa 1-4-9/BRRI dhan83	20	NGR 1168-1/BRRI dhan74	22
BRBa 1-4-9/BRRI dhan92	51	NGR 1178-1/BRBa 3-2-4	21
BRBa 1-4-9/Gota IRRI	36	NGR 521-1/BRRI dhan74	25
BRBa 2-1-3/AKT6	19	NGR 527-1/BRBa 3-2-4	86
BRBa 2-1-3/BRRI dhan83	16	NGR 527-1/MK 628	175
BRBa 2-1-3/BRRI dhan92	25	NGR 527-1/MK 630	271
BRBa 2-1-3/Gota IRRI	30	NGR 885-1/Kataribhog	230
BRBa 3-2-4/BRRI dhan67	132	NGR 885-1/Purple rice	174
		Total	1953

t/ha) and BRBa23-8-2-3-2-B-P1 (6.87 t/ha). The genotypes BRBa21-7-1-1-2-B-P1 and BRBa23-9-2-1-1-B-P1 took the shortest period (138 days) to get matured, while BRBa23-2-2-1-1 had the longest duration (152 days) to get matured. Based on phenotypic acceptability, growth duration and grain yield 63 lines were selected for further trial.

Preliminary yield trial (PYT). Two PYTs were conducted during Boro 2020-21. The PYT-1 consisting of thirty-five advanced breeding lines along with four checks, BRRI dhan58, BRRI dhan74, BRRI dhan88 and BRRI dhan92, were evaluated. Among the tested materials, the plant height was ranged from 81.6cm of BRRI dhan88 (ck) to 162.7 cm of BRBa17-28-4-1-2. BRRI dhan88 produced the highest number of panicles per hill (18.2) and that was the lowest (8.2) in BRBa11-39-1-4-3. The genotype BRBa17-28-4-1-2 took the longest period to get matured (152 days), followed by BRBa16-28-2-1-6 (151 days) and BRRI dhan92 (151 days), while BRRI dhan88 took the shortest period (133 days) to get matured. The genotype BRBa17-28-4-1-2 gave the highest grain yield (7.65 t/ha) followed by BRBa16-28-2-1-6 (7.35 t/ha), BRBa12-23-1-1-2 (7.00 t/ha), and BRRI dhan92 (6.9 t/ha). The thirteen entries were selected based on plant height, growth duration, phenotypic acceptability and grain yield for AYT in next Boro season. The PYT-2 comprising of eleven advanced breeding lines along with four checks BRRI dhan58, BRRI dhan74, BRRI dhan88 and BRRI dhan92 were evaluated. There was singnificant variation in plant height that was ranged between 84.7cm to 121.5 cm . None of the tested materials yielded better than the checks.

Regional yield trial (RYT).

T. Aus 2020. RYT consisting of four advanced breeding lines along with the two checks BRRI dhan27 and BRRI dhan48 was conducted at three locations of the Barishal region, namely North Ghatkhali, Amtali; South Ghatkhali and Manikjhuri, Amtali, Barguna. The highest plant height (142.2 cm) was recorded in BRRI dhan27 (147.2cm) followed by BR9829-78-1-3-2 (128.7cm), BR9829-78-1-2-1 (128.1cm). Growth duration was ranged from 105-118 days, whereas the average grain yield over the three locations was ranged from 3.24-4.21 t/ha. The genotype BR9829-78-1-2-1 produced a similar yield but 13 days longer growth duration than the check BRRI dhan48. The other tested line BR9830-5-2-2-3 (4.09 t/ha), yielded better than BRRI dhan27 (3.24 t/ha) but less than BRRI dhan48 (4.21 t/ha).

T. Aman 2020. Two regional yield trials of insect-resistant rice (IRR) were conducted at BRRI Charbadna farm, Barishal. The RYT#IRR-1 comprising 13 entries along with the three checks BRRI dhan33, BRRI dhan49 and BRRI dhan93 were grown. The highest panicle number per hill (13.1) was found in BR10039-15-7-1, while the lowest panicle number per hill (7.1) was recorded in the genotype BR9888-26-9-14-3. The growth duration was ranged between 118-134 days, and the grain yield was ranged between 4.31t/ha to 5.38 t/ha. The highest grain yield was found in the genotype BR9888-15-3-7-2 (5.8 t/ha) followed by BR10039-5-5-5 (5.67 t/ha) and BR10039-11-3-2 (5.57 t/ha). The lowest grain yield (4.31 t/ha) was recorded in the genotype BRRI dhan33. The RYT#IRR-2 consisting of twelve entries along with the three checks BRRI dhan33, BRRI dhan49 and BRRI dhan93 were grown. The highest panicle number per hill (11.7) was found in BRRI dhan49, while the lowest panicle number per hill (7.4) was recorded in the genotype BR10039-19-1-3. The highest grain yield was found in the genotype BR9880-24-2-1-14 (5.90 t/ha) followed by BR9882-17-2-2-32 (5.88 t/ha) and BR9888-26-9-14-3 (5.81 t/ha) which are signicantly higher than that of BRRI dhan33 and BRRI dhan49 with similar growth duration of check varieties, BRRI dhan 49 and BRRI dhan93.

Two RYTs of saline tolerant rice (STR) were conducted at BRRI Charbadna farm, Barishal. The RYT#STR-1 comprising nine entries along with the three checks BRRI dhan54, BRRI dhan73 and BRRI dhan87 were grown. The highest grain yield was found in the genotype IR108158-B-2-AJY1-1 (5.56 t/ha), followed by BR9536-2-17 (5.49 t/ha) and IR103499-B-2-AJY1 (5.48 t/ha). The RYT#STR-2 consists of ten entries along with the three checks BRRI dhan54, BRRI dhan73 and BRRI dhan87 were grown. The highest grain yield

was found in the genotype TP30649 (5.71 t/ha), followed by HHZ18-SAL14-SAL13-Y2 (5.63 t/ha) and HHZ18-DT7-SAL1-SAL1 (5.46 t/ha). The lowest grain yield (4.53 t/ha) was recorded in the genotype IR15T1408.

Boro 2020-21. A RYT for favourable Boro comprising seventeen entries along with the three checks BRRI dhan81, BRRI dhan84 and BRRI dhan89 were grown**.** The genotype BRC297-15-1-1-1 produced the highest number of tillers (18.1) and panicle (15.9) per hill that produced similar yield (6.35t/ha) of BRRI dhan84 (6.19 t/ha). The genotype SVIN069 provided the highest grain yield (6.92 t/ha) similar to that of BRRI dhan89 (6.88t/ha) but growth duration is 15 days shorter in SVIN069 (141).

A reginal yield maximization trial (RYMT) consisting two entries BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B along with the check BRRI dhan63 were grown at BRRI Charbadna farm, Barishal. Both the entrie produced similar yield (6.88 t/ha and 6.86t/ha) to BRRI dhan63 (6.74 t/ha) but with five days longer growth duration (145 days) than that of BRRI dhan63(140 days).

In RYT for zinc enriched rice, three entries along with three checks BRRI dhan74, BRRI dhan84 and BRRI dhan89 were tested. at BRRI Charbadna farm, Barishal, during Boro 2020-21. Test line BR9674-5-6-2-1-7-22 (6.71t/ha) produced similar yeld to BRRI dhan74 (6.68t/ha) but had six days higher growth duration. None of the test entries out yielded the check variety BRRI dhan89 that provided the highest grain yield (6.98 t/ha).

In RYT #GSR**,** five entries along with the two checks BRRI dhan58 and BRRI dhan88 were grown. FBR350 produced the highest grain yield (7.16 t/ha) followed by FBR336 (6.91t/ha), BRRI dhan58 (ck) (6.80 t/ha) with similar growth duration of 146 days.

A RYT for bacterial blight resistance, comprising of five entries along with two susceptible checks, BRRI dhan58 and BRRI dhan89, and a resistant check IRBB60, was conducted. None of the test entries outyielded BRRI dhan89 (7.45 t/ha) but BR9943-26-2-3-6 (6.97 t/ha), BR9943-2-2 (6.94 t/ha) outyielded the check variety BRRI dhan58 (6.77 t/ha). The lowest grain yield was found in resistant check IRBB60 (6.06 t/ha).

Two regional yield trials of saline tolerant rice (STR) were conducted at farmer's fields of Latifpur, Kalapara, Patuakhali. The RYT#STR-1 comprising 14 entries along with the four checks BRRI dhan67, BRRI dhan89, BRRI dhan97 and BINA dhan-10 were grown . In this trial, the check variety BRRI dhan97 produced the highest grain yield (6.80 t/ha) followed by BINA dhan-10 (6.70 t/ha), IR96184-24-1-1-AJY2 (6.58 t/ha) and BR9625-B-2-4-6 (6.23 t/ha). The RYT#STR-2 consists of 14 entries along with the four checks BRRI dhan67, BRRI dhan89, BRRI dhan97 and BINA dhan-10 were grown. The check variety BRRI dhan89 took the longest period to get matured (146 days), followed by IR 100638-6-CMU3-CMU1 (145 days), while BR9154-2-7-1-2 and BR9620-4-3-2-2 took the shortest period (134 days). BR9625--B-1-4-6 produced the highest grain yield (7.50 t/ha) followed by IR 100638-6-CMU3-CMU1 (7.13 t/ha), BR9156-4-1-7-9 (6.92 t/ha) and BRRI dhan97 (6.69 t/ha). The lowest grain yield was found in BRRI dhan89 (5.36 t/ha).

RYT#Cumilla. Two regional yield trials of favourable Boro rice (RYT#Cumilla) were conducted. The RYT#Cumilla-1comprising a total of six entries along with the three checks BRRI dhan81, BRRI dhan84 and BRRI dhan88 were evaluated. BRC366-2-2-4-2-3 provided highest grain yield (7.60 t/ha) followed by BRC366-2-2-4-2-1 (6.88 t/ha), BRC389-4-2-4-2 (6.62 t/ha), BRC401-1-1-1-1B (6.48 t/ha) and BRRI dhan84 (6.29 t/ha). The lowest grain yield was found in BRRI dhan88 (6.13 t/ha). The RYT#Cumilla-2 consisting seven entries along with the three checks BRRI dhan50, BRRI dhan58 and BRRI dhan89 were grown. The check variety BRRI dhan89 produced the highest grain yield (8.27 t/ha) followed by BRC428-2-2-1 (7.66 t/ha), BRC335-1-3-2-2-1(7.61t/ha), and BRRI dhan58 (7.55 t/ha) The lowest grain yield was found in BRRI dhan50 (6.02 t/ha).

RYT#Barishal-1. Six entries along with two checks BRRI dhan58 and BRRI dhan92 were grown. Among the tested materials, the plant height was ranged from 96.2 cm of BRBa3-2-4 to 113.2 cm of

BRBa1-4-9. BRRI dhan58 took shortest period (152 days) to get matured while BRBa1-4-9, BRBa2-1-3 and BRRI dhan92 took longest period (159 days) to get matured. The highest average grain yield (8.21 t/ha) was found in BRRI dhan92 and the lowest average grain yield (7.09 t/ha) was found in BRRI dhan58. There was significant yield variation among 11 test locations. All the tested materials provided statistically similar grain yield with the check BRRI dhan92 but produced the higher grain yield than the check BRRI dhan58. (Table 3).

RYT#Barishal-2. Seven entries along with two checks BRRI dhan58 and BRRI dhan92 were tested in eleven locations. Among the tested materials, the plant height was ranged from 96.0 cm of BRRI dhan58 to 104.9 cm of IR12A329. The genotype IR15A2854 took shortest period (150 days) to get matured while BRRI dhan92 took longest period (158 days) to get matured. The highest average grain yield (8.09 t/ha) was found in BRRI dhan92 which is statistically similar with those of IR12A329 (8.00 t/ha), IR04A429 (7.99 t/ha) and IR13A515 (7.75 t/ha). The lowest grain yield (6.90 t/ha) was found in IR15A2854 which is statistically similar with IR15A2820 (7.03 t/ha) and BRRI dhan58 (7.06 t/ha).

Advanced yield trial (AYT)

AYT, T. Aman 2020. Seventeen entries along with four checks BR23, BRRI dhan49, BRRI dhan52 and BRRI dhan87 were grown at BRRI Charbadna farm, Barishal during T. Aman 2020. The plant height was ranged between 101.8 cm to 133.9 cm, where the tallest genotype was IR 103411-B-B-3-3, and the shortest genotype was BRRI dhan49. Growth duration was ranged between 126 to148 days, whereas grain yield was ranged ranged 3.01-4.95 t/ha. Two entries IR16F1097 (4.95 t/ha) and IR14F690 (4.91 t/ha), produced similar yield the check variety, BRRI dhan87 (4.88 t/ha).

AYT, Standard Boro 2020-21. Two advanced yield trials of favourable Boro rice were conducted at BRRI Charbadna farm, Barishal. The AYT-SB#1 consists of 18 entries along with four checks BRRI dhan58, BRRI dhan74, BRRI dhan88 and BRRI dhan92 were grown. BRRI dhan92 took the longest period to get matured (144 days) followed by BRBa2-9-4 (143 days), while BRRI dhan88 took the shortest period (130 days) to get matured. The genotype BRBa3-1-6 provided the highest grain yield (6.81 t/ha) followed by BRBa3-4-2 (6.59 t/ha), BRBa3-2-2 (6.55 t/ha), BRBa5-4-1 (6.46 t/ha) and BRBa3-3-3 (6.15 t/ha). The lowest grain yield was found in BRBa7-1-3 (4.15 t/ha). The AYT-SB#2 comprising of entries along with four checks BRRI dhan58, BRRI dhan74, BRRI dhan88 and BRRI dhan92 were grown. Among the test entries, Ba Boro20-SVIN302 (6.83 t/ha) and Ba Boro 20-SVIN311 (6.73 t/ha) gave the significantly higher yield than those of BRRI dhan92 (6.12t/ha), BRRI dhan74 (5.92t/ha), and BRRI dhan58 (5.96t/ha) eventhough growth duration of both the test entries were 8-9 days shorter than that of BRRI dhan 92. Beside those entries, Ba Boro 20-SVIN044 (6.39 t/ha), Ba Boro 20-SVIN036 (6.32 t/ha) and Ba Boro 20-SVIN330 (6.27 t/ha), produced significantly higher yield than that of BRRI dhan88 (5.47 t/ha).

Table 3. Yield and ancillary characters of RYT (Barishal-1) genotypes, Boro 2020-2021.

Designation	PH (cm)	GD (day)	Yield (t/ha)		
			Lowest (location)	Highest(location)	Avg.
BRBa1-4-9	113.2	159	6.77 (Sirajgonj)	9.86 (Gopalgonj)	8.11
BRBa2-1-3	112.8	159	6.31 (Gazipur)	9.00 (Barishal)	7.96
BRBa2-5-3	98.1	154	7.02 (Gazipur)	10.22 (Bhanga)	8.06
BRBa3-1-7	97.6	156	7.01 (Rangpur)	10.56 (Bhanga)	8.12
BRBa3-2-4	96.2	156	6.37 (Rangpur)	11.20 (Bhanga)	7.86
BRBa3-3-1	97.7	156	6.19 (Gazipur)	10.95 (Bhanga)	7.93
BRRI dhan58 (ck)	96.5	152	4.94 (Gazipur)	7.96 (Barishal)	7.09
BRRI dhan92 (ck)	110.2	159	6.57 (Rangpur)	9.69 (Gopalgonj)	8.21
LSD at 0.05	1.96	1.08	0.46		0.38
CV (%)	4.11	1.48	10.31		

L1= BRRI Barishal; L2= BRRI Bhanga; L3= BRRI Cumilla; L4= BRRI Gazipur; L5= BRRI Gopalganj; L6= BRRI Habiganj; L7= BRRI Kustia; L8= BRRI Rajshahi; L9= BRRI Rangpur; L10= BRRI Satkhira; L11= BRRI Sirajganj; L12= BRRI Sonagazi

AYT, New Generation Rice (NGR). A total 521 promising breeding lines were planted in seven sets, SetA (8), SetB (46), SetC (38), SetD (48), SetE (184), SetF (52) and SetG (148), for better evalution during Boro 2020-21

NGR Set A. Eight entries along with four checks BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were grown in three blocks with different spacing, 20cmX25cm, 20cmX20cm, and 20cmX15cm. Most of the test entries along with BRRI hybrid5 produced higher yield in wider spacing (20cmX25cm) but irrespective of spacing NGR1019-2 and BRRI dhan74 performs equially. Even in lower spacing(20X15cm) NGR 1161-3 and BRRI dhan89 produced higher yield. Among the test entries, NGR1019-2 produced higher average yield (8.8t/ha) and that had also higher grain/panicle (308). BRRI dhan74 showed higher stable yield (8.2t/ha) than those of BRRI dhan89 (7.4t/ha) and BRRI dhan92(7.2t/ha) (Table 4.)

NGR Set-B. Forty-six entries along with the four checks BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were grown in two blocks with spacing 20X20cm and 20X15cm. Among the test materials- three entries, NGR417-2 (10.14 t/ha), NGR418-1(10.32 t/ha) and NGR440-2 (10.6t/ha), from 20X20cm spacing block out yielded BRRI Hybrid dhan5 (9.96t/ha) and two entries, NGR453-1(9.78 t/ha) and NGR414-1(10.69 t/ha), from 20X15cm spacing block out yielded BRRI Hybrid dhan5(9.68t/ha). Considering the average performance 22, 24 and 27 entries outyielded BRRI dhan 89 (8.75t/ha), BRRI dhan74 (8.69t/ha) and BRRI dhan92(8.65t/ha) respectively. The filled grains per panicle of all the better performing entries were ranged between 210 to 316 along with higher fertility percentage (82-94%). Panicle number per hill of better performing entries were ranged between 11 to 23 and the growth duration was ranged between 153 to156 days. That means higher number of panicles per hill and filled grain per panicles seems the major traits for the higher yield.

NGR Set-C. Thirty-eight entries along with four checks, BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5, were grown in three blocks with three different spacing viz. 20cmX25cm, 20cmX20cm, and 20cmX15cm. Four test entries, NGR1258-2(10.02t/ha), NGR721-2(9.9t/ha), NGR796-2(9.69t/ha), and NGR1258-1(9.67t/ha) produced higher yield than BRRI dhan89 (9.52t/ha) and five entries produced higher yield than BRRI hybrid dhan5 (9.38t/ha) in wider spacing (25cm) while nine entries gave higher yield than those of BRRI dhn89 (8.59t/ha) and BRRI hybrid dhan5 (8.73t/ha) in 20cmX20cm spacing but in closer spacing (20cmX15cm) none of the test entries outyielded BRRI Hybrid dhan5(9.91t/ha) but one, NGR1019-3 (9.5 t/ha), outyielded BRRI dhan92 (9.35t/ha). The number of filled grain per panicle was higher (211 - 567) while panicles per hill was less (5.8-16) in test entries. But there was not direct correlation found with higher yield and higher grain per panicle.

Table 4. Yield and ancillary characters of AYT NGR-SetA, Boro 2020-2021.

Designation	PH(cm)	GD (day)	Grain /panicle			Yield(t/ha)			
	Average	Average	B1	B2	B3	B1	B2	B3	Average
NGR 270-3	110	155	206	207	241	8.15	7.06	7.92	7.71
NGR 521-1	114	155	196	142	188	8.24	7.81	7.70	7.92
NGR 521-2	111	155	164	186	244	9.14	7.73	6.29	7.72
NGR 522-1	110	161	151	188	170	8.46	8.25	7.81	8.17
NGR 522-2	110	160	197	190	262	7.61	6.52	6.46	6.86
NGR1019-2	119	161	442	239	242	8.56	9.00	8.92	8.83
NGR 1161-2	109	160	189	201	186	8.04	7.01	7.52	7.52
NGR 1161-3	110	159	184	173	232	7.74	7.81	8.89	8.15
BRRI dhan74 (ck)	106	148	133	94	128	8.26	8.10	8.19	8.19
BRRI dhan89 (ck)	124	161	161	142	234	7.04	7.90	8.60	7.84
BRRI dhan92 (ck)	133	163	184	165	105	6.97	7.93	7.33	7.41
BRRI hybrid dhan5	113	154	253	183	195	9.96	8.95	8.74	9.22
Note: B1=(20X25cm), B2=(20X20cm), B3=(20X15); PH= Plant height, GD= Growth duration.									

NGR Set-D. Forty-eight entries along with four checks BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were grown in two blocks with spacing 20cmX20cm and 20cmX15cm. The maximum seventeen test entries outyielded (range 9.1-10.38t/ha) the check variety BRRI hybrid dhan5 (9.01t/ha) but icase closed spacing, 20cmX15cm, only NGR1255-2 (10.75t/ha) out yielded BRRI hybrid dhan5 (9.96t/ha). It indicated that the test entries performed better in 20cmX20cm spacing. The highest average grain yield was recorded in the genotype NGR 1255-2 (10.56 t/h) followed by genotypes NGR 680-2 (9.83 t/ha), NGR 1277-1 (9.71 t/ha), NGR 902-3 (9.59 t/ha) and NGR 1030-2 (9.58 t/ha) while the checks BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 produced average yield 7.79 t/ha, 9.17t/ha, 8.63t/ha and 9.49t/ha respectively.

NGR Set-E. A total of 184 entries along with four checks, BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were evaluated. Out of those test entriees 11 entries with similar growth duration outyelded all the check varieties. Among the test entries NGR1255-1 produced the highest yield of 11.61t/ha followed by NGR1331-1(10.99t/ha), NGR988-1(10.80t/ha), NGR857-1(10.42t/ha), NGR736-1(10.29t/ha), NGR966-1(10.23t/ha), and NGR839-1(10.22t/ha). The check varieties, BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5, produced the yield of 7.98t/ha, 8.95t/ha, 9.96t/ha and 9.11t/ha respectively.

NGR Set-F. A total of 52 entries along with four checks, BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were evaluated. Out of those test entriees NGR1203-2 (9.36t/ha) outyelded all the check varieties including BRRI hybrid dhan5 (8.98t/ha). The test entries, NGR1178-1 (8.93t/ha), NGR1203-1(8.88t/ha), NGR933-1(8.85t/ha), NGR1178-2(8.85t/ha) and NGR1168-1(8.77t/ha) also outyelded BRRI dhan89 (8.67t/ha) and BRRI dhan92 (8.65t/ha).

NGR Set-G. A total of 145 entries along with four checks, BRRI dhan74, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan5 were evaluated. Out of those the entriees NGR1308-2 (11.76 t/ha) produced the highest yield followed by NGR467-2 (11.44t/ha), NGR315-3(11.22t/ha), NGR268-2 (11.11 t/ha), NGR857-2 (11.10/ha), and NGR350-2 (10.73 t/ha) and these seven entries outyelded all the check varieties including BRRI hybrid dhan5 (10.52 t/ha) with similar growth duration.

INTERNATIONAL NETWORK FOR GENETIC EVALUATION OF RICE (INGER), BORO 2020-21

A total of 125 entries along with five checks BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan88 and BRRI dhan89 were grown at BRRI Charbadna farm, Barishal during Boro 2020-21. The data of ancilliary characteristics of INGER materials were recorded, the plant heights were between 80cm to115cm, the panicles per hill were ranged between 8-15.3, and the growth durations were ranged between 132 to 159 days. The genotype SVIN269 produced the highest grain yield (7.92 t/ha) followed by genotypes SVMET145 (7.83 t/ha), BRRI dhan89 (7.61 t/ha), SVIN275 (7.58 t/ha) and SVIN089 (7.56 t/ha). The lowest grain yield was found in SVIN368 (4.63 t/ha). Fourteen genotypes having grain yield of 7.17-7.92 t/ha were selected on the basis of yield and other phenotypic acceptability for further evaluation in the advanced yield trial.

DEVELOPMENT AND VALIDATION OF HIGH IRON AND ZINC RICE IN CONFINED FIELD TRIAL(CFT), BORO 2020-21

Eleven transgenic lines along with non-transgenic control as standard check variety BRRI dhan28 were evaluated at CFT site of BRRI RS, Barishal. There was a little variation among the transgenic lines in respect of plant height (range 103.7-107.9 cm), panicle number per plant (range 12.6-13.4), growth duration (range 133-135days) and the thousand-grain weight (range 20.0-21.4g) were found. But in respect of spikelet fertility, a significant variation was observed. The highest spikelet fertility was observed in IR133904TR-B-B 2-B-25(92.9%) followed by genotypes

IR133904TR-B-B-1-B-3(89.7%) and IR133904TR-B-B-3-B-28 (88.9%), whereas the lower lebel of spikelet fertility was observed in IR135161TR-4-B-6(78.5%), IR135161TR-4-B-35(79.5%) and IR135161TR-4-B-4 (79.6%).

There were variation observed in grain yield which was ranged between 7.18t/ha to 8.61 t/ha. Three transgenic lines, IR133904TR-B-B-1-B-3 (8.52 t/ha), IR133904TR-B-B-2-B-25 (8.53 t/ha) and IR133904TR-B-B-3-B-28(8.61 t/ha), produced significantly higher yield over non transgenic check BRRI dhan28 (7.86 t/ha). The transgenic entries IR135161TR-4-B-35, IR135161TR-4-B-2 and IR133904TR-B-B-1-B-3 got 5-20% neck blust infestation.

CHARACTERIZATION AND UTILIZATION OF LOCAL GERMPLASM

A total of 369 local Aman germplasm were grown in six-line plots for characterization, utilization and maintenance. Seven local germplasm viz., Lalpaika, Moulata, Nakuchimota, Sahi Balam, Sada Chikon,Sada Chikon and Shada Pajam, were utilized in hybridization in breeding programme for tidat submergence. Seeds were harvested and preserved for further evaluation and utilization.

PEST MANAGEMENT

Insect Management

Incidence of insect pests and natural enemies in light traps.

Data were collected from July 2020 to June 2021 at Sagordi farm, BRRI RS, Barishal. The appearance of insect pests was higher than that of reporting in the previous year. In 2020-21 the highest insect pest incidence was counted for brown planthopper (BPH) (8,562 no.), followed by yellow stem borer (YSB) (8,442 no.) and green leafhopper (7,546 no.). In case of natural enemies the highest counts were recorded for staphylinid beetle (14,526 no.) followed by green mirid bug (9415 nos) and carabid beetle (1,228 no.). In this reporting year insect pest populations were found higher than natural enemy, which might be attributed to practicing zero insecticides (GI) in the reporting period.Insect pest abundance was found throughout the year. However, insects were recorded higher in T. Aman season than that of Boro (Fig. 1).

There was an abundance of two major insects, Figer 2 shows YSB and BPH abandawe in the reporting year. YSB was found higher in T. Aman season than Boro season. In October and November 2020 higher incidence of YSB was observed. In 2020, a higher number of BPH was observed in November.

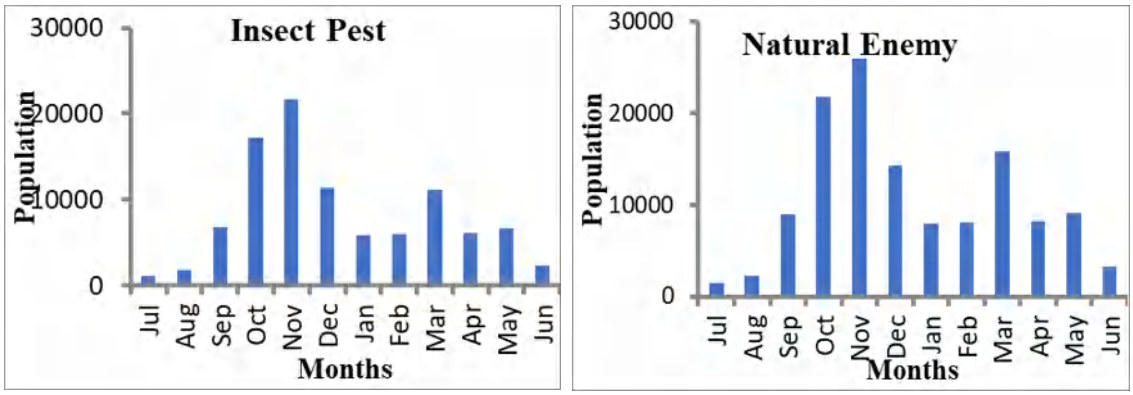

Fig. 1.Monthly insect pests and natural enemies observed in light traps at BRRI, Barishal, 2020-21.

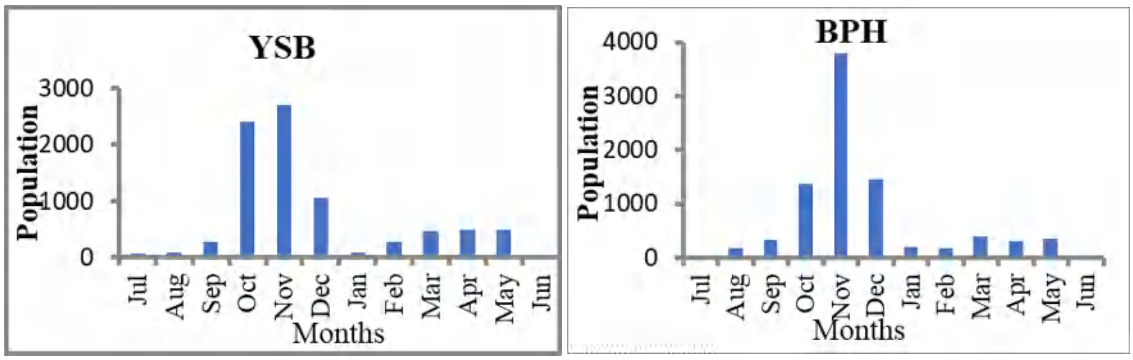

Fig. 2. Monthly yellow stem borer and brown planthopper abundance at BRRI RS farm, Barishal, 2020-21.

Species composition of stem borer

The abundance of YSB and dark headed borer (DHB) was compared on BRRI dhan28, BRRI dhan67, and BRRI dhan89 in Boro season 2020-21, at Charbadna farm, BRRI RS, Barishal. Dead heart and white head insects were collected from respective fields. In addition, larva of yellow and dark headed borer was counted in the Petri dish (Fig. 3).

Larva of YSB was found higher than DHB irrespective of rice variety. Larva of YSB was found in the highest percentage on BRRI dhan28 (83%), followed by on BRRI dhan67 (76%) and BRRI dhan89 (74%) (Fig. 4). However, in case of DHB, the infestation followed the opposite trend. For example, BRRI dhan89 was infested mostly by dark headed borer (26%) followed by BRRI dhan67 (24%) and BRRI dhan28 (17%). In conclusion, the newly released variety (BRRI dhan89) is more susceptible to DHB.

Fig. 3. Collected dead heart (left) in the field and dark headed stem borer larvae in Petri dish.

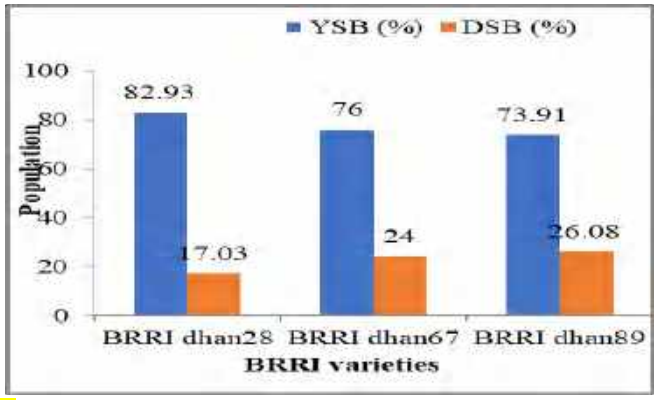

Fig. 4. Variety wise yellow stem borer and dark headed borer population in Barishal.

Survey of insect pest and natural enemy in seedbeds

The survey was conducted from 15 to 22 July 2020 at T. Aman seedbed in Charbadna farm, BRRI RS, Barishal to find out the incidence patterns of the major rice insect and their natural enemies in rice seedbed. Population intensities of rice insects and their natural enemies were captured through yellow sticky traps (YST). Insect pests and natural enemies after seven days of YST setup in the seedbed were then counted.

Brown planthopper (BPH), yellow stem borer (YSB), green leafhopper (GLH), grasshoppers (GH), rice hispa (RH) and long horn cricket (LHC) insects were found in yellow sticky trap (Table 5). Carabid beetle (CDB), lady bird beetle (LBB), green mirid bug (GMB), damsel fly (Dam. Fly) and spider (SPD) natural enemy were also found. A higher number of thrips were found in BR23, BRRI dhan44, BRRI dhan49, BRRI dhan52, BRRI dhan76 and BRRI dhan78. Green leafhopper insect was found higher in BR23, BRRI dhan34, and BRRI dhan77. A higher number of green mirid bugs were found in BR23, BRRI dhan34, and BRRI dhan72. Damsel flies were found higher in BRRI dhan44, BRRI dhan52 and BRRI dhan76 compared to the other varieties. Spiders were found higher in BRRI dhan49, BRRI dhan77, BRRI dhan78, and BRRI dhan87.

Survey of insect pests and natural enemies in selected blocks of Barishal region

The objective was to compare the infestation of insect pests and natural enemies in HYV and local cultivars. The survey was conducted on 15 October 2020 at the maximum tillering stage of T. Aman in Umidpur block, Kolapara upazila, Pathuakhali district, Barishal. Population abundance of rice insect pests and their natural enemies were counted after 20 complete sweeping with the help of a sweep net.

BR23, BRRI dhan49, BRRI dhan51, BRRI dhan57, BRRI dhan77 were infested mostly by Brown planthoppers (BPH) (Table 6). Similarly, BPH infestation was found higher in both Shakhorkhura and Mithamota local cultivars than in other insects infestations (Table 7). Green mirid bug (GMB) was found higher in HYV compared to local varieties. In contrast, higher numbers of spiders were found in local cultivars compared to HYV.

A comparison of insect infestation was also made according to rice cultivars. A higher number of green leafhopper (GLH) abundance was observed in local cultivars than HYV (Fig. 5). In contrast, presence of Brown planthopper (BPH) and YSB was found higher in HYV than local cultivars. The natural enemy is the predator of insect pests. Green mirid bug (GMB), damsel fly and parasitoids were higher in HYV than local cultivars (Fig. 6). Carabid beetle (CDB) and spider (SPD) were found higher in local cultivars than HYV.

Table 5. Variety wise insect pests and the natural enemies caught in yellow sticky trap. The insects were captured and counted from a 0.25 decimal seedbed area.

Insect	BR 23	BRRI dhan34	BRRI dhan44	BRRI dhan49	BRRI dhan52	BRRI dhan72	BRRI dhan76	BRRI dhan77	BRRI dhan78	BRRI dhan87
GH	5.5	7.5	5	3.5	1.67	3	1	4	4	10
YSB	0	0	0	0	0.33	0	0	0	0	0
Thrips	9.5	7	17	17.5	157.33	0	105	0	68.5	0
GLH	9.5	14.5	5	3	0	3	0	5.5	0.5	5
Hispa	2	1.5	0	2	0	1	0	3	0	3
LHC	3	0	0	0	0	46	0	2	0	100
Natural Enemy										
LBB	7.5	4			0	3.5	0			
CDB	2.5	0	0	2	0	1	0	1	1.75	3.5
SPD	6	3	7	3	0	3	0	1.5	3.25	6.5
Dam. Fly	0	0.5	8	1.5	2	1	2.67	0	1.25	2.5
GMB	10	10	0	0	0	4.5	0	0	0	0

Table 6. Total count of insect pests and natural enemies in different HYV, in Umidpur block, Kolapara, Patuakhali, Aman 2020.

Insect Pest	BR23	BRRI dhan49	BRRI dhan51	BRRI dhan57	BRRI dhan76	BRRI dhan77	Total
GLH	4	0	3.5	2	5.5	1	16
BPH	14	110	42.5	10	27	85	288.5
YSB	2	8	7.5	0	1.5	3	22
RLF	1	0	0	0	0	1	2
CW	0	0	1	1	1	1	4
Natural enemy							
GMB	3.5	0	0	0	8	12	23.5
Dam. Fly	15	0	0	2	2	3.5	22.5
CDB	1	0	0	0	0	0	1
SPD	3	0	7	2	5	5	22
Parasitoids	0	3	5.5	0	5.5	0	14

Table 7. Total count of insect pests and natural enemies in local cultivars in Umidpur block, Kolapara, Patuakhali, Aman 2020.

Insect Pest	Shakhorkhura	Mithamota	Total	Mean
GLH	3	5	8	4
BPH	10	10	20	10
YSB	2	3	5	2.5
RLF	1	1	2	1
Natural enemy				
Dam. Fly	3	2	5	2.5
CDB	2	3	5	2.5
SPD	1	8	9	4.5

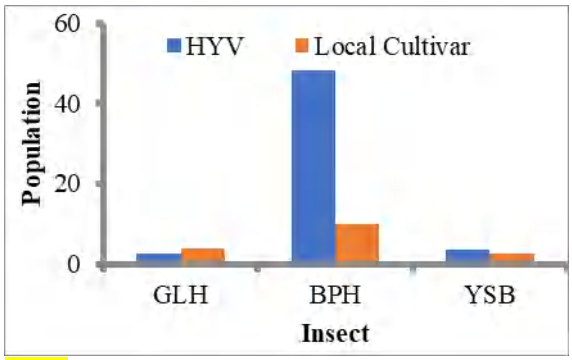

Fig. 5 . Green leafhopper (GLH), brown planthopper (BPH), and yellow stem borer (YSB) abundance in HYV and local cultivars.

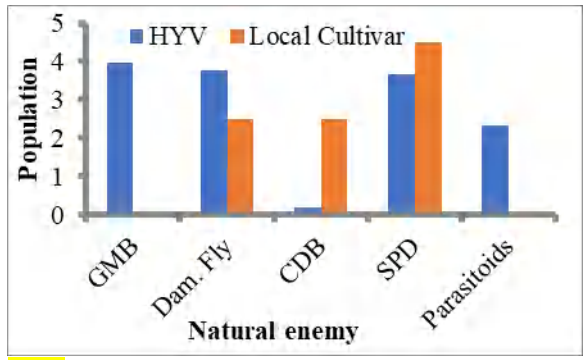

Fig. 6. Green mired bug (GMB), damsel fly, carabid beetle (CDB), spider (SPD) and parasitoids abundance in HYV and local cultivars.

Insecticide free rice production in BRRI RS farm, Barishal

The objective of the experiment was to reduce the uses of insecticides in Sagordi and Charbodna farm of BRRI RS, Barishal. A total of 100 dead perches were placed in a land of one hectare in Charbadna farm. Generally, YSB harbors the upper part of a leaf in the morning. Therefore, we have done sweeping during a period from 6.00 am to 12.00 am. Firstly, sweeping all plots in the farm was done at every seven-day interval from 14 days of transplanting to before the flowering stage. After every sweeping, harmful insect's were destroyed, and beneficial insects were released in the field. Then, 20 complete sweeping in BRRI dhan23, BRRI dhan76, and BRRI dhan77 plots were done for counting insect pests and natural enemies.

In T. Aman 2020, a higher number of insects were found in BRRI dhan77 plot, followed by BR23 and BRRI dhan76 (Table 8). Green leafhopper (GLH), white leafhopper (WLH), yellow stem borer (YSB), brown planthopper

(BPH), white-backed planthopper (WBPH), and leaf folder (LF) were found in all three variety plots. Higher number of natural enemies was found in BRRI dhan77 than BR23 and BRRI dhan76.

We successfully cultivated breeder seeds, TLS and experiment plots without any insecticide spray at BRRI Charbadna and Sagordi farms. The highest yield was recorded in BR23 (4.75 t/ha) than BRRI dhan76 (4.31t/ha) and BRRI dhan77 (3.54 t/ha).

Fall armyworm monitoring in BRRI, Barishal farm

To find out fall armyworm (FAW) population and damage symptom of rice field five pheromone traps (trap 1=T1, trap 2=T2, trap 3=T3, trap 4=T4, trap 5=T5) were set on 4 January 2021 at BRRI, Charbadna farm, BRRI RS, Barishal. The fall armyworm population was counted at seven days intervals up to 112 days after transplanting Boro rice. Pheromen trap lure was changed after 30 days interval.

Total 106 fall armyworms were captured by five traps in boro season 2021 (Fig. 7). Trap number 4 captured a maximum of 40 fall armyworms during 16 weeks. However, no leaf damage symptom was observed in rice plants.

DISEASE MANAGEMENT

Screening of available pesticides for controlling blast disease of rice, Aman 2020

Nine pesticides namely Zeal (dose 3.38 g/10L), Difa (dose 3.6 g/10L), Hayconazole 5EC (dose 4.5 ml/10L), Amister Top (dose 4.5 ml/10L), Tilt 250 EC (dose 4.5 ml/10L), Score 250 EC (dose 4.5 ml/10L), Trooper 75WP (dose 18.0 gm/10L), Bir 70WP (dose 18.0 gm/10L) and Nativo (dose 2.7 gm/10L) were used as test pesticides with one negative control (plain water). All the pesticides were tested on BRRI dhan34, a susceptible Aman HYV of rice to blast disease. Among the nine chemicals, Difa, Nativo, Amister Top, Trooper 75WP and Zeal significantly reduced neck blast (NB) disease at rates of 90.32%, 90.27%, 79.11%, 75.90% and 73.63%, respectively. Rest of the chemicals were ineffective (<70 % reduction) in reducing the blast disease. Further test of those effective chemicals was suggested for the next season.

Table 8. Insect pest and natural enemy population in BRRI RS, Barishal Charbadna farm, Aman 2020.

Insect	BR23	BRRI dhan76	BRRI dhan77
GLH	53	53	53
WLH	22	19	22
YSB	10	10	13
BPH	21	10	29
WBPH	24	7	25
LF	11	7	11
Total	141	106	153

NE	BR23	BRRI dhan76	BRRI dhan77
STPD	28	32	38
CDB	14	14	14
SPD	30	36	30
Dam. Fly	23	17	31
LBB	21	16	21
STPD	24	0	23
Dragon. Fly	24	17	21
Total	164	132	178

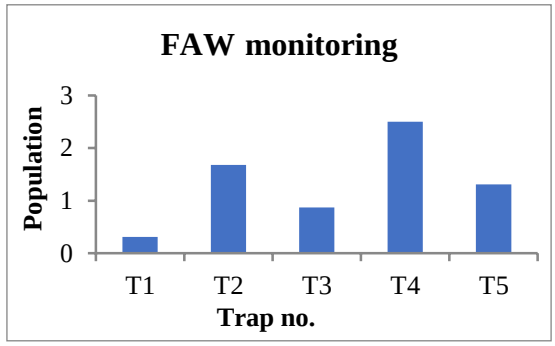

Fig. 7. Fall armyworm population abundance of Five pheromon trap in BRRI RS farm, Barishal, Boro 2021.

Survey and monitoring of rice diseases in selected areas of Barishal region

In Aman and Boro seasons, a survey on rice disease was conducted in 162 farmers' fields of Barishal district (Sadar, Ujirpur, Babuganj and Bakerganj upazila). Cropping pattern, rice growing ecosystem and cultivar adoption of the surveyed area were observed during the survey. Data on percent disease incidence (%DI) and severity (0-9 scale) were collected following the standard evaluation system (SES) for rice (IRRI, 2013). A zigzag pattern for the survey was followed in this study (Savaryet *al*., 1996). From each plot, randomly 20 hills were selected for recording the disease incidence and severity. (Fig. 8.)

Screening of available pesticides for controlling blast disease of rice, Boro 2020-21

Ten pesticides namely Zeal, Tilt 250 EC, Hayconazole 5EC, Amister Top, Chemojol Plus, Score 250 EC, Trooper 75WP, Filia, Hayconazole 5EC and Nativo were used as test pesticides keeping one negative control (plain water). Dose of pesticides in Boro were the same as in T. Aman (follow the previous section). Pesticides were tested on BRRI dhan28, a susceptible Boro HYV of rice to blast disease. Among the ten chemicals, Nativo, Trooper 75WP, Amister Top, and Zeal significantly reduced neck blast (NB) disease at rates of 76.37%, 71.50%, 64.53% and 60.01%. The rest of the chemicals were not effective (<60 % reduction) in reducing the blast disease. A further test of those effective chemicals was suggested for the next season.

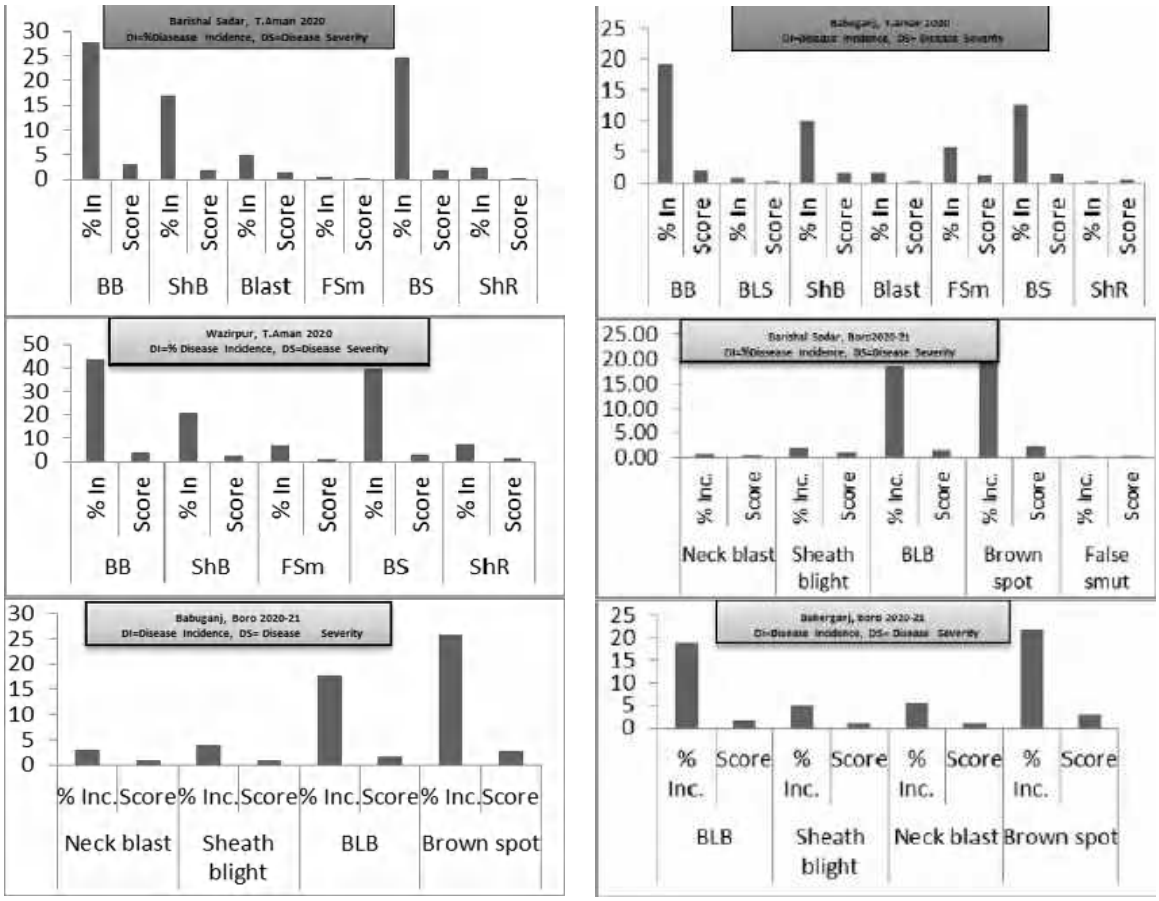

Fig. 8. Incidence and severity of different diseases in Barishal, T. Aman 2020. BB= Bacterial blight, ShB=Sheath blight, FSm=False smut, BS=Brown spot, ShR=Sheath rot, BLB=Bacterial leaf blight.

TECHNOLOGY TRANSFER

Varietal replacement through head to head trial in Boro 2020-21 under TRB project.

Three groups (short growth duration, long growth duration, saline tolerant) of modern rice varieties were tested at six locations of Barishal region during Boro 2020-21. The short duration group, comprising BRRI dhan28, BRRI dhan67, BRRI dhan81, BRRI dhan84, and BRRI dhan88, were tested in Barishal sadar and Bakerganj upazila of Barishal district. The long duration group, comprising BRRI dhan29, BRRI dhan58, BRRI dhan89 and BRRI dhan92 were tested in Nolcity, Jhalokathi and Kaukhali, Pirojpur. The saline tolerant group consists of BRRI dhan28, BRRI dhan67, BRRI dhan97, BRRI dhan99 and BINA dhan10, were tested in Babuganj, Barishal and Jhalokathi sadar, Jhalokathi. Among the short duration varieties, BRRI dhan28 provided the highest yield (6.57 t/ha) followed by BRRI dhan88 (6.44 t/ha), BRRI dhan84 (6.41 t/ha), BRRI dhan81 (5.98 t/ha) and BRRI dhan67 (5.96 t/ha). Comparing all long duration varieties, BRRI dhan92 gave the highest yield (7.8 t/ha^{-1}) followed by BRRI dhan29 (7.35 t/ha), BRRI dhan89 (7.2 t/ha^{-1}) and BRRI dhan58 (7.1 t/ha^{-1}). The highest yield (6.14 t/ha^{-1}) was achieved by BRRI dhan67, among all saline tolerant varieties, followed by BRRI dhan28 (5.99 t/ha^{-1}), BRRI dhan97 (5.92 t/ha^{-1}), BRRI dhan99 (5.57 t/ha^{-1}) and BINA dhan-10 (5.41 t/ha^{-1}). The trials suggested that despite BRRI dhan28 yielded the highest rice grain compared to other short duration varieties, BRRI dhan84 could be popular and be dessiminated among the farmers as a newly released variety. This fact is also reflected in the farmers choice since farmers stored 20 kg of BRRI dhan84 seed for use in the next Boro season.

Stability analysis of BRRI released varieties

This study was conducted to find out the suitable rice varieties in the Barishal region. Twelve BRRI released varieties were tested in Aus 2020 season. Forty-seven BRRI released varieties were tested with three groups, namely short duration (15), medium duration (21) and long duration variety (11) in Aman 2020 season. Forty-six BRRI released varieties with two groups, short duration (21) and long duration (25) were evaluated in Boro 2021 season. Stability studies in three seasons were conducted at Charbadna farm, BRRI RS, Barishal.

Among the tested 12 varieties in Aus 2020, the highest yield was achieved by BRRI hybrid dhan7 (5.43 t/ha) followed by BRRI dhan27 (4.19 t/ha) and BRRI dhan48 (4.18 t/ha). The lowest yield was found in BR21 (3.15 t/ha).

Among the tested 13 varieties of short duration in Aman 2020, BRRI hybrid dhan6 yielded the highest rice grain (5.00 t/ha), followed by BRRI hybrid dhan4 (4.57 t/ha) and BRRI dhan95 (4.57 t/ha). The lowest yield was found in BRRI dhan53 (3.07 t/ha). Among the medium duration varieties, the highest yield was found in BRRI dhan79 (5.00 t/ha) followed by BRRI dhan72 (4.46 t/ha) and BRRI dhan30 (4.43 t/ha). The lowest yield was observed in BR25 (3.16 t/ha). Among the long duration varieties, the highest yield was achieved by BRRI dhan76 (5.43 t/ha) followed by BRRI dhan46 (4.9 t ha) and BR 23 (4.3 t/ha). The lowest yield was achieved by BR5 (3.17 t/ha).

Among the short duration varieties in Boro 2021, the highest yield was observed in BRRI hybrid dhan5 (8.14 t/ha) followed by BRRI hybrid dhan5 (7.47 t/ha) and BRRI hybrid dhan2 (7.25 t/ha). The lowest yield was found in BRRI dhan61 (5.16 t/ha).

SOCIO-ECONOMIC AND POLICY

Advanced line adaptive research trial (ALART)

There were eleven ALARTS, six in Aus 2020, two in T. Aman 2020 and three in Boro 2020-21, in the farmers' field of Barishal.

ALART in T. Aus 2020

ALART, non saline tidal ecosystem (NSTE), in Ghotkhali, Amtali. Two advanced lines V1=BR8784-4-1-2-P2 and V2=BR8781-16-1-3-P2, along with two standard check varieties BRRI dhan27 and BRRI dhan48 were tested in Ghotkhali, Amtali upazila of Barguna district during T. Aus 2020. Among the advanced line and check varieties, the advanced line BR8781-16-1-3-P2 produced the highest yield (5.53 t/ha), followed by the check variety BRRI dhan48 that produced the 2nd highest average yield (5.47 t/ha). On average, all the entries matured within 110-119 days. Based

on higher yield and growth duration and farmers' opinions, BR8781-16-1-3-P2 may be considered for further research.

ALART, non saline tidal ecosystem (NSTE), in Kolapara, Patuakhali. Two advanced lines V1=BR8784-4-1-2-P2 and V2=BR8781-16-1-3-P2, along with 2 standard check varieties BRRI dhan27 and BRRI dhan48, were tested in Kolapara upazila of Patuakhali district during T. Aus 2020. Among the advanced lines and check varieties, the check variety BRRI dhan48 produced the highest yield (5.06 t/ha) followed by the advanced line BR8781-16-1-3-P2 (the 2nd highest average yield 5.00 t/ha). On average, all the entries matured within 117-128 days. Based on higher yield and growth duration and farmers' opinions, BR8781-16-1-3-P2 may be considered for further research.

ALART, NSTE), in Nilganj, Amtali, Barguna. Two advanced lines V1=BR8784-4-1-2-P2 and V2=BR8781-16-1-3-P2, along with two standard check varieties BRRI dhan27 and BRRI dhan48, were tested in Nilganj, Amtali upazila of Barguna district during T. Aus 2020. Among the advanced lines and check varieties, the advanced line BR8781-16-1-3-P2 produced the highest yield (3.84 t/ha) followed by the 2nd highest averaged yield (3.21 t/ha) by the check variety BRRI dhan27. On average, all the entries matured within 117-125 days. Based on higher yield and growth duration and farmers' opinion, BR8781-16-1-3-P2 may be considered for further research programme.

ALART, NSTE, in Taltali, Barguna. Two advanced line V1=BR8784-4-1-2-P2 and V2=BR8781-16-1-3-P2 along with two standard check varieties BRRI dhan27 and BRRI dhan48 were tested in Taltali upazila of Barguna district during T. Aus 2020. Among the advanced line and check varieties, the advanced line BR8784-4-1-2-P2 gave the highest yield (5.46 t/ha) followed by the 2nd highest averaged yield (5.43 t/ha) by the advance line BR8781-16-1-3-P2 and (5.36 t/ha) the check variety BRRI dhan48. On an average, all the entries matured within 111-121 days. Based on higher yield and growth duration and farmers' opinion, BR8784-4-1-2-P2 and BR8781-16-1-3-P2 may be considered for further research programme.

ALART, NSTE, in Kaukhali, Pirojpur.

Two advanced lines V1=BR8784-4-1-2-P2 and V2=BR8781-16-1-3-P2 along with two standard check varieties BRRI dhan27 and BRRI dhan48 were tested in Kaukhali upazila of Pirojpur district during T. Aus 2020. Among the advanced line and check varieties, the check variety BRRI dhan48 produced the highest yield (4.87 t/ha) followed by the 2nd highest average yield (4.72 t/ha) by the advanced line BR8781-16-1-3-P2. On average, all the entries matured within 118-132 days. Based on higher yield and growth duration and farmers' opinion, BR8781-16-1-3-P2 may be considered for further research programme.

ALART, favourable environment (FE), T. Aus 2020 in Taltali, Barguna. Two advanced lines V1=BR9005-53-1-1 and V2=BR9006-40-2-3-1 along with two standard check varieties BRRI dhan48 and BRRI dhan82 were tested in Taltali upazila of Barguna district during T. Aus 2020. Among the advanced line and check varieties, the advanced line BR9006-40-2-3-1 produced the highest yield (5.64 t/ha) followed by the 2nd highest average yield (5.54 t/ha) by the check variety BRRI dhan82. On average, all the entries matured within 105 -110 days. Based on higher yield and growth duration and farmers' opinion, the advanced line BR9006-40-2-3-1 may be considered for further research programme.

ALART in T. Aman 2020

ALART rainfed lowland rice (RLR), T. Aman 2020. Two advanced lines: V1=BR9571-13-1-9-1-1 and V2=BR9574-9-5-3-1-1along with two standard checks BRRI dhan49 and BRRI dhan87 were tested in Kaukhali upazila of Pirojpur district district during T. Aman 2020. Among the advanced lines and check varieties, the advanced line BR9571-13-1-9-1-1 gave the highest mean yield (4.36 t/ha). The yield difference between these genotypes was statistically significant. On an average, all the entries matured within 132-138 days. Based on higher yield and growth duration and farmers' opinion, advanced line BR9571-13-1-9-1-1 may be considered for further research program.

ALART zinc enriched rice (ZER), T. Aman 2020. One advanced lines: BR10001-94-2-B along with two standard checks BRRI dhan72 and BRRI dhan87 were tested in Kaukhali upazila of Pirojpur district district T. Aman 2020. Among the advanced

lines and check varieties, the advanced line BR10001-94-2-B produced the highest mean yield (4.43 t/ha). The yield difference between these genotypes was statistically significant. On average, all the entries matured within 129-135 days. Based on higher yield and growth duration and farmers' opinion, advanced line BR10001-94-2-B may be considered for further research programme.

A

LART in Boro 2020-2021

ALART, favourable boro rice-bhanga (FBR-Bhanga), Boro 2020-2021. Two advanced lines SVIN063-Boro-18-Bhanga and SVIN076-Boro-18-Bhanga along with check varieties BRRI dhan29 and BRRI dhan89 were tested in Protap, Nalsity, Jhalokathi during Boro 2020-21. Among the advanced line and check varieties, Advanced line SVIN076-Boro-18-Bhanga produced the highest yield (8.11 t/ha) followed by the 2nd highest average yield (8.05 t/ha) by SVIN076-Boro-18-Bhanga. On average, all the entries matured within 155-157 days. Based on higher yield and growth duration and farmers' opinions, SVIN063-Boro-18-Bhanga and SVIN076-Boro-18-Bhanga may be considered for further research programme.

ALART, zinc enriched rice (ZER), Boro 2020-21. Two advanced lines SVIN063-Boro-18-Bhanga and SVIN076-Boro-18-Bhanga along with check varieties BRRI dhan29 and BRRI dhan89 were tested in Protap, Nalsity, Jhalokathi during Boro 2020-21. Among the advanced line and check varieties, the advanced line BR8912-12-6-1-1-1-1 produced the highest yield (7.64 t/ha) followed by the 2 highest average yield (7.60 t/ha) by check variety BRRI dhan89. On average, all the entries matured within 145-157 days. Based on higher yield and growth duration and farmers' opinion, BR8912-12-6-1-1-1-1 may be considered for further research programme.

ALART, Bacterial blight resistant rice-biotechnology (BBRR-Bio), Boro 2020-21. Two advanced lines BR (Bio)11447-1-28-14-3 and BR (Bio)11447-3-10-7-1 along with check varieties BRRI dhan28 were tested in Protap, Nalsity, Jhalokathi during Boro 2020-21. Among the advanced line and check varieties, the advanced line BR (Bio)11447-3-10-7-1 produced the highest yield (5.68 t/ha) followed by the 2nd and 3rd highest averaged yield (5.50 t/ha) and (5.40t/ha) by advanced line BR(Bio)11447-1-28-14-3 and BRRI dhan28 (Std. and sus. ck); although there was no significant difference between them. On average, all the entries matured within 129-134 days. Based on higher yield and growth duration and farmers' opinion, BR(Bio)11447-3-10-7-1 and BR(Bio)11447-1-28-14-3 may be considered for further research programme.

DEMONSTRATION, SEED PRODUCTION AND SCALING UP OF BRRI RICE VARIETIES

Demonstration under SPIRA Project

Group 1

A total of seven varietal demonstrations among the selected groups of farmers received seed, fertilizer, insecticides, pesticides, irrigation and labour support. Three demonstration of two bighas each were conducted in Babuganj of Barishal, Kolapara of Patuakhali and Chunahali, Amtali of Barguna under SPIRA during T. Aman 2020. The highest yield was obtained by BRRI dhan23 (5.07t/ha) followed by BRRI dhan77 (4.93 t/ha) and BRRI dhan76 (4.91 t/ha),

Four demonstrations were conducted with four vatieries viz., BRRI dhan47, BRRI dhan74, BRRI dhan84 and BRRI dhan88 were demonstrated during Boro 2020-21 and the highest yield was achieved by BRRI dhan74 (6.96 t/ha) and lowest yield was achieved bt BRRI dhan47 (6.04 t/ha). Therefore, BRRI dhan74 were very promising to this region and farmers' were willing to cultivate these varieties next season.

Group 2

Block demonstrations of BR23, BRRI dhan52, BRRI dhan76, BRRI dhan77, BRRI hybrid dhan4 and BRRI hybrid dhan6 were established in T. Aman 2020 at five upazilas, namely Agailjhara, Babuganj, Amtoli, Kalapara under SPIRA. The selected groups of farmers received seed, fertilizer, insecticides, pesticides, irrigation and labour support. The highest yield was obtained by BRRI dhan52 (4.29t/ha) followed by BRRI dhan23 (4.15 t/ha) and BRRI

dhan76 (3.98 t/ha). The yield of BRRI hybrid rice varieties ranged from 3.11 to 3.18 t/ha could be attributed to the prolonged water logging during high tides. Farmers' stored seeds of BRRI dhan76 and BRRI dhan77 for the next Aman season and agreed to cultivate along with surrounding farmers.

Seed support demonstration

In total 126 block demonstrations were established by BRRI RS, Barishal in six districts of Barishal region (Fig. 9 and 10). Total land under the demonstration programme was 1,212 acres. Farmers were supplied BR3, BRRI dhan29, BRRI dhan47, BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan89, BRRI hybrid dhan3, BRRI hybrid dhan5 seeds free of cost. Scientists of BRRI RS, Barishal were assigned and monitored all demonstrations.

BRRI dhan89 (7.43 t/ha) performed the best among all inbred varieties (Fig. 11). However, farmers preferred BRRI dhan74 for yield (7.28 t/ha) its medium bold grain, shorted duration course and zinc content. BRRI hybrid dhan3 and 5 yielded 7.82 and 8.14 t/ha, respectively. Several field days were also conducted in different blocks where hundreds of direct and indirect farmers received knowledge and build their awareness about Boro cultivation and management. From these research programme, it can be concluded that block demonstrations are effective for the expansion of Boro cultivation in the fallow lands of Barishal region using the surface water. From the farmers opinion, if canals in Barishal region are reexcavated and Boro seeds are available, more fallow lands in this region can be brought under Boro cultivation and the cropping intensity could be increased.

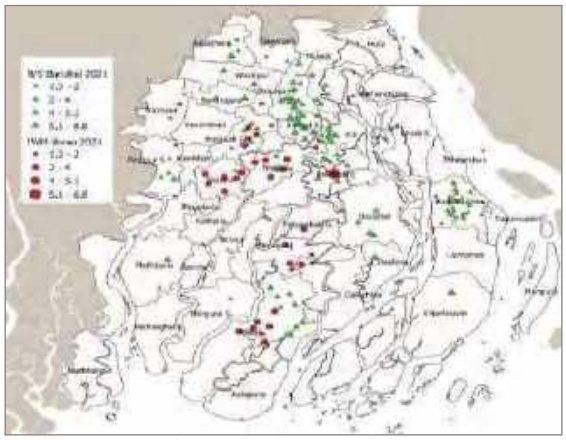

Fig. 9: Locations of 126 block demos established by BRRI RS, Barishal (green triangle), and 28 blocks by IWM Division (red circle) in Boro 2020-21.

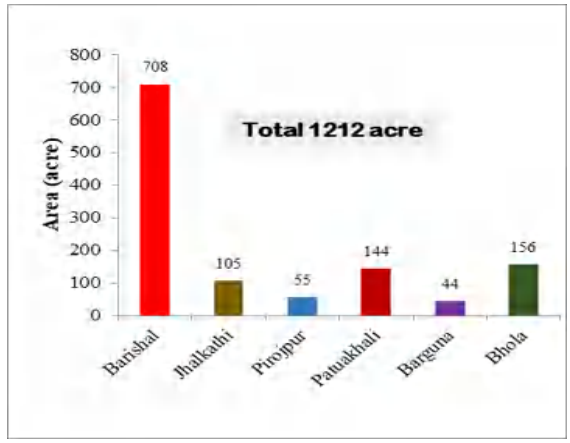

Fig. 10: Area under 126 block demos established by BRRI RS, Barishal in six district of Barishal region, Boro 2020-21.

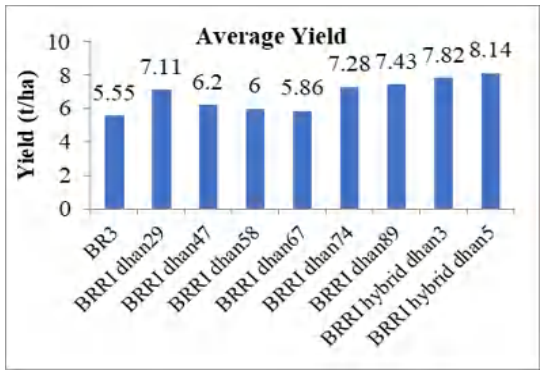

Fig. 11: Average yield of BRRI varieties under 126 block demonstrations, Boro 2020-21.

Farmers' training under different projects/GoB
BRRI RS, Barishal conducted 29 farmers' training in different locations of Barishal region during the reporting period. Twenty-four farmers' trainings were conducted under GoB programme, while five were under SPIRA project. A total of 710 male, 149 female farmers, 29 Imam and 22 NGO personnel were trained under GoB training programme. Under SPIRA project a total of 135 male, 47 female farmers, 11 Imam and seven NGO personnel received training on modern rice production technologies.

Farmers' field day under different projects/GoB
Thirteen field days were conducted and of then five were funded by BMGF and six were under SPIRA project and two under GoB during T. Aman 2020 and Boro, 2020-21. About 1,450 (703male and 747 female) farmers, extension personnel, administrative people, public leaders were targeted to participate in these programmes.

Workshops for T. Aman, Boro rice cultivation
One regional workshop was conducted at BRRI RS, Barishal Shagordi conference room where more than 100 personnel from different stakeholders in Agriculture sectors participated. The workshop title was "R,XQ RিP¢ØY hTN F T¢আhN আRTY িি িŠ ও আGTh িR ও FRTY T hও Yh T ". The workshop was chaired by the Director General of BRRI. Honorable Secretary of the Agriculture Ministry was the chief guest, Vice-chancellor Patuakhali Science and Technology University and Additional Director of Barishal Region, DAE were the special guests. DD, UAO, AEO, SAAO from DAE, Scientists from BRRI, BARI, BINA, BJRI, SRDI, and higher officials from BADC and other organizations, and farmers attended the meeting both physically and online platform. Presented Dr Md Alamgir Hossain, CSO and Head, BRRI RS, Barishal the keynote paper. Papers also presented on behalf of DAE, BINA and BADC.

Breeder seed and TLS production
Nucleus seeds of BR 23, BRRI dhan34, BRRI dhan49, BRRI dhan52, BRRI dhan76 and BRRI dhan77 for T. Aman 2019, while BR 26, BRRI dhan28, BRRI dhan29, BRRI dhan47, BRRI dhan67 and BRRI dhan74 for Boro 2019-20 were supplied by GRS Division, BRRI, HQ, Gazipur.

A total of 43,265 kg of breeder seed (BS) and 23,283 kg of truthfully labelled seed (TLS) were produced, processed and distributed in 2020-21. Presents the detailes of seed production according to season and variety. Table 10.

Table 10. Breeder Seed and TLS Production in T. Aman 2020 and Boro 2020-21.

Variety	BS	TLS	Variety	BS	TLS
T. Aman, 2020			Boro 2020-21		
BR23	2800	-	BRRI dhan26	1520	2200
BRRI dhan34	2520	1550	BRRI dhan28	9000	40
BRRI dhan41	-	370	BRRI dhan29	5500	3120
BRRI dhan34	-	650	BRRI dhan47	1160	500
BRRI dhan44	3000	140	BRRI dhan50	-	520
BRRI dhan49	800	-	BRRI dhan67	2760	2500
BRRI dhan52	-	1420	BRRI dhan74	6500	1400
BRRI dhan72	2000	1900	BRRI dhan83	-	185
BRRI dhan76	705	350	BRRI dhan84	-	444
BRRI dhan77	-	620	BRRI dhan88	-	444
BRRI dhan78	-	1230	BRRI dhan89	-	1770
BRRI dhan87			BRRI dhan92	5000	680
Total	11825	8230	BRRI dhan96		370
			BRRI dhan97		680
			BRRI dhan100		800
			Total	31440	15053

BRRI RS, Bhanga

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SUMMARY

Fifteen crosses were made using 17 parents and 706 F_1 seeds were produced for deepwater rice breeding and 12 crosses made and 706 F_1 seeds were produced for Aman rice. In Boro 2020-21, a total of 10,000 progenies from F_3 generation were grown following field RGA technique and 2,930 progenies of F_5 generation were grown and 2,671 F_6 plants harvested to initiate LST. In proposed variety trial (PVT) one set in T. Aman 2020 and, four sets (Set-1 for DRR, Set-2: ZER and Set-3 and for PQR) during Boro 2020-21 of inbred trials were evaluated at BRRI RS, Bhanga, Faridpur. In ALART (RLR) T. Aman, BR9574-9-5-3-1-1 produced 6.41 t ha^{-1} yield which was higher than the check varieties BRRI dhan49 (4.56 t ha^{-1}) and BRRI dhan87 (3.77 t ha^{-1}). Yield of BRRI dhan87 was severely reduced due to seedling mortality, rat damage, and pest infestation. In ALART (ZER) T. *Aman*, the advanced line BR10001-94-2-B produced lower yield (3.44 t ha^{-1}) than the standard check BRRI dhan72 (4.04 t ha^{-1}) and similar to BRRI dhan87 (3.44 t ha^{-1}). In ALART (ZER) Boro, BR8912-12-6-1-1-1-1 produced the highest yield (11.2 t ha^{-1}) comparing with check varieties BRRI dhan74 (4.26 t ha^{-1}) and BRRI dhan89 (10.8 t ha^{-1}). Yield of IR105837-8-95-2-1 and BRRI dhan74 was severely reduced because of rat damage and pest infestation. In ALART (FBR) Boro, the advanced line SVIN063 and SVIN076 produced higher yield (10.96 t ha^{-1}, 10.18 t ha^{-1}) than the check BRRI dhan29 (10.04 t ha^{-1}) and BRRI dhan89 (9.96 t ha^{-1}). Mean growth duration of the both test entries was similar (157 days, 158 days) to the check varieties. Ten regional yield trials (RYTs) were conducted in BRRI RS, Bhanga during Boro 2020-21 season. In RYT (GSR), mean grain yield of the FBR336, WANXIAN7777-P10-P3 advanced lines (11.12, 11.47 t ha^{-1}) was higher than the check variety BRRI dhan58 (10.51 t ha^{-1}) and BRRI dhan88 (10.21 t ha^{-1}). In RYT (ZER), all advanced lines such as BR8419-8-2-1-4-1-3-8-5, BR8913-12-4-8-9-2-3-11-22 and BR9674-5-6-2-1-7-22 produced higher yield (ranged from 8.28-10.1 t ha^{-1}) than the check variety BRRI dhan84 (7.51 t ha^{-1}). However, all breeding lines produced lower yield compared with the other checks BRRI dhan74 (10.11 t ha^{-1}) and BRRI dhan89 (10.34 t ha^{-1}). In RYT (RYMT), two advanced breeding lines, BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B produced higher yield (9.34 and 8.63 t ha^{-1}) than the check variety BRRI dhan63 (8.4 t ha^{-1}). Twenty-seven deepwater rice germplasm accessions were characterized. From the qualitative and quantitative characterization results, it revealed that wide diversity found in the DWR rice germplasm using UPGMA cluster analysis. Eleven tons of breeder seeds (BRRI dhan29, BRRI dhan89 and BRRI dhan92) and 22.0 tons TLS of recently released BRRI varieties were produced in BRRI RS, Bhanga. We conducted 128 demonstrations using recently released BRRI varieties and also organized 24 training programmes where 730 farmers and DAE personnel received the training and arranged six farmers' field days.

VARIETAL DEVELOPMENT

Hybridization. In Aman 2020 season, 12 crosses were made and 586 F_1seeds were produced for developing high yielding transplanting Aman rice varieties having desirable characters with emphasis on water stagnation tolerance, anaerobic tillering, earliness as well as good grain quality.

For deepwater rice variety development, 15 crosses were made and 706 F_1 seeds were produced with desirable characters with emphasis on kneeing ability, nodal tillering, earliness and awnless good grain quality.

FRGA. A total of 2,930 plants of F_5 generation were grown during Boro 2020-21 followed Field RGA and 2671 progenies of F_6 generation were maintained by collecting single panicle from each plant (Table 1) to conduct LST under 'Breeding for developing high yielding boro rice varieties' programme.

PVT (T. Aman). One set (Set-1) of inbred trial (Aman 2020) was evaluated under PVT at BRRI RS, Gopalganj with the full support and supervision of BRRI RS, Bhanga, Faridpur. The trial was not possible to establish in Faridpur because of severe flood in Faridpur (Table 2).

Set-1. In a proposed variety trial, one advanced breeding line I-018 along with two checks (I-019 and I-020) was tested. The line no. I-018 produced 7.37% and 11.36% higher yield than both the check varieties coded as I-019 and I-020, respectively. The growth duration of line no. I-018 was 145 days which was 11 days longer than both I-019 and I-020 (134 days) line (Table 2).

PVT (Boro). Four sets (Set-1, Set-2, Set-3 and Set-4) of inbred trial (Boro 2020-21) were carried out at BRRI Bhanga, Faridpur (Table 3).

Set-1. In a proposed variety trial, one advanced breeding line I-021 along with check (I-022) was tested. The line no. I-021 produced 8.99 t ha^{-1} which was 5.27% higher yield than the check variety coded as I-022 (8.54 t ha^{-1}). The growth duration of line no. I-021 was similar to I-022.

Set-2. One advanced breeding line I-023 was evaluated along with check I-024. The line no. I-023 (8.90 t ha^{-1}) yielded 9.91% lower than the check I-024 (9.88 t ha^{-1}) with similiar growth duration.

Set-3. One advanced breeding line (I-025) along with check (I-026) were tested. The line no. I-025 (7.79 t ha^{-1}) gave 2.64% higher yield than the check I-026 (7.59 t ha^{-1}). Average growth duration of the tested line I-025 (141 days) was five days earlier than check I-026 (146 days).

Set-4. One advanced breeding line I-027 was tested along with check I-028. The line no. I-027 yielded (8.50 t ha^{-1}) 0.71% higher than the check I-028 (8.44 t ha^{-1}) with similiar growth duration (148 days).

ALART (Aus). Two advanced lines BR9005-53-1-1 and BR9006-40-2-3-1 along with two checks such as BRRI dhan48 (ck) and BRRI dhan82 (ck) were tested at farmers' field in Azimnagar, Bhanga, Faridpur. Two test entries produced higher yield (4.75 and 5.33 t ha^{-1}) than the yield of check variety BRRI dhan48 (4.67 t ha^{-1}) and BRRI dhan82 (4.39 t ha^{-1}). Mean growth duration of BR9005-53-1-1 of was 112 days which was three days earlier than BRRI dhan48 but eight days longer than the check variety BRRI dhan82 (104). Flowering and maturity of these lines were regular and uniform (Table 4).

ALART (RLR) T. Aman. Advanced line adaptive research trial (ALART) was conducted using two advanced lines BR9571-13-1-9-1-1 and BR9574-9-5-3-1-1 along with two checks (BRRI dhan49 and BRRI dhan87) at farmers' field in Tambulkhana, sadar, Faridpur. BR9574-9-5-3-1-1 produced 6.41 t ha^{-1} yield which was higher than the yield of check varieties BRRI dhan49 (4.56 t ha^{-1}) and BRRI dhan87 (3.77 t ha^{-1}). Yield of BRRI dhan87 was drastically reduced due to seedling mortality, rat damage, and pest infestation. Mean growth duration of BR9571-13-1-9-1-1 was 144 days which was higher than both the check varieties BRRI dhan49 (137 days) and BRRI dhan87 (132 days). But BR9574-9-5-3-1-1 was seven and two days earlier than BRRI dhan49 and BRRI dhan87 respectively. Flowering and maturity of these lines was uniform (Table 5).

ALART (ZER) T. Aman. ALART (ZER) was undertaken using one advanced line BR10001-94-2-B along with BRRI dhan72 and BRRI dhan87 as checks at on farm condition in Tambulkhana, sadar, Faridpur. The advanced line BR10001-94-2-B produced lower yield (3.44 t ha^{-1}) than the standard check BRRI dhan72 (4.04 t ha^{-1}) and similar as BRRI dhan87 (3.44 t ha^{-1}). Mean growth duration of the advanced line BR10001-94-2-B (135 days) was similar to the check variety BRRI dhan72 and 4 days longer than the other check BRRI dhan87 (Table 6).

ALART (ZER) Boro. Two advanced lines BR8912-12-6-1-1-1-1 and IR105837-8-95-2-1 with BRRI dhan74 and BRRI dhan89 as a check were tested at farmers' field at Krishnanagar, Nagarkanda, Faridpur. BR8912-12-6-1-1-1-1 out yielded (11.2 t ha^{-1}) the check varieties BRRI dhan74 (4.26 t ha^{-1}) and BRRI dhan89 (10.8 t ha^{-1}). Due to rat damage, pest infestation, yield of IR105837-8-95-2-1 and BRRI dhan74 was severely reduced. Mean growth duration of BR8912-12-6-1-1-1-1 of was 158 days which was two days earlier than check variety BRRI dhan89 (160 days). Regular flowering and maturity were observed of these lines (Table 7).

ALART (FBR) Boro. Two advanced lines SVIN063-Bhanga and SVIN076-Bhanga along with BRRI dhan29 and BRRI dhan89 as checks were evaluated at farmer's field at Krishnanagar, Nagarkanda, Faridpur. Both the advanced lines

SVIN063 and SVIN076 produced higher yield (10.96 t ha^{-1}, 10.18 t ha^{-1}) than the check BRRI dhan29 (10.04 t ha^{-1}) and BRRI dhan89 (9.96 t ha^{-1}). Mean growth duration of advanced line SVIN063-Bhanga and SVIN076-Bhanga (157 days, 158 days) was similar to the check varieties (Table 8).

RYT (GSR). Five advanced lines were evaluated against three standard checks BRRI dhan58 and BRRI dhan88 in RYT (GSR). Average grain yield of the FBR336, WANXIAN7777-P10-P3 advanced lines (11.12, 11.47 t ha^{-1}) was higher than the check variety BRRI dhan58 (10.51 t ha^{-1}) and BRRI dhan88 (10.21 t ha^{-1}). On the other hand, three advanced lines FBR189, FBR335 and FBR350 produced lower grain yield (8.12, 9.84 and 9.78 t ha^{-1}) than the check varieties BRRI dhan58 and BRRI dhan88, respectively (Table 9).

RYT (ZER). RYT (ZER) was conducted using three advanced lines, BR8419-8-2-1-4-1-3-8-5, BR8913-12-4-8-9-2-3-11-22 and BR9674-5-6-2-1-7-22 along with three check varieties like BRRI dhan74, BRRI dhan84 and BRRI dhan89. All the advanced lines produced higher yield (ranged from 8.28-10.1 t ha^{-1}) than the check variety BRRI dhan84 (7.51 t ha^{-1}). But all the advanced lines produced lower yield compared with the other checks BRRI dhan74 (10.11 t ha^{-1}) and BRRI dhan89 (10.34 t ha^{-1}) (Table 10).

RYT (RYMT). Two advanced lines BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B and one check variety BRRI dhan63 were grown. BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B advanced lines produced higher yield (9.34 and 8.63 t ha^{-1}) than the check variety BRRI dhan63 (8.4 t ha^{-1}) (Table 11).

RYT (Barishal-1). Six advanced lines were evaluated against two check varieties, BRRI dhan58 and BRRI dhan92. All advanced lines produced higher yield (8.34-10.95 t ha^{-1}) than the standard check BRRI dhan58 (7.91 t ha^{-1}) and BRRI dhan92 (9.31 t ha^{-1}) (Table 12).

RYT (Barishal-2). Seven advanced lines were evaluated with two check varieties BRRI dhan58 and BRRI dhan92. All advance lines gave lower yield (8.69-10.44 t ha^{-1}) than the standard check BRRI dhan58 (10.54 t ha^{-1}) and BRRI dhan92 (11.58 t ha^{-1}) (Table 13).

RYT (DRR-BB). Five advanced lines along with two susceptible checks BRRI dhan58, BRRI dhan89 and one resistant check IRBB60 were grown. All the advanced lines produced higher yield (8.02-9.96 t ha^{-1}) than the resistant check IRBB60 (7.77 t ha^{-1}). However, three advanced lines BR9943-2-2 (9.07 t ha^{-1}), BR9943-35-2-1-2-B2 (9.13 t ha^{-1}) and BR9650-108-2-3 (9.96 t ha^{-1}) produced higher yield compared with two susceptible checks BRRI dhan58 (8.51 t ha^{-1}), BRRI dhan89 (9.01 t ha^{-1}) (Table 14).

RYT (FBR-MD) Boro. Seventeen advanced breeding lines along with three checks BRRI dhan81, BRRI dhan84 and BRRI dhan89 were tested. All the test entries perform better (5.51-9.58 t ha^{-1}) over the check BRRI dhan81 (5.3 t ha^{-1}) except IR108000-B-B RGA-B RGA-185-1 (5.12 t ha^{-1}). Two advanced lines, BRC302-1-4-4-4 (9.58 t ha^{-1}) and BRC297-15-1-1-1 (9.28 produced higher yield, than the check variety BRRI dhan84 (9.1 t ha^{-1}). In comparison with BRRI dhan89 (8.73 t ha^{-1}), two advanced lines BRC302-1-4-4-4, BRC297-15-1-1-1 and SVIN266 produced higher yield 9.58, 9.28 and 8.76 t ha^{-1} respectively (Table 15).

RYT (Cumilla-1). Six advanced breeding lines with three checks BRRI dhan81, BRRI dhan84 and BRRI dhan88 were tested. All the advanced lines produced higher yield (7.51-9.66 t ha^{-1}) than the check BRRI dhan81 (7.12 t ha^{-1}) and BRRI dhan84 (7.35 t ha^{-1}). However, all advanced lines produced higher yield (8.02-9.66 t ha^{-1}) compared with BRRI dhan88 (7.7 t ha^{-1}; Ck) except BRC427-9-1-3 (7.51 t ha^{-1}) (Table 16).

RYT (Cumilla-2). Seven advanced lines along with two checks BRRI dhan50 and BRRI dhan58 were tested. BRC398-4-1-1-1B produced higher yield (8.95 t ha^{-1}) than both the checks BRRI dhan50 (7.42 t ha^{-1}) and BRRI dhan58 (8.77 t ha^{-1}). However, BRC394-1-1-1-5A produced lower yield (6.83 t ha^{-1}) compared with the checks (Table 17).

RYT (STR). Eighteen advanced breeding lines along with four checks BINA dhan10, BRRI dhan67, BRRI dhan89 and BRRI dhan97 were tested. BR11723-4R-12 produced higher yield (9.66 t ha^{-1}) than all the checks. BRRI dhan67 was severely damaged by rat. In addition, BR11716-4R-102 (8.72 t ha^{-1}) and BR11716-4R-105 (9.12 t ha^{-1})

showed superior yield performance than BINA dhan10 (8.04 t ha^{-1}) with shorter growth duration (Table 18).

Characterization of deep water rice (DWR) germplasm

Twenty-seven (27) deepwater rice germplasm (Table 19) were characterized for 51 different agro-morphological traits (31 qualitative and 20 quantitative characters) using the Rice Germplasm Descriptors and Evaluation Form. Twenty seven DWR germplasm were characterized during T. Aman, 2020 season. From the qualitative and quantitative characterization results, it revealed that wide diversity existed in the DWR rice germplasm. Polymorphism was found in 18 of the 21 qualitative traits under studied; the non-polymorphic traits were ligule colour, ligule shape and scent of decorticated grains. Cluster analysis indicated that the 27 DWR rice germplasm could be divided into four categories, using the euclidean distance of 0.29 as evident from Fig. 1. Maximum 17 germplasm were grouped into the cluster II followed by five in cluster III and three in cluster I. The cluster IV contained the lowest (2) number of germplasm). Table 19 shows the yield performance and other studied parameters of the diverse germplasm. The shortest plant height (62.8 cm) was observed in Kartiksail-1(G16) and the longest (199.808 cm) in (Laksmidigha-4). The highest yield per hill (17.4 g) was observed in Jogdal (G1) and the lowest (8.0 g) in Dudkalom-3 (G26). In conclusion, the variety having higher yield would be utilized in a crossing programme, if other characters satisfy the breeder's objectives.

FARMING SYSTEMS RESEARCH

Onion+Pumpkin-Jute-T. Aman cropping pattern produced higher rice equivalent yield (REY) (25.2 t $ha^{-1}yr^{-1}$ against existing cropping pattern (23.2 t $ha^{-1}yr^{-1}$). Higher rice equivalent yield was obtained in alternate cropping pattern due to introduction of new crop (Pumpkin) and varieties. REY was found to increase 8.62% over existing cropping sequence (Table 20). Farmer's cropping pattern onion-jute-T. Aman required in an average 297 days field duration and alternate cropping pattern Potato-Maize-Jute-T. Aman required 335 days (excluding seeding age of rice) to complete the cycle.

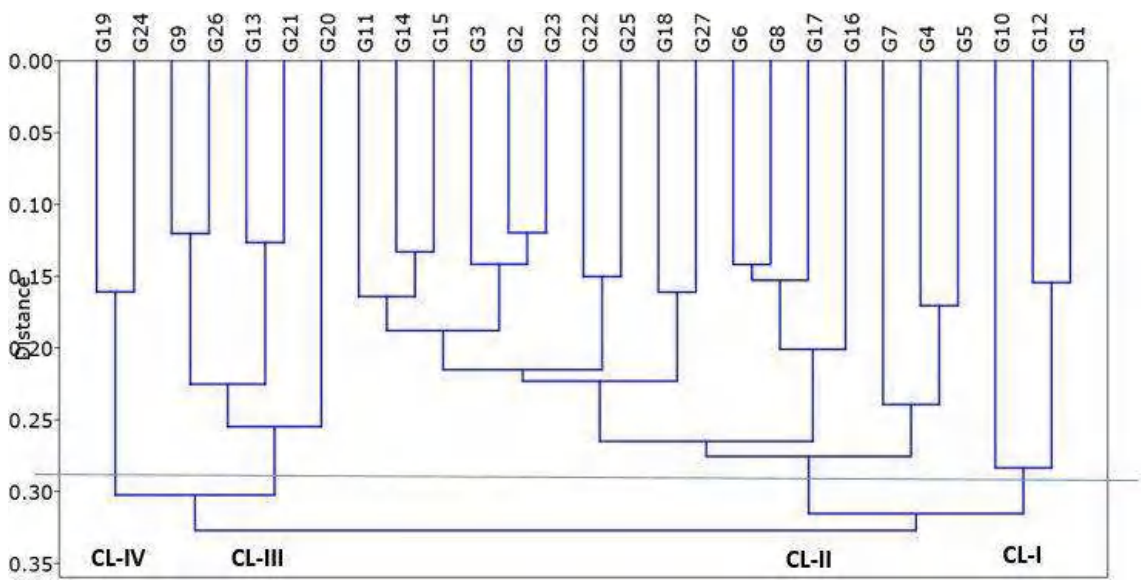

Fig. 1. Dendrograms of 27 deepwater rice germplasm obtained using UPGMA cluster analysis of quantitative data.

BCR, OER and NIFR of improved cropping pattern is 2.92, 34.28 and 65.72 which in 2.86, 35.2, 64.98 in existing cropping pattern respectively (Table 21).

CROP-SOIL-WATER MANAGEMENT

An experiment was conducted on 'Effect of polythene covering on seedling raising in Boro season' to identify the most suitable technique for protecting Boro rice seedling from cold injury.

Considering all the treatments we found the highest shoot height (49.22 cm), shoot weight (2.35 g), root weight (0.98 g), mortality rate (421) with the lowest growth duration (146 days) in treatment 5 (T_5): Polythene covering for all time with round shape opening (20 cm diameter) at both end of the seedbed cover). We also observed the highest root length (19.45 cm) and leaf number (6) in T6: No polythene covering/ control and T_3: Polythene covering from 11.0 am to sun set respectively but the lowest value was observed for both root length (11.41) and leaf number (4) in T_1 (Table 22). Thus treatment 5 (T_5) was found as a suitable technique for protecting Boro rice seedling from cold injury.

SOCIO-ECONOMICS AND POLICY

Stability analysis

For short duration Aman varieties, BRRI dhan87, BRRI dhan75 and BRRI dhan90 produced 6.49 t ha^{-1}, 5.26 t ha^{-1} and 4.79 t ha^{-1} which was higher yield than the other varieties like BRRI dhan39 and BRRI dhan57 (Table 23). In medium duration Aman varieties based on yield BRRI dhan72, BRRI dhan49 and BRRI dhan79 produced the highest grain yield 5.49 t ha^{-1}, 5.39 t ha^{-1} and 5.09 t ha^{-1} followed by BR11 (4.99 t ha^{-1}) and BRRI dhan80 (4.80 t ha^{-1}) (Table 24). In long duration T. Aman varieties BR22 yielded high (4.94 t ha^{-1}) followed by BR10 (4.86 t ha^{-1}) and BRRI dhan76 (4.79 t ha^{-1}) (Table 25). In Boro season, for short duration Boro varieties BRRI hybrid dhan5 yielded high (8.12 t ha^{-1}) followed by BRRI dhan67 (7.75 t ha^{-1}) and BRRI hybrid dhan2 (7.62 t ha^{-1}) (Table 26). For long duration, BRRI dhan89, BRRI dhan92 and BRRI dhan29 produced the highest grain yield 8.85 t ha^{-1}, 8.74 t ha^{-1} and 8.25 t ha^{-1} followed by BRRI dhan58 (7.50 t ha^{-1}) and BRRI dhan99 (7.32 t ha^{-1}) (Table 27).

TECHNOLOGY DISSEMINATION

A total of 128 demonstrations (15 demos in T. Aus, 50 demos in T. Aman and 63 in Boro seasons) using BRRI developed modern rice varieties during T. Aus, T. Aman 2020 and Boro 2020-21 were carried out in different farmers' fields of sadar, Faridpur; sadar, Rajbari; Kalkini, Madaripur; Nagarkanda, Faridpur; Rajoir, Madaripur, Naria, Shoriatpur under BRRI RS, Bhanga, Faridpur with the financial assistance of BRRI-SPIRA project.

Mean grain yields with growth duration of Aman varieties were: 4.68 t ha^{-1} with 128 days for BRRI dhan39, 4.51 t ha^{-1} with 150 days for BRRI dhan51 and 5.18 t ha^{-1} with 145 days for BRRI dhan52, 4.6 t ha^{-1} with 113 days for BRRI dhan57, 5.02 t ha^{-1} with 118 days for BRRI dhan71, 5.51 t ha^{-1} with 116 days for BRRI dhan75, 5.13 t ha^{-1} with 145 days for BRRI dhan79, 5.58 t ha^{-1} with 135 days for BRRI dhan80, 5.56 t ha^{-1} with 132 days for BRRI dhan87, 5.09 t ha^{-1} with 136 days for BRRI dhan93, 4.91 t ha^{-1} with 137 days for BRRI dhan94 and 4.90 t ha^{-1} with 129 days for BRRI dhan95.

In Boro 2020-21, mean grain yield of BRRI dhan28 was 6.89 t ha^{-1} with growth duration of 143 days, 8.04 t ha^{-1} with 159 days for BRRI dhan29, 7.73 t ha^{-1} with 152 days for BRRI dhan58, 7.61 t ha^{-1} with 148 days for BRRI dhan67, 7.58 t ha^{-1} with 145 days for BRRI dhan81, 7.31 t ha^{-1} with 145 days for BRRI dhan84, 7.66 t ha^{-1} with 144 days for BRRI dhan88, 8.19 t ha^{-1} with 159 days for BRRI dhan89 and 8.57 t ha^{-1} with 160 days for BRRI dhan92. At the maturity of the crop, one field day was arranged with the help of DAE. During field day, the trial farmers shared their experience to neighbouring farmers, which made them interested to these varieties to cultivate those in their own plots and thereby a demand for quality seeds was generated.

In Aman, 2020 five varietal replacement through head to head trials were conducted in five upazilas of two districts namely Faridpur and

Rajbari under supervision of BRRI RS, Bhanga with the financial assistance of BRRI-TRB project. Sixteen genotypes (BRRI, BRRI, local, advanced line) like BINA dhan11, BINA dhan16, BINA dhan17, BINA dhan22, BRRI dhan39, BRRI dhan51, BRRI dhan51, BRRI dhan71, BRRI dhan75, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan94, BRRI dhan95 and one advanced line designated by IR13F441 were included in this trial. The highest grain yield in different locations were as follows: 4.95 t ha^{-1} in BRRI dhan39 at Kholilpur, sadar, Faridpur; 5.06 t ha^{-1}, 5.51 t ha^{-1} in BRRI dhan71 and BRRI dhan75 at Tambulkhana, sadar, Faridpur; 5.16 t ha^{-1} in BRRI dhan79 at Kholilpur, sadar, Faridpur; 4.67 t ha^{-1}, 5.96 t ha^{-1}, 5.18 t ha^{-1}, 5.01 t ha^{-1} and 5.6 t ha^{-1} in BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan94 and BRRI dhan95 respectively at Darponarayanpur, sadar, Rajbari. Advanced line IR13F441 produced higher yield 4.66 t ha^{-1} at Koijuri, sadar, Faridpur.

Similarly, in Boro, 2020-21 a total of nine varieties BRRI dhan28,67,81,84,88 were included in BRRI dhan28 group while BRRI dhan29,58,89,92 are included in BRRI dhan29 group. Seven (four BRRI dhan28 group and three BRRI dhan29 group) varietal replacement through head to head trials were conducted in six upazilas of four districts namely Faridpur, Madaripur and Rajbari districts under BRRI RS, Bhanga with the financial assistance of BRRI-TRB project. The highest grain yield with growth duration in different locations were as follows: 8.23 t ha^{-1} with BRRI dhan28 in Kathiyabari, Nagarkanda, Faridpur; 8.91 t ha^{-1} with BRRI dhan67 in Dhuasar, Kalkini, Madaripur; 8.00 t ha^{-1} with BRRI dhan81 in Kathiyabari, Nagarkanda, Faridpur; 7.81 t ha^{-1} with BRRI dhan84 in Dhuasar, Kalkini, Madaripur; 8.34 t ha^{-1} BRRI dhan88 in Kathiyabari, Nagarkanda, Faridpur; 8.79 t ha^{-1} BRRI dhan29 in Mirpara, Rajbari sadar, Rajbari; 10.07 t ha^{-1} BRRI dhan58 Mirpara, Rajbari Sadar, Rajbari; 8.97 t ha^{-1} BRRI dhan89 in Mirpara, Rajbari sadar, Rajbari and 9.37 t ha^{-1} BRRI dhan92 in Dhuasar, Kalkini, Madaripur. The trial farmers stored their seeds according to their choice for growing in the next Boro season.

BRRI RS, Bhanga farm, produced ~33.0 ton seeds in total 11 tons of breeder seed of BRRI dhan29, BRRI dhan89 and BRRI dhan92 and the rest about 22.0 were TLS of short duration Aman varieties. BRRI dhan71, BRRI dhan75, BRRI dhan79 and BRRI dhan87 as well as Boro varieties of BRRI dhan29, BRRI dhan50, BRRI dhan58, BRRI dhan81, BRRI dhan84, BRRI dhan88, BRRI dhan89 and BRRI dhan92 during Boro 2020 -21 season.

We conducted 24 training programmes where 730 participants consisting of farmers, DAE personnel and mechanics of greater Faridpur region took part in the training on modern rice production technologies and farm machinery operation and maintenance with the cooperation of DAE and the financial assistance of GOB, SMPRA-BRRI and BRRI-SPIRA project.

Table 1. List of generation in FRGA.

Cross	No. of plant (F_6)
BR11723-4R-12 / BRRI dhan67	248
BR11716-4R-129 / BRRI dhan67	202
BR11716-4R-129/ BRRI dhan67	229
BR11712-4R-218 / BRRI dhan67	256
BR11712-4R-218 / BRRI dhan67	400
BR11715-4R-186 / BRRI dhan67	108
BR716-4R-113 / D (R)-6	431
IR107989-13-BRGA-BRGA-396 / WAXX1A7777-P8	555
BR11723-4R-172 / IR58443-6B-10-3	242
Total	2671

Table 2: Performance of proposed variety trial in Aman 2020-21 at BRRI RS, Gopalganj under the supervision of BRRI RS, Bhanga.

PVT Set	Location	Code No.	Growth duration (day)	Yield (t ha^{-1})
Set-1	BRRI RS Gopalganj	I-018	145	5.39
		I-019	134	5.02
		I-020	134	4.84

Table 3. Performance of proposed variety trial in Boro 2020-21 at BRRI RS, Bhanga, Faridpur.

PVT Set	Location	Code no.	Growth duration (day)	Yield (t ha^{-1})
Set-1	BRRI RS, Bhanga	I-021	145	8.99
		I-022	145	8.54
Set-2	BRRI RS, Bhanga	I-023	151	8.90
		I-024	151	9.88
Set-3	BRRI RS, Bhanga	I-025	141	7.79
		I-026	146	7.59
Set-4	BRRI RS, Bhanga	I-027	148	8.50
		I-028	148	8.44

Table 4. Grain yield and agronomic characters of ALART, Aus 2020 at BRRI RS, Bhanga.

Designation	GD (day)	PH (cm)	Paricle/m^2	Filled grain	Unfilled grain	Sterility (%)	Yield (t ha^{-1})
V1=BR9005-53-1-1	112	101.0	263	119	19	14.0	4.75
V2=BR9006-40-2-3-1	108	112.9	151	130	26	17.3	5.33
V3=BRRI dhan48 (ck)	115	107.9	246	126	51	28.4	4.67
V4=BRRI dhan82 (ck)	104	112.5	139	138	54	28.0	4.39

Table 5. Grain yield and agronomic characters of ALART RLR, T. Aman 2020 at BRRI RS, Bhanga.

Designation	Plant height (cm)	Panicle/m^2	Growth duration (day)	Yield (t ha^{-1})
BR9571-13-1-9-1-1	121.27	307	144	3.2
BR9574-9-5-3-1-1	112.47	317	130	6.41
BRRI dhan49 (ck)	102.8	339	137.33	4.56
BRRI dhan87 (ck)	117.87	233	132	3.77
CV (%)	1.79	14.31	0.368	7.24
LSD (<0.05)	4.07	NS	0.99	0.65

Table 6. Grain yield and agronomic characters of ALART ZER, Aman 2020 at BRRI RS, Bhanga, Faridpur.

Designation	Plant height (cm)	Panicle/m^2	Growth duration (day)	Yield (t ha^{-1})
BR10001-94-2-B	112.17	205	135	3.44
BRRI dhan72 (ck)	108.73	244	135	4.04
BRRI dhan87 (ck)	114.3	258	131	3.44
CV (%)	0.43	14.11	3.28	15.08
LSD (<0.05)	1.31	NS	NS	NS

Table 7. Grain yield and agronomic characters of ALART ZER, Boro 2020-21 at BRRI RS, Bhanga, Faridpur.

Designation	Plant height (cm)	Panicle/m^2	Growth duration (day)	Yield (t ha^{-1})
BR8912-12-6-1-1-1-1	104.67	336.67	158	11.2
IR105837-8-95-2-1	119.73	211	151	4.54
BRRI dhan74 (ck)	97.87	224	146	4.26
BRRI dhan89 (ck)	107.87	278.67	160	10.8
CV (%)	2.63	5.34	4.19	5.52
LSD (<0.05)	5.66	28.03	NS	0.85

Table 8. Grain yield and agronomic characters of ALART (FBR) Bhanga, 2020-2021 at BRRI RS, Bhanga, Faridpur

Designation	Plant height (cm)	Panicle/m^2	Growth duration (day)	Yield (t ha^{-1})
SVIN063-Bhanga	112.2	302	157	10.96
SVIN076-Bhanga	103.4	282	158	10.18
BRRI dhan29 (ck)	103.53	320	158	10.04
BRRI dhan89 (ck)	111.27	283	156	9.96
CV (%)	7.24	6.07	0.61	4.46
LSD (<0.05)	0.65	NS	NS	NS

Table 9. Grain yield and ancillary characters of RYT (GSR) Boro, 2020-2021 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
FBR189	106.4	123	8.12
FBR335	105.93	120	9.84
FBR336	104	128	11.12
FBR350	105.47	121	9.78
WANXIAN7777-P10-P3	100.53	121	11.47
BRRI dhan58 (ck)	101.6	123	10.51
BRRI dhan88 (ck)	99.8	125	10.21
Mean	103.39	123	10.15
CV (%)	1.41		6.37
HSD (0.05)	4.16		1.85

Table 10. Grain yield and ancillary characters of RYT (ZER) Boro, 2020-2021 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR8419-8-2-1-4-1-3-8-5	105	149	8.28
BR8913-12-4-8-9-2-3-11-22	99.13	149	10.1
BR9674-5-6-2-1-7-22	95.4	148	8.7
BRRI dhan74 (ck)	101.47	146	10.11
BRRI dhan84 (ck)	115.33	144	7.51
BRRI dhan89 (ck)	115.8	149	10.34
Mean	105.35	147	9.17
CV (%)	4.49	0.42	7.58
LSD (<0.05)	8.61	1.13	1.26

Table 11. Grain yield and ancillary characters of RYT (RYMT) Boro, 2020-2021 at BRRI RS, Bhanga, Faridpur.

Designation	GD (day)	PH (cm)	PL	ETH	Yield (t ha^{-1})
RH11-9-11-4-5B-HR3	145	103.6	25.13	13.93	9.34
BRH13-2-4-6-4B	145	103.63	24.93	14.07	8.63
BRRI dhan63 (check)	146	93.47	23.93	15	8.4
Mean	145.33	100.23	24.67	14.33	8.79
CV (%)		0.43	2.85	12.96	14.08
LSD (<0.05)	NS	0.99	NS	NS	NS

Table 12. Grain yield and ancillary characters of RYT (Barishal-1) Boro, 2020-21 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	PN/hill	GD (day)	Yield (t ha^{-1})
BRBa 1-4-9	128	14	158	8.93
BRBa 2-1-3	127.67	14	157	8.34
BRBa 2-5-3	109.67	15	143	10.22
BRBa 3-1-7	105.07	14	145	10.56
BRBa 3-2-4	105.2	17	145	11.2
BRBa 3-3-1	104.73	15	145	10.95
BRRI dhan58 (ck)	105.6	15	143	7.91
BRRI dhan92 (ck)	126.73	14	157	9.31
Mean	114.08	15	149	9.68
CV (%)	2.49	7.68	0.27	15.79
HSD (0.05)	8.18	NS	1.18	NS

Table 13. Grain yield and ancillary characters of RYT (Barishal-2) Boro, 2020-2021 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	PN/hill	GD (day)	Yield (t ha^{-1})
IR04A429	115.8	15	153	9.67
IR12A329	115.8	14	153	8.69
IR13A515	113.73	14	149	10.5
IR15A2820	106.13	18	145	9.46
IR15A2854	110.47	13	145	9.55
IR15A3466	111.93	12	143	10.44
IR16A2022	107.2	16	142	10.36
BRRI dhan58 (ck)	104.27	12	144	10.54
BRRI dhan92 (ck)	126.87	17	157	11.58
Mean	112.47	15	148	10.09
CV (%)	1.82	7.8	0.81	11.58
HSD (0.05)	5.94	3.3	3.49	NS

Table 14. Grain yield and ancillary characters of RYT (DRR-BB) Boro, 2020-2021 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR9650-108-2-3	104.2	155	9.96
BR9942-1-2-1-1-B1	97	155	8.12
BR9943-2-2	106.27	159	9.07
BR9943-35-2-1-2-B2	99.87	151	9.13
BR9943-35-26-2-3-6	115.6	159	8.02
BRRI dhan58 (sus ck)	104.73	147	8.51
BRRI dhan89 (sus ck)	116.07	157	9.01
IRBB60 (res ck)	80	152	7.77
Mean	102.97	154	8.69
CV (%)	2.37	0.55	6.21
LSD (<0.05)	4.27	1.47	0.95

Table 15. Grain yield and ancillary characters of RYT (FBR-MD) Boro, 2020-2021 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR8899-14-4-1-2-2-1	91.67	127	6.99
BRC297-15-1-1-1	115.67	125	9.28
BRC302-1-4-4-4	115.07	126	9.58
IR106236-B-B-B-PRN B-PRN B-PRN 261	119.87	132	7.04
IR106236-B-B-B-PRN B-PRN B-PRN 50	113.8	125	8.48
IR108000-B-B RGA-B RGA-185-1	102.4	125	5.12
IR15A2874	129.07	124	7.91
IR15A3500	107.13	124	7.5
IR15A3768	113.4	130	8.27
IR16A1135	103.8	126	7.82
IR16A2011	119.13	127	7.57
IR99982-B-B-B-B-18	102.93	128	5.51
SVIN069	101.4	124	7.84
SVIN109	113.79	129	8.5
SVIN266	106.53	124	8.76
TP21654	98.73	124	7.87
TP30610	119.53	128	7.47
BRRI dhan81	103.33	123	5.3
BRRI dhan84	95.2	143	9.1
BRRI dhan89	190.4	135	8.73
Mean	113.14	127	7.73
CV (%)	24.04	1.18	8.99

Table 16. Grain yield and ancillary characters of RYT (Cumilla-1) Boro, 2020-21 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BRC366-2-2-4-2-1	97.8	151	9.66
BRC366-2-2-4-2-3	99.47	151	9.23
BRC389-4-2-4-2	104.53	153	8.54
BRC401-1-1-1-1B	99.33	147	8.52
BRC426-4-2-1	99.8	151	8.02
BRC427-9-1-3	115.27	153	7.51
BRRI dhan81 (ck)	102.2	145	7.12
BRRI dhan84 (ck)	117.4	144	7.35
BRRI dhan88 (ck)	96.53	145	7.7
Mean	103.59	149	7.99
CV (%)	1.25		7.02
HSD (0.05)	3.77	NS	1.67

Table 17. Grain yield and ancillary characters of RYT (Cumilla-2) Boro 2020-2021 at BRRI RS, Bhanga, Faridpur.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BRC335-1-3-2-2-1	120.27	151	8.01
BRC394-1-1-1-2	131.33	155	8.57
BRC394-1-1-1-5A	103.07	158	6.83
BRC398-4-1-1-1B	116.67	157	8.95
BRC428-2-2-1	98.67	157	8.54
BRC428-3-1-1	97.47	150	7.47
BRC428-3-1-2	98.4	152	8.26
BRRI dhan50 (ck)	93.73	144	7.42
BRRI dhan58 (ck)	104.87	144	8.77
BRRI dhan89 (ck)	123.47	159	7.67
Mean	108.79	153	8.05
CV (%)	1.77	0.26	16.78
LSD (<0.05)	3.29	0.67	NS

Table 18. Grain yield and ancillary characters of RYT (STR) Boro 2020-21 at BRRI RS, Bhanga, Faridpur.

Designation	GD (day)	PH (cm)	TN	PN	Yield (t ha^{-1})
BR11723-4R-172	150	108.6	15	15	7.82
BR11716-4R-102	151	106.1	16.9	16.9	8.72
BR11715-4R-186	155	102.8	14.8	14.8	7.20
BR11716-4R-108	164	105	14.2	13.8	6.55
BR11716-4R-120	165	97.4	15.2	15.1	8.28
BR11712-4R-218	167	99.2	13.8	13.8	7.42
BR11723-4R-27	153	101.2	12.6	12.6	7.96
BR11716-4R-129	167	99.8	14.9	14	8.14
BR11723-4R-48	165	103.2	17.7	17.7	8.94
BR11716-4R-105	152	98	18.5	18.4	9.12
BR11723-4R-12	156	105.1	14.9	14.7	9.66
BR11716-4R-147	164	100.5	14.8	14.6	7.92
BR11712-4R-227	164	104.7	15.6	15.3	8.57
BR11716-4R-123	166	99	13.3	13.2	8.05
BR11716-4R-114	165	101.3	16.1	15.9	8.52
SVIN355	166	99.8	12	11.9	7.44
SVIN415	165	102.2	13.6	13.6	5.27
BR10672-1-3-7-12	148	110.4	18.5	18.5	7.81
BRRI dhan67*	157	106.6	13.1	13.1	5.04
BRRI dhan89	150	107.8	16.8	16.8	9.35
BRRI dhan97	155	104.4	21.2	21.2	9.53
BINA dhan10	150	88.9	19.7	19.7	8.04
Mean	161	102.36	15.6	15.48	7.97
CV (%)	0.094	1.68	9.6	9.88	6.39
LSD (<0.05)	0.31	3.57	3.11	3.18	1.06

Table 19. Deepwater rice germplasm characterized for different important quantitative traits during Aman 2020 season

Genotype	Code no.	PH (cm)	DF	DM	ET no.	PL (cm)	FG/P	GL (mm)	GB (mm)	1000 gwt.(g)	Yield/hill(g)
Jogdal	G1	177.60	142	170	11	29.60	179	8.29	2.61	24.45	17.00
Maitagorol	G2	168.80	141	169	8	29.40	156	9.10	2.91	28.14	15.00
Shialjota	G3	177.20	139	168	8	28.00	95	8.93	2.85	27.56	14.00
Sissumoti	G4	169.60	140	168	7	30.00	103	9.79	2.99	29.00	11.00
Bashiraj	G5	173.60	144	171	6	24.60	115	9.10	3.00	28.50	9.00
Hijoldigha-1	G6	170.00	145	172	9	23.00	101	7.75	2.73	27.18	14.00
Hijoldigha-2	G7	192.00	147	175	7	29.60	90	7.63	2.91	28.00	12.00
Hijoldigha-3	G8	158.00	144	172	9.	25.00	78	8.15	2.86	26.17	10.50
Dudkalom-1	G9	140.00	141	169	7	25.00	105	8.46	3.70	23.58	9.00
Moynamati	G10	159.00	148	175	12	29.80	150	7.02	3.02	23.88	14.00
Devmoni-1	G11	156.40	142	171	13	27.40	124	8.60	2.82	27.42	15.00
BRRI dhan91	G12	183.00	138	166	9	28.40	193	7.62	2.48	23.50	16.50
Kachkolom-1	G13	158.40	135	160	7	29.50	105	8.70	2.80	23.00	11.00
Dudkalom-2	G14	158.00	140	168	11	27.00	113	8.09	3.16	28.12	13.00
Laksmidigha-1	G15	151.00	142	170	9	29.00	105	8.45	3.17	26.62	12.00
Kartiksail-1	G16	138.00	148	169	9	19.00	112	8.37	2.60	27.03	13.00
Sahevdigha	G17	160.60	144	172	9	25.40	157	8.25	2.55	26.39	15.00
Laksmidigha-2	G18	162.80	130	160	11	29.00	139	8.43	3.21	28.61	12.00
Kartiksail-2	G19	145.00	127	155	10	24.00	120	7.65	2.90	22.65	14.00
Khaiamatar	G20	174.20	140	168	9	24.20	98	7.54	3.50	23.50	14.00
Kachkalom-2	G21	180.60	138	166	7	28.80	97	8.85	2.75	24.50	11.00
Kartiksail-3	G22	166.20	143	171	11	26.60	177	7.71	2.94	28.50	15.00
Laksmidigha-3	G23	182.20	141	169	10	29.00	159	8.60	3.00	26.41	14.00
Debmoni-2	G24	151.00	133	161	10	24.00	110	8.50	2.78	24.72	13.00
Laksmidigha-4	G25	199.80	143	172	11	28.50	190	8.72	3.27	28.50	15.00
Dudkalom-3	G26	162.40	139	167	7	29.40	105	8.42	3.74	24.14	8.00
Dudmoni	G27	168.60	138	166	11	29.40	136	8.60	3.71	28.00	14.00
Min.		138.00	127.00	155	6	19.00	78	7.02	2.48	22.65	8.00
Max.		199.80	148.00	175	13	30.00	193	9.79	3.74	29.00	17.00
Mean.		166.07	140.44	168.15	9.19	27.13	126.54	8.35	3.00	26.22	13.00
CV (%)		8.95	3.52	2.76	19.81	10.13	25.83	7.11	11.47	7.87	17.43
LSD (<0.05)		5.61	1.86	1.75	0.69	1.04	12.33	0.22	0.13	0.78	0.85

PH: plant height, DF: days to flowering, DM: days to maturity, ET no.: effective tiller number, PL: panicle length, FGP: filled grains per panicle, GL: grain length, GB: grain breadth, TGW: 1000-grain weight, Y/hill: yield per hill

Table 20. Yield performance of different improved cropping pattern for medium high land area in Faridpur district.

Cropping pattern (CP)	Rabi			Kharif-1 (Jute)		Kharif-2 (Aman)
	Crop	Partitioning yield (t in ha)	Partitioning REY (t in ha)	Component yield ($t\ ha^{-1}$)	Component REY ($t\ ha^{-1}$)	Component yield ($t\ ha^{-1}$)
CP1= Potato+Maize-Jute-T.Aman	Potato	12.0	11.5	3.2	6.4	4.9
	Maize	5.1	3.9			
CP2= Onion+Pumpkin-Jute-T.Aman	Onion	11.2	10.8	3	6	6.1
	Pumpkin	5.0	2.3			
CP3= Lentil+Maskmelon-Jute-T.Aman	Lentil	2.56	4.9	3.1	6.2	6
	Maskmelon	2.0	0.6			
CP4= Mustard+watermelon-Mungbean-Jute-T.Aman	Mustard	1.12	2.4	3.2	6.4	5.1
	watermelon	2.4	2.3			
	Mungbean	1.2	3.2			
CP5= Onion-Jute-T.Aman (Ck)	Onion	13.0	12.5	3.3	6.6	4.1

Table 21. Comparative profitability performance of different cropping pattern with existing one.

Cropping pattern (CP)	REY ($t\ ha^{-1}$)	Increasing REY (%)	GR (Tk)	TVC (Tk)	TC (Tk)	GM (TK) (GR-TVC)	NR (TK) (GR-TC)	BCR (GR/TC)	OER (%)	NFIR (%)
CP1= Potato+Maize-Jute-T.Aman	26.7	(+) 15.09	684500	244063	254063	440437	430437	2.69	37.12	62.88
CP2= Onion+Pumpkin-Jute-T.Aman	25.2	(+) 8.62	642500	210223	220223	432277	422277	2.92	34.28	65.72
CP3= Lentil+Maskmelon-Jute-T.Aman	17.7	(-) 23.70	449000	166894	176894	282106	272106	2.54	39.40	60.60
CP4= Mustard+watermelon-Mungbean-Jute-T.Aman	25.63	(+) 10.47	488100	188189	198189	299911	289911	2.46	40.60	59.40
CP5= Onion-Jute-T.Aman (CK)	23.2	-	592500	197516	207516	394984	384984	2.86	35.02	64.98

GR= Gross return, TVC= Total variable cost, TC= Total cost, GM= Gross margin, NR= Net return, BCR= Benefit cost ratio, OER= Operating expense ratio, NFIR= Net farm income ratio

Table 22. Effect of different treatments using polythene cover in seed bed to identify effective technique for protecting Boro rice seedling from cold injury.

Treatment	SH (cm)	RL (cm)	LN	SW (g)	RW (g)	Mortality/m^2	GD (day)
T1	37.22	11.41	3.96	2.17	0.90	358.12	148
T2	34.48	16.05	4.61	2.25	0.90	400.52	146
T3	41.95	17.7	5.82	2.3	0.90	420	146
T4	38.54	15.78	4.52	2.23	0.97	420.63	146
T5	49.22	17.52	4.63	2.13	0.90	378.07	146
T6	40.94	19.45	4.88	2.23	0.93	393.12	146
Mean	40.39	16.32	4.74	2.22	0.92	395.08	146.33
CV (%)	12.03	21.32	16.41	8.0	11.44	10.6	

SH: Shoot height, RL: Root length, LN: Leaf number, RW: Root weight

T1: Polythene covering for all time at seedbed

T2: Polythene covering for 24 hrs at seedbed during cold wave (little or no sunshine, foggy weather all day long, average temperature less than 15º C)

T3: Polythene covering from 11.0 am to sun set

T4: Polythene covering for whole night

T5: Polythene covering for all time with round shape opening (20 cm diameter) at both end of the seedbed cover

T6: No polythene covering/ Control

Table 23. Grain yield and agronomic characters of BRRI released short duration Aman varieties under stability analysis in T. Aman, 2020 at BRRI RS, Bhanga, Faridpur.

Variety	GD (day)	PH (cm)	Tiller/hill	Panicles/hill	PL (cm)	Yield (t ha^{-1})
BRRI dhan33	121	91.2	10.07	9.47	22.87	4.11
BRRI dhan39	125	89.67	12.53	11.73	22.87	4.53
BRRI dhan53	130	98.07	9.8	8.67	24.4	3.93
BRRI dhan56	115	99.87	7.93	8.93	23.73	3.33
BRRI dhan57	110	80.2	8.93	8.07	23.87	3.44
BRRI dhan62	108	74.8	9.73	8.73	23	4.19
BRRI dhan66	119	90.13	9.27	8.4	22.53	3.91
BRRI dhan71	118	86.93	8.67	8.26	21.93	4.61
BRRI dhan73	128	102.53	10.93	10.07	22.73	4.03
BRRI dhan75	120	87.27	9.73	8.93	23.67	5.26
BRRI dhan87	131	109.6	10.53	9.33	25.33	6.49
BRRI dhan90	127	109.8	8.8	8.33	23.67	4.79
BRRI dhan95	130	119.4	12.73	11.47	24.53	4.99
BRRI hybrid dhan4	123	83.2	11.07	10.33	23	6.42
BRRI hybrid dhan6	125	88.07	9.67	8.6	21.87	6.47

Table 24. Grain yield and agronomic characters of BRRI released medium duration T. Aman varieties under stability analysis in T. Aman, 2020 at BRRI RS, Bhanga, Faridpur.

Variety	GD (day)	PH (cm)	Tiller/hill	Panicle/hill	PL (cm)	Yield (t ha^{-1})
BR3	150	66.53	12.27	12.27	21.6	3.16
BR4	149	123	9.6	9.6	23.93	3.48
BR11	148	97.27	11.4	11.4	23.67	4.99
BR25	140	110.06	8.33	8.33	24.6	4.34
BRRI dhan30	150	106.73	11.8	11.8	24.27	4.54
BRRI dhan31	143	112.67	8.53	8.53	26	4.35
BRRI dhan32	135	102.47	7.6	7.6	24.2	4.32
BRRI dhan40	146	118.93	11.07	11.07	25.07	4.3
BRRI dhan44	146	111.13	7.33	7.33	24.4	4.78
BRRI dhan49	140	87.53	10.53	10.53	21.27	5.39
BRRI dhan51	150	75.33	9.4	9.4	19.73	4.1
BRRI dhan52	149	98.93	9.2	9.2	21.07	4.43
BRRI dhan54	138	103.47	8.4	8.4	23.07	4.02
BRRI dhan70	135	113.2	9.13	9.13	24.33	4.79
BRRI dhan72	131	113.06	11.2	11.2	25.13	5.49
BRRI dhan77	154	137.06	12.87	12.87	26.27	3.92
BRRI dhan78	139	81.73	9.27	9.27	24.33	4.19
BRRI dhan79	145	89.06	8.53	8.53	25.06	5.09
BRRI dhan80	135	89.8	7.2	7.2	24.73	4.8
BRRI dhan93	140	108.8	13.07	13.07	25.13	4.39
BRRI dhan94	138	119.73	15.6	15.6	25.87	4.73

Table 25. Grain yield and agronomic characters of BRRI released long duration T. Aman varieties under stability analysis in T. Aman, 2020 at BRRI RS, Bhanga, Faridpur.

Variety	GD (day)	PH (cm)	Tiller/hill	Panicle/hill	PL (cm)	Yield (t ha^{-1})
BR5	156	125	12	11	22.5	2.76
BR10	154	98	12	11	24.2	4.86
BR22	155	106	12	10	25.3	4.94
BR23	154	108	13	12	24	3.27
BRRI dhan34	142	123	12	10	20.86	3.09
BRRI dhan37	146	108	11	11	23.33	2.84
BRRI dhan38	143	108	17	16	23.47	2.68
BRRI dhan41	154	120	11	10	24.4	3.51
BRRI dhan46	152	117	10	9	22.06	4.24
BRRI dhan76	161	124	11	9	24.67	4.79
BRRI dhan91	160	175	15	15	28.87	2.06

Table 26. Grain yield and agronomic characters of BRRI released short duration Boro varieties under stability analysis in Boro, 2020-21 at BRRI RS, Bhanga, Faridpur.

Variety	GD	PH (cm)	Tiller/hill	Panicle/hill	PL (cm)	Yield (t ha^{-1})
BR1	154	87.2	14	13	22.5	5.45
BR6	145	99.5	13	13	22.8	5.78
BR26	142	108	13	13	21.4	5.58
BRRI dhan27	135	119.23	13	12	23.2	5.75
BRRI dhan28	143	92.12	13	12	23.12	6.5
BRRI dhan36	145	91.54	15	12	22.5	5.23
BRRI dhan45	138	102	12	11	23.2	4.8
BRRI dhan55	148	98.78	12	12	24.8	5.12
BRRI dhan61	152	95.42	11	11	23.21	5.35
BRRI dhan63	150	86.31	13	12	22.5	6.35
BRRI dhan67	148	97.15	16	16	23.87	7.75
BRRI dhan68	152	96.14	13	11	22.12	6.35
BRRI dhan74	148	96.12	14	12	23.45	6.5
BRRI dhan81	144	101.42	15	15	23.21	6.86
BRRI dhan84	145	95.12	14	13	23.5	6.75
BRRI dhan86	143	95.42	15	12	23.75	5.64
BRRI dhan88	145	94.56	16	15	22.78	7.25
BRRI dhan96	146	85.32	15	15	22.56	7.23
BRRI hybrid dhan2	148	103.42	16	15	24.52	7.62
BRRI hybrid dhan3	147	102.14	16	16	23.85	7.51
BRRI hybrid dhan5	147	107.45	17	16	25.57	8.12

Table 27. Grain yield and agronomic characters of BRRI released long duration Boro varieties under stability analysis in Boro, 2020-21 at BRRI RS, Bhanga, Faridpur.

Variety	GD	PH (cm)	Tiller/hill	Panicle/hill	PL (cm)	Yield (t ha^{-1})
BR2	165	115.28	13	13	21.95	5.25
BR3	173	93.84	13	12	22.75	5.75
BR7	157	118.34	13	13	23.24	6.65
BR8	161	118.42	13	13	22.13	6.55
BR9	157	117.45	13	13	22.95	5.46
BR12	169	103.48	12	12	23.14	5.87
BR14	158	115.26	13	13	22.72	5.67
BR15	168	89.36	11	11	22.74	5.46
BR16	167	88.46	11	11	23.45	6.12
BR17	158	118.47	12	12	22.42	5.98
BR18	173	113.47	12	12	22.36	5.92
BR19	171	108.12	11	11	23.18	6.32
BRRI dhan29	158	92.53	16	16	24.85	8.25
BRRI dhan35	154	101.42	13	13	22.65	5.41
BRRI dhan47	146	101.48	14	12	24.1	5.24
BRRI dhan50	158	78.95	14	12	23.12	5.5
BRRI dhan58	149	97.42	15	15	24.62	7.5
BRRI dhan59	148	81.47	13	12	22.31	5.56
BRRI dhan60	147	96.23	12	12	22.14	5.55
BRRI dhan64	156	85.98	12	12	23.24	6.21
BRRI dhan69	154	102.45	11	11	23.63	5.37
BRRI dhan89	158	104.14	17	16	23.85	8.85
BRRI dhan92	160	105.42	16	16	24.75	8.74
BRRI dhan97	154	99	15	15	23.75	7.12
BRRI dhan99	157	93	15	14	23.45	7.32

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BRRI RS, Cumilla

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SUMMARY

Altogether 42 crosses were made and 39 crosses were confirmed during T. Aman and Boro seasons. A total of 688, 470, 458 and 227 plants were selected from F_2, F_3, F_4 and F_5 generation, respectively. Seventy five breeding lines were bulked from F_5 to F_6 generation. From LST, total 241entries were selected from six crosses. Twenty genotypes were selected from OYT (Cum) based on high yield performance, disease reaction and other good agronomic characters. Seven and four entries from PYT#1 and PYT#2, and 7, 5, 4, 2, 3, 5 genotypes from SYT#1 (Cum), SYT#2 (Cum)-INGER, SYT#3 (Cum)- GSR, AYT, AYT#1 (Cum) and AYT#3 (Cum), respectively were selected. One and three entries were selected from RYT#1, RYT#1 (Cum). In ALART (IRR), one entry performed better than check varieties. During T. Aman season 3, 1, 3, 2, 2, 1, 4, 2, 2 genotypes were selected from AYT (SSG), AYT (LSG), RYT#2 (BPH & GM), RYT (BB), RYT#1 (RLR), RYT#2 (RLR), RYT#1 (PQR), RYT#2 (PQR) and RYT#2 (ZER), respectively. In Boro season, 1, 2, 0, 4, 2, 5, 2, 11 genotypes performed better than check varieties in RYT (STR), RTY (BB), RYT (GSR), RYT (PQR), RYT (ZER), RYT#1 (Barishal), RYT#2 (Barishal) and RYT (MD), respectively.

Under Transforming Rice Breeding (TRB) Project, 15, 3, 24 and 6 genotypes performed better than check varieties in PYT (IRR) (BPH and GM), PYT#1(BB), PYT#2 (BB) and in PYT (DTR), respectively. Seventy, 44 and 67 genotypes were selected from OYT (BB), OYT (IRR) (BPH and GM) and OYT (FBR), respectively. Five, 30, 17 and 24 genotypes performed better than check varieties in AYT (IRR) (BPH and GM), AYT (FBR), AYT (BPH) and BVE. Three entries were selected in Confined Field Trial (CFT) under healthier rice project (HRP).

Neck blast in aromatic rice, sheath blight, bacterial blight, tungro, false smut in T. Aman, and neck blast, bacterial blight, Tungro, sheath blight diseases in Boro season were found predominant in Cumilla region. Three lines from MLT and 38 preselected lines were confirmed and reselected for blast resistant lines. Major factors for rice tungro disease development were identified. Tungro disease was prevented from the seedbed to main field by following the tungro disease technology in Nangalkot, Cumilla. Result from disease development indicated that the false smut disease might be air-borne but the result needs further evaluation. In the crop loss assessment, overall yield loss was not determined as predominant.

Nitrogen was the most yield limiting factor for T. Aman and Boro seasons. A combination of 200 kg K and 100 kg N for BRRI dhan87 and 200 kg K and 140 kg N for BRRI dhan89 were observed suitable for desired yield. For DAP experiment, treatments T_2 (DAP + Urea 100% STB) and T_7 (DAP + Urea 60% STB) were observed producing higher yield in BRRI dhan96 and BRRI dhan87, respectively compared to other treatments. BRRI dhan93 (4.2 t ha^{-1}) and BRRI dhan89 (7.67 t ha^{-1}) produced higher grain yield upto 04 August and 30 November planting, respectively. The best sowing time for long duration varieties (>140 days) was 15 and 30 November. Polythene covering for all time with round shape opening at both ends of the seedbed highly performed in terms of seedling dry weight and height.

Under stability analysis BRRI hybrid dhan7 (5.11 t/ha), BRRI hybrid dhan6 (5.60 t/ha) and BRRI hybrid dhan3 (9.52 t/ha) gave the highest yield during T. Aus 2020, T. Aman 2020 and Boro 2020-21, respectively.

A total of 150 demonstration trials were conducted under Head to Head (TRB-ARD project), SPIRA project and GoB funded programs. Among the demonstrations farmers' first preference was BRRI dhan71 (SD), BRRI dhan87, BRRI dhan94 (medium short duration) for T. Aman; BRRI dhan81 (SD), BRRI dhan89 (long duration) and BRRI dhan92 for Boro season due to their grain quality, panicle length and higher yield. Fourteen farmers' trainings and 11 field days were conducted in the block demonstration areas at Cumilla region. BRRI RS, Cumilla also participated in two Krishimela, one agricultural fair and one development fair.

VARIETAL DEVELOPMENT

T. Aus rice. Two (BR9829-30-3-2-1, BR9029-51-3-5) and BR9830-53-3-5-2 genotypes were selected from AYT, RYT#1 respectively (Table 1).

Table 1. Performance of entries in RYT#1, T.Aus 2020-21, BRRI RS, Cumilla.

Designation	GD (day)	PH (cm)	ET/hill	Y (t/ha)
BR9829-80-2-2-1	106	103	12	4.50
BR9830-53-3-5-2**	108	104	12	5.14
BR9830-74-4-3-1	102	107	12	4.64
BRRI dhan48 (ck)	105	111	11	4.72
BRRI dhan82 (ck)	97	107	11	4.37
LSD (0.05)	0.92	ns	1.02	0.51
Heritability	0.99	0.22	0.79	0.62

**performed better DS: 17 Apr 2020 DT: 6 May 2020

T. Aman rice. Twenty-two crosses were made, 26 F_1 were confirmed and considering improved plant type, earliness, acceptable grain quality and high yield potentiality total 197, 78 and 21 plants were selected from F_3, F_4 and F_5 generations, respectively and 27 breeding lines were bulked from F_5 to F_6 generation. Four genotypes (BRC457-2-2-1-1, BRC457-3-2-1-1, BRC457-3-1-3-1 and BRC464-29-1-1-1) performed better than check varieties in OYT (Cum) and 3 (BRC368-2-2-3-2-4, BRC375-18-1-1-3-3,BRC375-18-1-1-2-2), 3 (IR93340:11-B-6-2-12-1RGA-2RGA-1-B, IR93339:29-B-7-7-18-1RGA-2RGA-1-B, IR104548:8-B-15-10-3-11-3-B) , 4 (IR2-12-R5-Y1-L2, IR1-DQ125-L2-D2, IR1-DQ126-R4-Y1, IR1-DQ189-R1-L2), 3 (BRC355-9-1-1-1, TP30523, BRC315-14-2-3-1-1-H1), 5 (BR9571-28-2-1-2-1, BR9573-28-2-5-1-1, BR9881-24-2-2-25, BR9880-2-2-2-1, BR10001-94-2-B) genotypes were selected from SYT#1 (Cum), SYT#2 (Cum)-INGER, SYT#3 (Cum)- GSR, AYT#1 (Cum) and AYT#3 (Cum) respectively. Three (BRH11-7-17-10B, BRH15-24-7-B, BRH14-9-13-16B), 1 (BRH11-2-4-7B), 3 (BR9880-24-2-1-14, BR9882-17-2-2-32, BR9888-26-9-14-3), 2 (BR10397-3-2-1-1, BR10392-B-B-12-P2), 2 (BR9857-7-6-5-1, IR98396-B-B-B-B-40), 1 (BR8492-9-5-3-2-HR1), 4 (BR8493-3-5-1-P1, BR9590-45-1-3-2-P2, BR8515-28-1-1-3-HR3 (Cum), Krishnobhog type), 2 (BR9054-6-1-2-3, BR9581-16-3-5-3), 2 (BR9674-1-1-5-2-P4, BR9674-3-3-1-1-P3) genotypes performed better than check varieties in AYT (SSG), AYT (LSG), RYT#2 (BPH and GM), RYT (BB), RYT#1 (RLR), RYT#2 (RLR), RYT#1 (PQR), RYT#2 (PQR) and RYT#2 (ZER) respectively. In ALART (IRR), BR9880-27-4-1-18 performed better than check varieties (Table 2).

Boro rice: 20 crosses were made, 13 F_1 were confirmed and 58 plant progenies were selected from F_2 generation. Considering earliness, strong culm, high yield potential and disease and insect resistance 272, 379 and 204 plants were selected from F_3, F_4 and F_5 generation, respectively and 47 breeding lines were bulked from F_6 generation. From LST, 241 entries were selected from six crosses. Based on high yield performance, disease reaction and other good agronomic characters 16 (BRC466-37-5-1-B1, BRC466-37-5-1-B2, BRC466-48-3-1-B1, BRC471-1-1-1- B1, BRC471-1-1-2- B1, BRC471-1-1-2- B3, BRC472-19-1-1-B1, BRC472-19-1-1-B3, BRC477-2-1-4-B2, BRC477-2-1-4-B4, BRC477-2-1-4-B5, BRC480-14-1-1-B2, BRC491-5-2-1-B1, BRC491-5-2-1-B2, BRC491-5-2-1-B3, BRC451-13-1-2-2-B3) genotypes performed better than check varieties in OYT (Cum). Seven (BRC542-32-1-4, BRC546-19-1-10, BRC546-5-1-5, BRC468-14-3-2-10, BRC479-24-2-1-27, BRC454-36-3-1-4-5, BRC455-2-1-1-1-3) and four (BRC548-22-1-6, BRC548-43-1-9, BRC468-7-1-3-3, BRC480-2-1-1-2) entries were selected from PYT#1 and PYT#2 respectively. Four (BRC491-5-2-1, BRC454-36-3-3, BRC430-2-1-1-1, BRC430-14-1-4-4) and two (BRC430-2-1-3-1, BRC430-12-1-8-6) genotypes were selected from SYT#1 and SYT#2 respectively. BRC366-2-2-4-2-1, BRC389-4-2-4-2, BRC401-1-1-1-1B and BRC366-2-2-4-2-3 were selected from RYT#1 (Cum). One (BR11712-4R-232), 2 (BR9943-2-2-P1-HR2, BR9650-108-2-3-P3), 4 (BR9930-2-2-4-1, BR9930-2-2-4-3, BR9930-2-3-2-2, BR9938-20-1-1-1), 2 (BR8419-8-2-1-4-1-3-8-5, BR9674-5-6-2-1-7-22), 5 (BRBa 2-1-3, BRBa 2-5-3, BRBa 3-1-7, BRBa 3-2-4, BRBa 3-3-1), 2 (IR04A429, IR12A329), 11(IR15A2874, IR16A2011, IR106236-B-B-B-PRN B-PRN B-PRN 50, IR106236-B-B-B-PRN B-PRN B-PRN 261, TP30610, SVIN266, BRC297-15-1-1-1, BRC302-1-4-4-4, IR15A3768, TP21654) genotypes performed better than check varieties in RYT (STR), RTY (BB), RYT (PQR), RYT (ZER), RYT#1 (Barishal), RYT#2 (Barishal) and RYT (MD) respectively (Table 3).

Table 2. Performance of entries in ALART (IRR-BPH), T. Aman 2020.

Designation	GD (day)	PH (cm)	Y (t/ha)
V1=BR9880-40-1-3-34	127	116	4.15
V2=BR9881-24-2-2-25	127	115	3.55
V3=BR9880-27-4-1-18**	125	118	4.90
V4=BR9880-2-2-2-1	1230	116	3.89
V5=BRRI dhan93 (ck)	129	114	4.42
V6=T27A (R. ck)	142	135	3.28
LSD (0.05)	1.132	6.41	ns

**performed better Location: Chandina, Cumilla DS: 5 Jul 20 DT: 4 Aug 20

Table 3. Performance of entries in RYT#1-Cum (HQ and RS), Boro 2020-21.

Designation	GD* (days)	PH* (cm)	Yield (t/ha)										
			Bar	Bha	Cum	Gaz	Hbj	Kus	Raj	Ran	Sat	Srj	Average
BRC426-4-2-1	153	98	6.2	8.02	6.02	5.51	7.37	6.16	7.61	5.17	6.65	8.73	6.74
BRC366-2-2-4-2-1**	155	95	6.88	9.65	7.34	6.31	8.00	7.05	8.45	7.0	7.13	7.18	7.50
BRC427-9-1-3	157	102	6.03	7.51	5.95	4.52	5.98	5.83	7.7	6.07	6.35	9.15	6.51
BRC389-4-2-4-2**	151	98	6.62	8.54	6.62	5.56	6.06	6.24	6.97	7.09	7.11	9.83	7.06
BRC401-1-1-1-1B**	155	97	6.48	8.52	7.97	6.61	6.22	6.14	8.78	7.18	7.49	8.92	7.43
BRC366-2-2-4-2-3**	156	95	7.6	9.23	7.07	6.15	6.77	6.75	8.95	7.09	5.8	8.15	7.36
BRRI dhan81 (Ck)	148	97	6.15	7.12	6.49	5.25	6.35	6.07	6	5.08	6.43	8.38	6.33
BRRI dhan84 (Ck)	146	108	6.29	7.35	6.81	5.13	6.60	5.57	4.29	5.58	6.41	8.14	6.22
BRRI dhan88 (Ck)	148	90	6.13	7.7	6.73	4.66	7.57	5.43	6.51	6.33	6.88	7.39	6.53
			0.39	0.86	0.68	0.8	0.37	0.45	0.82	1.01	0.78	ns	
			0.92	0.87	0.84	0.84	0.97	0.9	0.96	0.81	0.71	0.33	

*average of ten locations ** selected entries

ϒ Investigators: A K M Shalahuddin, P Nandi, M Hossain, K M Iftekharuddaula, Atiqul Islam, Shamsunnaher, I Zahan and A Islam.

TRB Project. In T. Aman season, thirty-nine (39) and 44 genotypes produced yield more than 5.50 t/ha and 6.50 t/ha in OYT (BB) and OYT (IRR) (BPH and GM) genotypes such as, respectively. Fifteen (BR10772-4R-13, BR10769-4R-4, BR10763-4R-2, BR10762-4R-3, BR10772-4R-14, BR10772-4R-17, BR10762-4R-15, BR10772-4R-9, BR10762-4R-15, BR10764-4R-7, BR10762-4R-17, BR10762-4R-6, BR10762-4R-14, BR10774-4R-14, SVIN351), 2 (BR10395-19-4-4-1, BR10393-4-1-1-6-1), 9 (BR10913-21-1-2, BR10919-13-6-1, BR10923-4-1-1, BR10925-14-1-1, BR10927-4-4-5, BR10510-8-1-1-4-2, BR10510-20-3-1-3, BR10510-20-3-2-1, BR10510-30-3-1-3) and seven (BR10535-12-2-3-1-2, BR10537-7-2-1-3-2, BR10538-2-1-2-3-1, BR10538-2-1-2-3-2, BR10539-8-1-3-2-2, BR10540-4-1-2-4-1, BR10540-4-1-2-4-4) performed better than the check varieties in PYT (IRR) (BPH and GM), PYT#1 (BB), PYT#2 (BB) and in PYT (DTR) respectively. Five genotyes (IRBPHN-SVIN002-18, IRBPHN-SVIN007-18, IRBPHN-SVIN039-18, IRBPHN-SVIN049-18, IRBPHN-SVIN288-18) performed better than the check varieties in AYT (IRR) (BPH and GM).

In Boro season, 31 entries produced yield more than 6.50 t/ha in OYT (BB) and 67 entries produced yield more than 7.50 t/ha in OYT (FBR). One and 15 entries performed better than check varieties in PYT#1 (BB) and PYT#2 (BB) respectively. 30 entries produced yield more than 7.0 t/ha in AYT (FBR) and 17 genotypes gave yield more than 6.50 t/ha in AYT (BPH).

24 entries gave yield more than 7.00 t/ha in BVE.

ϒ Investigators: A K M Shalahuddin, I Zahan, A Islam and K M Iftekharuddaula.

Healthier Rice Project. Three entries (IR 135161 TR-4-B-23, IR 133904 TR-B-B 2-B-25 and IR 133904 TR-B-B 3-B-28) performed better than standard check variety BRRI dhan28 in confined field trial (CFT) during Boro season.

ϒ Investigators: A K M Shalahuddin, M M Rashid, A Islam and A Kader.

PEST MANAGEMENT

Rice tungro disease management technology. Experiments were conducted to develop a technology for rice tungro disease management at BRRI RS, Cumilla. Preventive measure was observed as the only way to control rice tungro disease. Recommended rice tungro disease management technology was as follows: (1) Seedbed along with surroundings should be kept free from GLH by light trapping/hand sweeping/insecticide spray; (2) Spray registered systemic insecticide viz. MIPC 2.6g /Cartap 2.4g /Carbaryl 3.4g / Chorpyriphos 2ml / Carbosulfan 2ml per litre water are the most effective in the seedbed for 2 times for controlling GLH. The season-wise spray times: (a) During Aus season, 10 days after seeding (DAS) and about 3-5 days before transplanting, (b) During T. Aman season, 10-15 DAS and about five days before transplanting, (c) During Boro season, 15-20 DAS and about five days before transplanting. Benefit of the technology: Cost of two times insecticide spray in two decimal seedbed was only 22-44 taka which could protect one bigha (33 decimal) rice field from tungro. Farmers could save at least Tk 16640/- (1040/- x 16 maund) per bigha.

ϒ Investigators: M M Rashid, M S Mian, M Hossain, A Islam, F H Khan S A I Nihad, M A I Khan, M A Latif.

Survey and monitoring of rice diseases in selected areas during 2020-21. Digital disease survey was conducted in total 476 spots of five upazila viz sadar Dakshin (71 spots), Barura (55 spots), Burichang (76 spots), Debidwar (19 spots), Chauddogram (9 spots) during T. Aman 2020 and 3 upazila namely Nangalkot (48 spots), Laksam (86 spots) and Burichang (112 spots) during Boro 2020-21 season in Cumilla district using ODK mobile Apps to know the present status of different rice diseases under various climatic environments. During T. Aman 2020, disease incidence (% DI) of neck blast (in aromatic rice), sheath blight, bacterial blight, tungro, false smut, sheath rot and brown spot were 1-35, 22-70, 26-53, 2-90, 1-20, 1-2 and 20-60 %, respectively**.** During Boro 2020-21 season neck blast, bacterial blight, tungro, sheath blight and brown spot were recorded as major rice diseases of which % DI were ranged from 1-6, 10-45, 20-100, 10-60 and 22-90%, respectively in BRRI developed and local varieties. Neck blast, along with other major rice diseases, was observed having very low incidence during Boro season.

ϒ Investigators: M Hossain, M M Rashid, M A I Khan, T H Ansari, M A Latif, A Islam.

Multi-Location Trial (MLT) of Blast resistant advanced lines during Boro season 2020-21. Multi-Location Trial (MLT) consisting of 11 advanced lines along with susceptible check BRRI dhan28 was evaluated at farmers' field in blast prone area of Debidwar, Cumilla to evaluate specific blast disease resistance and general adaptability of the advance breeding lines. Fungicides recommended for blast or other diseases were not applied. Out of 11 advanced lines, six lines such as BR (path) 12452-BC3-35-21-8-5, BR (path) 12452-BC3-42-22-11-4, BR (path) 12452-BC6-53-21-11, BR (path) 13784-BC3-61-1-6-HR3, BR (path) 13784-BC3-62-3-5-HR2, BR (path) 13784-BC3-63-6-4-HR showed resistant against leaf and neck blast whereas check variety BRRI dhan28 showed susceptible reaction to blast (18% DI and DS 9). Grain yield was ranged from 6.06 to 6.66 t/ha. Out of six blast disease free lines three lines viz BR (path) 13784-BC3-61-1-6-HR3, BR (path) 13784-BC3-62-3-5-HR2, BR (path) 13784-BC3-63-6-4-HR showed very good phenotype.

ϒ Investigators: M M Rashid, M Hossain, A Islam, M A I Khan, T H Ansari, M A Latif.

Field evaluation of 38 blast resistant lines in blast hot spot area in Cumilla: Thirty-eight highly leaf and neck blast resistant lines were selected from 3988 tested lines during Boro 2019-20. Those 38 lines along with four susceptible/parent checks were used for blast disease resistant confirmation during Boro 2020-21 in blast hot spot area in Debidwar, Cumilla. All the 38 genotypes showed neck blast resistant whereas, susceptible checks showed 10-30 % neck blast with severity scores 9.

ϒ Investigators: M M Rashid, M Hossain, A Islam, M Khatun, S S Dipti, M A Hasan, T H Ansari, M A I Khan, M A Latif and Y Fukuta.

Effectiveness of formulated biopesticides to control bakanae disease of rice in field condition. Two field trials were conducted in Debidwar, Cumilla during Boro 2020-21 season with three treatments namely, T1=Trichoderma treated in the seedbed, T2=Root dipping with

Trichoderma+ Bacteria 1 for 30 min and T3=Control with three replications to evaluate field efficiency of formulated biopesticides against bakanae disease of rice in field condition. The experiment was funded by NATP-2 (ID.159). Rice bakanae disease was not found both in the seedbed and in the main field after transplanting. Some bakanae disease was found in both the trials during split booting stage which was non-significant in yield parameters.

ϒ Investigators: Q S A Jahan, M Hossain, M M Rashid, A Islam, M A Latif.

Factors affecting rice tungro disease and its management in Cumilla region. From the field experiments in different locations of Nangalkot and Laksam upazila, Cumilla during Boro seasons 2020-21, the main factors for tungro devastation in Cumilla region were revealed which were (1) presence of abundant GLH in the seedbed, (2) tungro disease symptom appears in the seedbed, (3) Intensive rice cultivation (Rice-Rice-Rice), (4) High rainfall with higher number of rainy days, (5) High temperature 35ºC to 38ºC, (6) Susceptible rice cultivars including Indian varieties, (7) Presence of source plants around the year. During Aus 2020 season, tungro disease devastation (DI 90%, DS 9) was found in Hybrid Balia 2 at Atakora, Nangalkot, Cumilla. Yield of that variety was 0.75 t/ha with 125 days growth duration (expected yield of Hybrid Balia 2 was 6.5 t/ha hence, yield lose was 89%). Tungro disease symptom was observed in the seedbed at Atakora, Nangalkot, Cumilla during T. Aman 2020. BRRI dhan75 infected from seedling stage with tungro disease showed severe infection (DI 95%, DS 9) at field level. Grain yield was 0.56 t/ha with GD 124 days (expected yield of BRRI dhan75 was 6.0 t/ha hence, yield lose was 91%). During Boro 2020-21, field experiments were conducted in different locations of Nangalkot (Ossodia, Jorpukuria and Mandra). Forty-six seedbeds were selected for tungro disease management. Tungro disease was not found in the experimental areas whereas, in adjacent village (Atakora) BRRI dhan29 and Hybrid Hira-2 were infected by tungro with DI 70-90% and DS 9 and yield loss was obtained upto 75-91 % from the infected plot. About 6,000 leaflets of tungro disease management technology were distributed to the farmers and extension personnel of Cumilla, B Baria and Chandpur before T. Aman seedbed 2020.

ϒ Investigators: M M Rashid, M S Mian, M Hossain, A Islam, F H Khan, S A I Nihad, M A I Khan, M A Latif.

Validation of rice neck blast disease management technology under farmer's field condition. A blast disease management field validation trial was conducted at BRRI RS farm, Cumilla during T. Aman 2020 using highly susceptible rice variety BRRI dhan34 to build up farmers' awareness on rice blast disease management and minimize yield loss. Five kg MOP/bigha was applied additionally during last top dress of urea and sprayed fungicide Trooper or Tricyclazole group @ 1 g/L water for 2 times as preventive, 1st spray at late booting stage and 2nd one at flowering stage in the evening. Neck blast disease was obtained severe (46% DI) in BRRI dhan34 in farmers practice compared to BRRI practice (6 % DI). Rice yield loss was saved upto71% by managing neck blast disease following BRRI developed blast disease management technology.

ϒ Investigators: M M Rashid, F H Khan, M Hossain, M A I Khan and M A Latif, A Islam.

Tracking the infection source of rice false smut disease. An experiment was set up by using infected and healthy seeds of BRRI dhan49 during T. Aman 2020 to identify infection source (seed/soil and/or air born) of FSm pathogen. 30-day-old seedlings were transplanted in plastic pots (3 plants/pot) with three replications and two lines with 20 hills in the field each of having four seeding time viz 21 June, 5 July, 20 July and 5 Aug 2020. Sterilized soils were collected from 4ft-depth unused soil. False smut disease was not present in each treatment in the pot experiment. False smut disease was observed in 4th set (5 Aug 2020) in T2 treatment (treated healthy seeds + sterilized soil) in the field condition (Table 4). It might be air-borne but the result needs more evaluation.

ϒ Investigators: M M Rashid, B Nessa, M Hossain, M A Latif, A Islam.

Crop loss assessment at Nangalkot, Cumilla during Boro 2020-21. Village Jorpukuria of Nangalkot, Cumilla was selected to estimate the rice yield loss due to major rice diseases for crop

Table 4. Source(s) effect on FSm disease development in BRRI dhan49 from field experiment (DS: 5 Aug, DT: 30 Aug, DF: 5 Nov 2020).

Treatment	FSm Ball/Panicle	Source of Infection		
		Seed	Seed	Seed
T1= infected seeds + sterilized soil	0			
T2= treated healthy seeds + sterilized soil	3 1	X	X	X
T3= treated healthy seeds + infected soil	0			
T4= infected seeds + infected soil	0			

loss assessment experiment. Basic information of the location for crop loss assessment was collected from the DAE, Nangalkot. Fifty rice production plots were randomly selected for the experiment. Different rice disease data, crop cut, different rice production information from the respective farmers were collected using ODK Apps from 100 spots of 50 plots (2 spots per plot). Two major rice diseases, neck blast and sheath blight, were observed in Jorpukuria with DI 2-95% and 35-55%, respectively. Maximum yield loss (about 54%) was occurred in case of due to neck blast disease (95% DI and DS 9) followed by BRRI dhan58 (about 5 %).

ϒ Investigators: M M Rashid, M A I Khan, M Hossain, M A Latif, A Islam.

CROP-SOIL-WATER MANAGEMENT

Long-term missing element trail. For the trial, six fertilizer treatments viz. T_1= N omission (-N), T_2= P omission (-P), T_3= K omission (-K), T_4= S omission (-S), T_5= Zn omission (-Zn) and T_6= NPKZnS (STB) were imposed in the subplots and rice varieties in the main plots following a split-plot design with three replications. Fertilizer doses were NPKZnS @ 110-15-42-9-1.5 kg/ha for T Aman and 145-31-77-13-1.5 kg/ha for Boro. Twenty-five and 43-day-old seedlings were transplanted during T. Aman and Boro, respectively. During T. Aman 2020, BRRI dhan49, BRRI dhan79 and BRRI dhan87 produced 5.86, 6.13 and 6.12 t/ha grain yield, respectively with NPKZnS fertilizers (Table 5). However, yield differences of K missing plots were found significant among the tested three varieties viz BRRI dhan49, BRRI dhan79 and BRRI dhan87. On the other hand, omission of N from complete treatment had a significant effect on grain and straw yield of tested varieties indicating that a soil test based dose of fertilizer is enough for these varieties. In Boro 2020-21, BRRI dhan84, BRRI dhan86 and BRRI dhan88 produced 6.48, 7.45 and 7.43 t/ha grain yield, respectively with NPKZnS fertilizers. In case of BRRI dhan84 and BRRI dhan88, grain yield was drastically reduced due to omission of Potassium. On the other hand, omission of N from complete treatment had a significant effect on grain yield and straw yield of tested varieties indicating that a maintenance dose of fertilizer was enough for these entries (Table 5).

ϒ Investigators: F H Khan, B Saha, T Ferdous, M M Rashid, M Hossain and A Islam

Table 5. Effect of N, P, K, Zn and S and their omission on grain yield of BRRI varieties T. Aman 2020 and Boro 2020-21.

Treat	Grain yield (t/ha) T. Aman 2020			Grain yield (t/ha) Boro 2020-21		
	BRRI dhan49	BRRI dhan79	BRRI dhan87	BRRI dhan84	BRRI dhan86	BRRI dhan88
PKSZn (-N)	3.35	3.61	3.79	4.68	4.58	4.31
NKSZn (-P)	5.34	5.20	4.98	6.57	7.00	7.42
NPSZn (-K)	4.07	4.67	3.88	6.42	7.12	7.21
NPKZn(-S)	5.54	5.32	5.21	6.46	7.44	7.43
NPKS(-Zn)	5.31	5.62	5.62	6.52	6.77	7.19
NPKZnS	5.86	6.13	6.12	6.48	7.45	7.43
Variety Mean	4.94	5.09	4.93	6.27	6.73	6.83
CV (%)	(a) 4.55 (b) 7.24			(a) 7.60 (b) 6.55		
ANOVA(p values)	Treatment(T)=0.0000; Variety(V)=0.1358 (NS); TxV=0.3144(NS)			Treatment(T)=0.0000; Variety(V)=0.0332(NS); TxV=0.3394(NS)		
D/S: 27-06-2020; D/T:23-07-2020				D/S:30-11-2021; D/T:10-01-2021		

Influence of nitrogen and potassium rates on performance of modern rice. The experiment was conducted to find out suitable ratio of N and K for MV rice cultivation and to study N and K dynamics in soil and plant. Five doses of K (0, 50, 100, 150 and 200 kg/ha) in the main plot and four doses of N (0, 50, 75 and 100 kg/ha during T. Aman 2020 with BRRI dhan87 and 0, 100, 120 and 140 kg/ha in Boro 2020-21 with BRRI dhan89) in the subplots were tested. The experimental design was split-plot with three replications. Phosphorus and S was applied as blanket dose. Twenty five day old seedlings in T. Aman season and 43 day-old seedlings in Boro season were transplanted maintaining 20×20 cm spacing. Different levels of K and N application showed significant interaction effects on yield and yield contributing characters of both T. Aman and Boro rice. A combination of 200 kg K and 100 kg N for T. Aman rice (BRRI dhan87) and 200 kg K and 140 kg N for Boro rice (BRRI dhan89) cultivation seems to be suitable for desired yield (Table 6).

Efficiency of DAP for the supplementation of nitrogen fertilizer. The experiment was conducted to evaluate the efficacy of DAP fertilizer for reducing urea application. Twenty-five-day-old seedlings of BRRI dhan87 and 37-day-old seedlings of BRRI dhan96 were transplanted at 20cm × 20cm spacing during T. Aman 2020 and Boro 2020-21, respectively. The experiment was laid down in RCBD design with three replications. Replications were imposed in the fertilizer doses NPKSZn @ 110-15-42-9-1.5 kg/ha for T. Aman and 145-31-77-13-1.5 kg/ha for Boro. Treatments were T_1 = DAP, T_2 = DAP + Urea appli 100% STB (15+30+45 DAT), T_3 = TSP + Urea appli 100% STB (15+30+45 DAT), T_4 = DAP + Urea appli 100% STB (30+45 DAT), T_5 = DAP + Urea appli 80% STB (15+30+45 DAT), T_6 = DAP + Urea appli 80% STB (30+45 DAT), T_7 = DAP + Urea appli 60% STB (15+30+45 DAT) and T_8 = DAP + Urea appli 60% STB (30+45 DAT). In T. Aman, T_7= DAP + Urea appli 60% STB (15+30+45 DAT) produced highest grain yield (5.21 t/ha) and T_4= DAP + Urea appli 100% STB (30+45 DAT) produced the highest straw yield (6.77 t/ha) in BRRI dhan87. In Boro season, T_2 = DAP + Urea appli 100% STB (15+30+45 DAT) produced highest grain yield (7.33 t/ha) and T_5= DAP + Urea appli 80% STB (15+30+45 DAT) produced highest straw yield (7.26 t/ha) in BRRI dhan96.

ϒ Investigators: B Saha, F H Khan, T Ferdous, M M Rashid, M Hossain and and A Islam.

Effect of planting time on growth and grain yield of newly released rice varieties. The experiment was conducted to identify the optimum planting time and suitable variety for Cumilla region. Standard management practices including STB fertilizers were maintained for growing the crops for both the seasons. During T. Aman 2020 three newly released varieties viz. BRRI dhan93, BRRI dhan94, BRRI dhan95 along with the check BRRI dhan49 were evaluated in a time series of planting date (T1 = 15 Jul, T2 = 25 Jul, T3 = 04 Aug, T4= 14 Aug and T5= 24 Aug). Thirty-day-old seedlings were transplanted at 20cm × 20cm spacing. The experiment was laid down in split-plot design with three replications where planting date was set in main plot and varieties in sub-plot. All varieties including the check produced higher yield in planting time of 25 July. After 4 Aug, the yield of all tested varieties decreased sharply. Among all the varieties, BRRI dhan93 produced higher grain yield (4.2 t ha^{-1}) upto 4 August planting. Growth duration were severely affected by heavy rainfall during PI and ripening stage. During Boro season BRRI dhan89, BRRI dhan92 and BRRI dhan96

Table 6. Effect of N and K on grain yield of BRRI dhan87 and BRRI dhan89 during T. Aman 2020 and Boro 2020-21.

K doses (kg/ha)	N doses (kg/ha) T. Aman 2020; BRRI dhan87				N doses (kg/ha) Boro 2020-21; BRRI dhan89			
	0	50	75	100	0	100	120	140
0	4.31a	4.25bc	4.61b	4.65b	3.69	4.94	6.12	6.51
50	4.63a	4.89bc	5.50a	5.25b	4.47	5.51	7.03	7.35
100	4.47a	5.60ab	5.61a	6.81a	4.93	6.37	7.85	9.09
150	4.68a	5.65ab	6.11a	6.75a	5.23	6.90	8.55	8.93
200	4.80a	5.58a	5.93a	7.15a	4.93	7.05	8.30	9.24
K mean	4.58	5.25	5.55	6.12				
CV (%)	(a) 6.18 (b)=8.13				(a) 7.54 (b) 7.80			
$LSD_{0.05}$	K = 0.0014 N= 0.0000 K×N= 0.0109				K = 0.0003 N= 0.0000 K×N= 0.0503			

along with check variety BRRI dhan29 were cultivated using 40-day-old seedlings. Boro varieties were transplanted from 25 December to 8 February with 15 days interval. BRRI dhan89, BRRI dhan92 and BRRI dhan29 produced the highest grain yield within 150-156 days in first two planting time.BRRI dhan88 and BRRI dhan96 showed expected higher yield with wide range of planting time. It was observed that the best sowing time for long varieties (>140 days) was 15 and 30 November.

ϒ Investigators: T Ferdous, B Saha, F H Khan, M M Rashid, M Hossain and A Islam.

Effect of polythene covering on seedling raising in Boro season. The experiment was conducted at BRRI RS farm, Cumilla from December to May 2020-2021. The treatments were considered as i) polythene covering for all time at seedbed ii) polythene covering for 24 hrs at seedbed during cold wave (little or no sunshine, foggy weather all day long, average temperature less than 15º C) iii) polythene covering from 11.0 am to sunset iv) polythene covering for the whole night; v) polythene covering for all time with round shape opening (20 cm diameter) at both ends of the seedbed vi) no polythene covering/ Control (Open). The plot size of the seedbed was 1m^2 and the polythene covering height was 0.75 m. The rice variety BRRI dhan92 was used as a test crop. The experimental design was RCBD with three replications. Forty-day-old seedlings were transplanted to the main field. The results obtained from the seedbed exhibited that all-time polythene cover with round shape opening (T_5) produced the highest seedling dry matter (2.54g) followed by polythene covering from 11.0 am to sunset (T_3) (2.36g). Likewise, the highest seedling height was noticed by the application of T_5 treatment (28.52 cm). However, under field conditions, an insignificant effect of different seedling raising techniques was recorded on yield and yield components of BRRI dhan92 except for grains/panicle. Similar to the seedbed results, the highest grains/panicle (102) was generated from the plot which received T_5 treatment (Table 7).

Means having the same letter in a column do not differ significantly using Lsd at P>0.05; T_1=polythene covering for all time at seedbed; T_2= polythene covering for 24 hrs at seedbed during cold wave (little or no sunshine, foggy weather all day long, average temperature less than 15º C); T_3= polythene covering from 11.0 am to sunset; T_4= polythene covering for the whole night; T_5= polythene covering for all time with round shape opening (20 cm diameter) at both ends of the seedbed; T_6= No polythene covering/ Control (Open).

ϒ Investigators: R Shultana, M M Rashid, T Ferdous, M Hossain, A Islam.

SOCIO-ECONOMIC AND POLICY

Stability analysis of BRRI developed rice varieties. During T. Aus 2020, T. Aman 2020 and Boro 2020-21 a total of 12, 47 and 44 varieties, respectively were evaluated to determine the stability index at BRRI, Cumilla. Twenty, 25 and 30-day-old seedlings were used in the respective seasons. The experiment was laid out in RCB design with three replications. During Aus 2020, among the 12 varieties, BRRI hybrid dhan7 (5.11 t/ha) gave highest yield followed by BRRI dhan85 (3.88 t/ha), BRRI dhan43 (3.87 t/ha), BRRI dhan65 (3.75 t/ha), BRRI dhan82 (3.71 t/ha) and BRRI dhan42 (3.65 t/ha). Growth duration of those varieties ranged from 106-112 days. During T. Aman 2020, among the 47 varieties, BRRI hybrid

Table 7. Effect of polythene covering techniques on seedling growth, yield and yield components in boro season 2020-2021.

Treat	Seedbed		Main field			
	Seedling dry matter (g)	Seedling height (cm)	Panicle/m2	Grains/panicle	1000gwt (g)	Grain Yield(t/ha)
T_1	1.45f	22.05c	275	101a	23.07	8.30
T_2	1.99e	25.77b	264	86bc	22.96	8.19
T_3	2.36a	26.48b	285	82d	24.39	8.44
T_4	2.08d	25.22b	298	83cd	22.85	8.41
T_5	2.54a	28.52a	291	102a	23.28	8.36
T_6	2.25c	25.47b	263	87b	22.78	8.31
CV (%)	2.12	4.23	7.17	2.02	5.49	7.36
Lsd	0.08	1.97	NS	3.31	NS	NS

dhan6 (5.60 t/ha) produced the highest yield followed by BRRI hybrid dhan4 (5.50 t/ha), BRRI dhan93 (5.55 t/ha), BRRI dhan52 (5.33t/ha), BRRI dhan51 (5.31 t/ha), BRRI dhan87 (5.28 t/ha) and BRRI dhan71 (5.25 t/ha). Growth duration of those varieties ranged from 105-167 days. During Boro 2020-21, among the 44 varieties, BRRI hybrid dhan3 gave highest yield (9.52 t/ha) followed by BRRI dhan89 (8.95 t/ha), BRRI hybrid dhan (8.79 t/ha), BRRI dhan29 (8.51 t/ha), BRRI hybrid dhan5 (8.40 t/ha), BRRI dhan29 (8.37 t/ha) BRRI dhan92 (8.01 t/ha). Growth duration of those varieties ranged from 142-161 days.

ϒ Investigators: F H Khan, M M Rashid, B Saha, T Ferdous, M Hossain and A Islam.

TECHNOLOGY TRANSFER

Varietal replacement through head to head (HTH) trial (TRB-ARD project). During T. Aman 2020 five HTH trials with five rice varieties and during Boro 2020-21, six HTH trials with six varieties were conducted to test the adaptability and replacement ability of newly released rice varieties in Cumilla and Brahmanbaria districts. Seedling age was 20-25 and 35-40 days for the respective seasons. One bigha of land was used for each trial. Among the tested T. Aman varieties, the yield of BRRI dhan87 and BRRI dhan93 was the highest (upto 6.28 & 6.39 t/ha, respectively) compared to other rice varieties. During Boro 2020-21 season, the maximum yield was obtained form BRRI dhan92 (upto 10.50 t/ha) followed by BRRI dhan89 (upto 9.99 t/ha), BRRI dhan29 (upto 8.78 t/ha), BRRI dhan84 (upto 7.96 t/ha), BRRI dhan67 (upto 7.90 t/ha), BRRI dhan88 (upto 7.88 t/ha) and BRRI dhan58 (upto 7.88 t/ha), BRRI dhan81 (upto 7.70 t/ha) while the minimum yield was recorded in BRRI dhan28 (upto 6.87 t/ha). Farmers' first preference was BRRI dhan94 (medium short duration) and BRRI dhan71 (SD) for T. Aman; BRRI dhan81 (SD) and BRRI dhan89 (long duration) for Boro season due to their higher yield.

ϒ Investigators: F H Khan, M M Rashid, B Saha, T Ferdous, M Hossain, A Islam.

Block demonstration, dissemination and quality seed production (SPIRA project). Three block demonstrations using new rice varieties BRRI dhan87, BRRI dhan90, BRRI dhan93, BRRI dhan94 and BRRI dhan95 during T. Aman 2020 and three block demonstrations using BRRI dhan84, BRRI dhan86, BRRI dhan89 and BRRI dhan92 during Boro 2020-21 were conducted to investigate the performance and dissemination of newly released promising rice varieties in the farmers field levels. About two acres of land was selected for each block demonstration in different locations of Cumilla and Brahmanbaria districts. The average yield of BRRI dhan87, BRRI dhan90, BRRI dhan93, BRRI dhan94 and BRRI dhan95 were about 6.51, 3.98, 5.80, 5.00 and 5.75 t/ha, respectively. During Boro 2020-21, the yield of BRRI dhan84, BRRI dhan86, BRRI dhan89 and BRRI dhan92 were 6.51, 6.21, 8.63 and 8.60 t/ha, respectively. Demo farmers as well as neighbour farmers were interested to cultivate BRRI dhan87 in T. Aman; BRRI dhan89 and BRRI dhan92 in Boro season due to the higher yield and grain quality.

ϒ Investigators: F H Khan, M M Rashid, B Saha, T Ferdous, M Hossain, A Islam.

Field demonstration of BRRI rice varieties by BBRI Cumilla. A total of 133 (12 in T. Aus, 54 in T. Aman and 67 in Boro) field demonstrations (above 1 bigha each) of newly released developed BRRI varieties were conducted in Cumilla (82 trials), Chadpur (24 trials) and Brahmanbaria (27 trials) districts. The average yield of BRRI dhan82 and BRRI Hybrid dhan7 were 3.62 and 4.54 t/ha, respectively. The average yield of BRRI dhan75 and BRRI dhan87 were 4.75 and 6.13 t/ha, respectively. Farmer's acceptance of BRRI dhan87 for T. Aman season and for Boro varieties, BRRI dhan88 (7.54 t/ha), BRRI dhan89 (8.15 t/ha), BRRI dhan92 (8.23 t/ha) and BRRI dhan96 (8.12 t/ha) were very high in those respective areas for its grain size, panicle length and higher yield.

ϒ Investigators: F H Khan, M M Rashid, B Saha, T Ferdous, M Hossain, A Islam.

Farmer's training, field day and fair. Fourteen farmers' trainings were conducted in different locations of Cumilla region (nine GoB and five SPIRA funded). A total of 470 farmers (8 SAAO male, 423 male farmers and 39 female farmers) were trained up. 11 field days were conducted in the block demonstration areas at Cumilla region funded by GoB,SPIRA-BRRI and BMGF project. About 1479 farmers as well as extension personnel's were attended in the field days. Most of the farmers got interested to cultivate new rice varieties in their areas specially BRRI dhan87, BRRI dhan88, BRRI dhan89, BRRI dhan92 and BRRI dhan96. BRRI Cumilla also participated in two Krishimela, one agricultural fair and one development fair.

BRRI RS, Habiganj

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SUMMARY

Deep water rice genotypes. BR7733-2-1-2B and BR7921-1-1-1-3B produced 0.5 t ha^{-1} more yield over the check Hbj. Aman-I and Hbj. Aman-IV in AYT. Three advanced lines in Habiganj and Cumilla with RYT, BR7730-1-1-2B (1.75 t ha^{-1}), BR7918-1-2-3B (1.5 t ha^{-1}) and BR7919-1-1-3B (1.6 t ha^{-1}) produced higher yield than Lalmohon (0.78 t ha^{-1}) and other local checks Dud Laki (1.3 t ha^{-1}), Vobani (0.79 t ha^{-1})) during Broadcast Aman.

Growing of F_3 population, a total of 1866 F_4 progenies from 13 crosses were selected based on grain type, plant type and others agronomic traits in field RGA.

Zinc enriched rice genotype. BR8913-12-4-8-9-2-3-11-22 (7.2 t ha^{-1}, 159 days) gave higher yield than the check BRRI dhan74 (6.96 t ha^{-1}) and BRRI dhan84 (6.80 t ha^{-1}) in RYT during Boro.

The genotype BRC366-2-2-4-2-1 produced the highest yield (8.0 t ha^{-1}) among the six tested entries with 161 days growth duration in RYT#Cum-1.

In RYT#Ba, the genotype BRBa1-4-9 (8.62 t ha^{-1}) and IR12A329 (9.18 t ha^{-1}) produced the highest yield among the tested entries with 162 days growth duration.

DRR-BB rice genotypes, none of the genotype produced higher yield than the check BRRI dhan89 (8.83 t ha^{-1}) but the genotype BR9943-2-2 (7.76 t ha^{-1}), BR9650-108-2-3 (7.96 t ha^{-1}), BR9943-35-2-1-2-B2 (7.36 t ha^{-1}) and BR9943-26-2-3-5 (8.25 t ha^{-1}) showed higher yield over the checks BRRI dhan58 and IRBB60 with almost same growth duration.

The genotype BR (Path) 13784-BC3-63-6-4-HR6 produced significantly higher grain yield with similar duration of the check variety BRRI dhan28 in MLT.

In YMT, the genotype BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B showed almost similar yield and growth duration with the check variety BRRI dhan63 (6.82 t ha^{-1}, 148 days).

Out of 125, only five genotypes were selected according to their yield performance, phenotypic acceptance and growth duration from IIRON, Boro 2020-21.

In ALART, line BR(Bio)11447-3-10-1 showed significantly higher yield (7.78 t ha^{-1}) with shortest growth duration (147 Days) followed by BR(Bio)11447-1-28-14-3 and check variety BRRI dhan28.

From a long term missing element trial of Boro-Fallow-Fallow cropping pattern, it was found that besides N, K and NK is the most yield limiting nutrient element in BRRI Habiganj farm.

Application of N @ 140 kg ha^{-1} with 50 kg K ha^{-1} BRRI dhan92 produced significantly higher grain yield of 8.49 t ha^{-1} than other the combination of N and K fertilization during Boro in Habiganj farm.

Vermicompost organic manure during Boro rice cultivation could be very useful for soil management strategy to reduce about 31-62% of GHGI and 21-53% of global warming potential and increase rice yield about 5-7%.

The Alternate wetting and drying and irrigation suspension at 20-40 DAT with AWD irrigation system significantly reduced about 66-68% of total global warming potential and 43-63% of GHGI than continuous flooding because of reducing CH_4 emission rates.

Mechanical transplanting along with mixed fertilizer deep placement showed significantly higher grain yield and reducing GWP than the mechanical transplanting and top dressing of fertilizer and farmer practices in Kushtia and Gazipur locations during T. Aman season. Nutrient use efficiency was also higher with mechanical transplanter with mixed fertilizer.

BRRI dhan92 also reduced about 7-10% CH_4 emission than BRRI dhan29.

Insect pests, GLH populations were found the highest followed by WBPH, BPH and YSB. Among the natural enemies green mirid bug (GMB) populations were found the highest followed by carabid beetle (CBB) and lady bird beetle (LBB).

The highest grain yield was observed in BRRI dhan29 and BRRI dhan92 (8.64 and 8.85 t ha^{-1}) with direct seeding at BRRI RS farm, Habiganj and also reduced 8-10 days growth duration than transplanting methods

About 17 tons truthfully labeled seeds were distributed to the stakeholders from previous year's

stock and produced more than 20 tons during the reporting year. About 26 tons breeder seeds were also produced and sent to the Genetic Resource and Seed Division.

The station conducted one special workshop for high officials of MoA, DAE and NARS Institutes. It has also trained 410 farmers and DAE personnel of Sylhet region on rice production technology for submergence and cold environment.

VARIETY DEVELOPMENT (BROADCAST AMAN)

Advanced yield trial (AYT)

Broadcast Aman. Two AYT, one with ten promising local and another with ten advanced deep water rice genotypes were evaluated during B. Aman 2020-21. Wet direct seeding was done in a unit plot size 5.0 m × 24 rows with 25 cm row spacing in RCB design with three replications. Fertilizers were applied @ 60:90:45:8 kg ha^{-1} respectively TSP, MOP, gypsum and zinc sulphate at final land preparation and urea @ 130 kg ha^{-1} in two splits at 25 and 35 days after seed emergence. Crop management practices were done as and when necessary. Data were recorded on date of flowering and maturity, plant height, phenotypic acceptability at vegetative and maturity stage and yield.

All genotypes produced almost similar yield except BRRI dhan91 in AYT with local (Table 1) and BR7733-2-1-2B and BR7921-1-1-1-3B produced 0.5 t ha^{-1} more yield over the check Hbj. Aman-I and Hbj. Aman-I in AYT with Advanced genotype, (Table 2).

Table 1. Yield performance of local deep water rice genotypes in AYT, B. Aman 2020.

Entry	Yield (t ha^{-1}) at 14%M
Lal-mohan	1.5
Dud-laki	1.6
Kipho-digha	0.8
Laxmi-digha	1.5
Bashiraj	0.8
Sor-soria	1.5
Bila-digha	1.5
Hizal-digha	1.2
Charali	1.5
BRRI dhan91 (Std. ck)	-
$LSD_{0.05}$	0.2

Table 2. Yield performance of advanced deep water rice genotypes in AYT, B. Aman 2020.

Entry	Yield (t ha^{-1}) at 14%M
BR7733-2-1-2B	2.1
BR7735-1-1-2B	1.8
BR7738-2-2-2B	1.5
BR7920-1-2-3B	1.3
BR7921-1-1-1-3B	1.9
BR7731-1-1-2-2B	1.8
BR7737-1-2-2B	1.8
Hbj.aman-IV (L. ck)	1.5
Hbj.aman-I (L. ck)	1.2
BRRI dhan91 (std. ck)	0.0
$LSD_{0.05}$	0.2

Regional yield trials (RYT)

Six genotypes along with local (Dud Laki, Vobani) and standard (BRRI dhan91) check were evaluated during B. Aman 2020-21. Wet direct seeding was done in a unit plot size 5.0 m × 24 rows with 25 cm row spacing in RCB design with three replications. Fertilization with P:K:S:Zn @ 12:45:8:2.5 kg ha^{-1} from TSP, MoP, gypsum and $ZnSO_4$ were applied at final land preparation. Nitrogen @ 60 kg ha^{-1} from urea was applied in two equal splits at 25 and 35 days after seed emergence. Crop management practices were done as and when necessary. Data were recorded on date of flowering and maturity, plant height, phenotypic acceptability at vegetative and maturity stage and yield calculated.

All the advanced lines (BR7730-1-1-2B, BR7918-1-2-3B and BR7919-1-1-3B) produced higher yield than Lalmohon and other checks (Table 3).

Hybridization and maintenance breeding

Genotypes for trait development and agronomic performance were transplanted in 5.4 m × 12 rows plot with 20 × 20 cm spacing using 29 day old seedlings with replications. Fertilization with P:K:S:Zn @ 17.4:58.5:14:3.6 kg ha^{-1} from TSP, MoP, Gypsum and $ZnSO_4$ were applied at final land preparation. Nitrogen @ 95 kg ha^{-1} from urea was applied in three equal splits at 15 and 30 DAT and five days before PI stage. Crop management practices were done as and when necessary. For trait introgression, hybridization was made as per trait and flowering synchronization. Data were recorded on date of flowering and maturity, plant height, phenotypic acceptability at vegetative and maturity stage and yield for germplasm evaluation.

Seven crosses were made with selected traits. On the other hand, 15 germplasm were collected and evaluated (Table 4).

TRANSPLANTED AMAN (RAIN-FED)

Growing of F_3 population in field RGA (Pigmented/Anti-oxidant rice)

In total, 3175 progenies from 20 F_3 populations were grown. Thirty days old single seedlings were transplanted at a spacing of 20 cm × 20 cm. Fertilization with P:K:S:Zn @ 15:50:12:3.6 kg ha^{-1} from TSP, MoP, gypsum and $ZnSO_4$ were applied at final land preparation. Nitrogen @ 83 kg ha^{-1} from urea was applied in three equal splits at 5-10 and 20-25 and 35-40 DAT. A total of 1866 F_4 progenies from 13 crosses were selected based on grain type, plant type and others agronomic traits in field RGA.

BORO (IRRIGATED RICE)

Regional yield trial (RYT).

Genotypes for specific and general adaptability were evaluated. Seedlings of 40 days were transplanted in 5.4 m × 12 rows plot using 2-3 seedlings $hill^{-1}$ in RCB design with three replications. Fertilization with P:K:S:Zn@ 20:60:20:3.6 kg ha^{-1} from TSP, MoP, gypsum and $ZnSO_4$ were applied at final land preparation. Nitrogen @ 120 kg ha^{-1} from urea was applied in three equal splits at 15 and 30 DAT and five days before PI stage. Crop management practices were done as and when necessary. Data were recorded on

Table 3. Yield performance of selected genotypes in RYT-1, B. Aman 2020.

Entry	Yield (t ha^{-1})			
	Habiganj	Cumilla	Bhanga	Avg.
BR7730-1-1-2B	2.3	1.2	-	1.75
BR7918-1-2-3B	2.1	0.9	-	1.50
BR7919-1-1-3B	2.4	0.8	-	1.60
Lalmohon	1.2	0.35	-	0.78
BRRI dhan91(Std. ck)	0.0	0.0	-	
Dud Laki, Vobani (L. ck)	1.3	0.79	-	
$LSD_{0.05}$	0.5			

Table 4. List of crosses and expected characters, T. Aman 2020.

Cross	F_1 seed	Expected character
ASED-1 /BRRI dhan50	25	High tillering with LS grain
BRRI dhan50/ASED-1	25	High tillering with LS grain
Posusail/ASED-1	15	High tillering with SD
ASED-1/ Posusail	30	High tillering with SD
Khoiyaboro/JaHua	14	High tillering with SD
BRRI dhan50/JaHua	18	High tillering with LS grain
JaHua/BRRI dhan50	29	High tillering with LS grain

flowering and maturity dates, plant height, phenotypic acceptability at vegetative and maturity stages and yield.

RYT# ZER

Three genotypes along with three checks BRRI dhan74, BRRI dhan84 and BRRI dhan89 were evaluated.

None of the genotype produced higher yield over BRRI dhan89 (ck), but the genotype BR8913-12-4-8-9-2-3-11-22 (7.2 t ha^{-1}, 159 days) gave higher yield than the check BRRI dhan74 (6.96 t ha^{-1}) and BRRI dhan84 (6.80 t ha^{-1}) (Table 5).

RYT# GSR

Five genotypes along with two checks BRRI dhan88 and BRRI dhan58 were evaluated.

None of the genotype produced higher yield than the check varieties. The genotype FBR189 produced higher grain yield (7.05 t ha^{-1}) than all the tested varieties (Table 6).

RYT# Cum-1

Six genotypes along with three check varieties BRRI dhan81, BRRI dhan84 and BRRI dhan88 were evaluated.

The genotype BRC366-2-2-4-2-1 produced the highest yield (8.0 t ha^{-1}) among the tested entries with 161 days growth duration (Table 7).

Table 5. Yield and ancillary character of ZER materials, Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR8419-8-2-1-4-1-3-8-5	97	160	4.91*
BR8913-12-4-8-9-2-3-11-22	97	159	7.20
BR9674-5-6-2-1-7-22	94	160	6.44**
BRRI dhan74(ck)	104	151	6.96
BRRI dhan84(ck)	118	150	6.80
BRRI dhan89(ck)	112	161	8.24
$LSD_{0.05}$	7.62	3.90	0.87

DS: 16 Nov 2020 DT: 26 Dec 2020 *40% BLB, **15%BLB

Table 6. Yield and ancillary character of GSR lines, Boro 2019-20.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
FBR189	106	151	7.05
FBR336	104	158	6.32
BRRI dhan84(ck)	116	149	6.54
FBR355	121	153	6.41
WANXIAN777-P10-P3	92	159	5.52
BRRI dhan88(ck)	96	153	7.53
BRRI dhan58(ck)	101	154	7.16
$LSD_{0.05}$	7.6	2.8	0.5

DS: 16 Nov 2020 D/T: 26 Dec 2020

Table 7. Yield and ancillary character of tested lines, Boro 2020-221.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRC426-4-2-1	98	155	7.37
BRC366-2-2-4-2-1	97	161	8.00
BRC427-9-1-3	106	161	5.98
BRC389-4-2-4-2	102	155	6.06
BRC401-1-1-1-1B	96	159	6.22
BRC366-2-2-4-2-3	96	160	6.77
BRRI dhan81(ck)	92	152	6.35
BRRI dhan84(ck)	117	147	6.60
BRRI dhan88(ck)	90	151	7.57
$LSD_{0.05}$	5.3	3.3	0.5

DS: 18 Nov 2020 DT: 01 Jan 2021

RYT# Cum-2

Seven genotypes along with three check varieties BRRI dhan50, BRRI dhan58 and BRRI dhan89 were evaluated.

None of the genotype produced higher yield than the check BRRI dhan89 but the genotype BRC394-1-1-1-5A (7.21 t ha^{-1}, 160 days) and BRC335-1-3-2-2-1 (8.55 t ha^{-1}, 159 days) showed higher yield over the checks BRRI dhan50 and BRRI dhan58 (Table 8). **RYT# Ba-1**

Six genotypes along with two check varieties BRRI dhan58 and BRRI dhan92 were evaluated.

The genotype BRBa1-4-9 gave the highest yield (8.62 t ha^{-1}) among the tested entries with 162 days growth duration. Besides, the genotype BRBa2-1-3 (8.21 t ha^{-1}, 160 days) and BRBa3-3-1 (8.45 t ha^{-1}, 158 days) showed almost same yield and growth duration with the check BRRI dhan92 (8.54 t ha^{-1}, 162 days) (Table 9).

Table 8. Yield and ancillary character of tested lines, Boro 2020-221.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRC398-4-1-1-1B	116	160	8.02
BRC428-2-2-1	82	161	7.08
BRC428-3-1-1	86	160	6.45
BRC428-3-1-2	88	159	6.62
BRC394-1-1-1-2	121	158	5.22
BRC394-1-1-1-5A	101	160	7.21
BRC335-1-3-2-2-1	110	159	8.55
BRRI dhan50(ck)	91	157	6.23
BRRI dhan58(ck)	99	156	7.03
BRRI dhan89(ck)	107	160	8.92
$LSD_{0.05}$	8.2	1.0	0.7

DS: 21 Nov 2020 DT: 02 Jan 2021

Table 9. Yield and ancillary character of tested Lines, Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRBa1-4-9	117	162	8.62
BRBa2-1-3	116	160	8.21
BRBa2-5-3	97	160	7.79
BRBa3-1-7	98	159	7.53
BRBa3-2-4	98	158	7.78
BRBa3-3-1	99	158	8.45
BRRI dhan58(ck)	101	158	7.19
BRRI dhan92(ck)	110	162	8.54
$LSD_{0.05}$	5.8	1.2	0.4

DS: 16 Nov 2020 DT: 29 Dec 2020

RYT# Ba-2

Seven genotypes along with two check varieties BRRI dhan58 and BRRI dhan92 were evaluated.

The genotype IR12A329, IR13A515 and IR15A3466 gave higher yield over the checks and among them; the genotype IR12A329 produced the highest yield (9.18 t ha^{-1}) with 164 days growth duration (Table 10).

RYT# DRR-BB

Five genotypes along with three checks BRRI dhan58, BRRIdhan89 and IRBB60 were evaluated during Boro 2020-21.

None of the genotype produced higher yield than the check BRRI dhan89 (8.83 t ha^{-1}) but the genotype BR9943-2-2 (7.76 t ha^{-1}), BR9650-108-2-3 (7.96 t ha^{-1}), BR9943-35-2-1-2-B2 (7.36 t ha^{-1}) and BR9943-26-2-3-5 (8.25 t ha^{-1}) showed higher yield over the checks BRRI dhan58 and IRBB60 with almost same growth duration (Table 11).

Multi location yield trial (MLT# Path)

Eleven advanced lines along with one check variety BRRI dhan28 were evaluated during Boro 2020-21. > >

The genotype BR (Path) 12452-BC6-36-11-5, BR (Path)12452-BC6-48-18-7, BR (Path) 13784-BC3-5-3-8-HR4 and BR (Path) 13784-BC3-63-6-4-HR6 gave almost similar grain yield with similar duration of the check variety BRRI dhan28 (6.74 t ha^{-1} , 145 days) (Table 12).

Table 10. Yield and ancillary character of tested Lines, Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
IR04A429	106	161	8.09
IR12A329	110	164	9.18
IR13A515	107	163	8.44
IR15A2820	98	156	5.85
IR15A2854	102	152	6.45
IR15A3466	102	159	8.61
IR16A2022	105	153	7.12
BRRI dhan58(ck)	99	155	7.12
BRRI dhan92(ck)	111	160	8.35
$LSD_{0.05}$	3.0	2.8	0.7

DS: 16 Nov 2020 DT: 29 Dec 2020

Table 11. Yield and ancillary character of DRR-BB Lines, Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR9943-2-2	98	157	7.76
BR9650-108-2-3	100	156	7.96
BR9942-1-2-1-1-B1	92	157	6.30
BR9943-35-2-1-2-B2	98	153	7.36
BR9943-26-2-3-5	106	158	8.25
BRRI dhan58 (ck)	99	152	7.17
BRRI dhan89 (ck)	107	156	8.83
IRBB60 (ck)	81	158	5.77
$LSD_{0.05}$	5.8	1.5	0.7

DS: 21 Nov 2020 DT: 03 Jan 2021

Table 12. Yield and ancillary character of MLT lines (Path), Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR (Path)12452-BC3-35-21-8-5	121	146	5.59
BR (Path)12452-BC3-42-22-11-4	113	143	6.53
BR (Path)12452-BC4-77-25-11-8-5	116	144	5.93
BR (Path) 12452-BC6-36-11-5	111	144	6.95
BR (Path) 12452-BC6-53-21-11	117	142	6.37
BR (Path) 12452-BC6-48-18-7	122	143	6.93
Bekui-HR (Path)-4-3(ZM82)	123	143	6.05
BR (Path) 13784-BC3-5-3-8-HR4	101	141	6.93
BR (Path) 13784-BC3-61-1-6-HR3	103	144	6.32
BR (Path) 13784-BC3-62-3-5-HR2	98	141	6.07
BR (Path) 13784-BC3-63-6-4-HR6	101	142	7.13
BRRI dhan28 (ck)	112	145	6.74
$LSD_{0.05}$	5.0	1.5	0.3

DS: 24 Nov 2020 DT: 03 Jan 2021

Yield maximization trial (YMT# FB)

Two advanced lines along with one check variety BRRI dhan63 were evaluated during Boro 2020-21.

The genotype BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B showed almost similar yield and growth duration with the check variety BRRI dhan63 (6.82 t ha^{-1}, 148 days) (Table 13).

International Irrigated Rice Observational Nursery (IIRON2020).

Yield and adaptability test of varieties/ breeding lines from abroad were done to select the best ones. Seventy-nine genotypes along with one HYV (BRRI dhan28) check were planted in a 5.4m × 4 rows plot with 20 cm spacing.

Out of 125, only five genotypes were selected according to their yield performance, phenotypic acceptance and growth duration. These materials will be re-tested in the next season. (Table 14).

Table 13. Yield and ancillary character of FBR lines, Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRH11-9-11-4-5B-HR3	100	150	7.00
BRH13-2-4-6-4B	101	151	7.05
BRRI dhan63 (ck)	86	148	6.82
$LSD_{0.05}$	9.5	1.5	0.2

DS: 21 Nov 2020 DT: 03 Jan 2021

Table 14. Yield and ancillary characters of selected entries from IIRON, Boro 2020-21.

Entry no.	Designation	Plant height (cm)	Duration (day)	Yield (t ha^{-1})
10	SVIN263	98	145	7.41
22	SVIN038	101	148	7.76
71	SVIN211	102	150	7.54
73	SVIN229	99	145	7.68
104	SVMET264	104	144	7.72
$LSD_{0.05}$		2.10	2.22	0.13

DS: 28 Nov 2020 DT: 11 Jan 2021

ALART in Boro 2020-21

Zinc enriched rice (ZER)

Two advanced lines BR8912-12-6-1-1-1-1 and IR105837-8-95-2-1 along with check varieties BRRI dhan89 and BRRI dhan74 were tested in Khatkal, Baniachong and Habiganj during Boro 2020-21.

Among the tested entries showed significantly lower yield than the check variety. The teste entry produced statistically similar yield 6.97 and 6.64 t ha^{-1} in 163 and 158 days respectively (Table 15).

Favourable Boro rice (FBR-Bhanga)

Two advance lines SVNO63-Boro-18-Bhanga and SVNO76-Boro-18-Bhanga along with check varieties BRRI dhan29 and BRRI dhan89 were tested in Khatkal, Baniachong, and Habiganj during Boro 2020-21. All the genotypes produced statistically similar yield where BRRI dhan89 produced the highest yield (7.75 t ha^{-1}) followed by BRRI dhan29 (7.60 t ha^{-1}), SVNO63-Boro-18-Bhanga (7.67 t ha^{-1}) and SVNO76-Boro-18-Bhanga (7.66 t ha^{-1}) (Table 16). The growth duration of all genotypes were more about similar (ranges from 161-163 days).

Bacterial blas resistant rice (BBRR-Bio)

Two advance lines BR(Bio)11447-1-28-14-3-Bhanga and BR (Bio)11447-3-10-1 along with check variety BRRI dhan28 were tested in Khatkal, Baniachong, Habiganj during Boro 2020-21.

Among the line BR(Bio)11447-3-10-1 showed significantly higher yield (7.78 t ha^{-1}) with the shortest growth duration (147 days) followed by BR (Bio) 11447-1-28-14-3 and check variety (Table 17).

CROP-SOIL-WATER MANAGEMENT

Long-term missing element trial for diagnosing the limiting nutrient in soil.

Long term experiments were initiated at BRRI RS, Habiganj farm in 2007-08 to identify the yield limiting nutrient. The experiments comprising eight treatments in RCB design with three replications. The treatments were- T_1= NPKS (Complete), T_2 =PKS (-N), T_3= NKS (-P), T_4= NPS (-K), T_5= NPK (-S), T_6= KS (-NP), T_7= PS (-NK) and T_8= all missing (-NPKS). Boro 2020-21 was the 13th year continuation of this experiment. NPKSZn @ 120-38-50-9-3 kg ha^{-1}, respectively were used. Tested cropping pattern was Boro-Fallow-Fallow. BRRI dhan92 was used as a test crop.

Table 15. Yield and growth duration of ALART Zinc enriched rice (ZER), Boro 2020-21.

Genotypes (ZER)	Yield (t ha^{-1})	Growth duration (day)
BR8912-12-6-1-1-1-1	6.97	163
IR105837-8-95-2-1	6.65	158
BRRI dhan74	7.51	155
BRRI dhan89	7.97	165
$LSD_{0.05}$	0.45	

Table 16. Yield and growth duration of ALART Favourable Boro rice (FBR-Bhanga), Boro 2020-21.

Genotypes (FBR-Bhanga)	Yield (t ha^{-1})	Growth duration (day)
SVNO63-Boro-18-Bhanga	7.67	163
SVNO76-Boro-18-Bhanga	7.66	161
BRRI dhan29	7.60	163
BRRI dhan89	7.75	161
$LSD_{0.05}$	0.31	

Table 17. Yield and growth duration of ALART Bacterial Blas resistant rice (BBRR-Bio), Boro 2020-21.

Genotype (BBRR-Bio)	Yield (t ha^{-1})	Growth duration (day)
BR(Bio)11447-1-28-14-3	6.65	149
BR(Bio)11447-3-10-1	7.78	147
BRRI dhan28	6.62	150
$LSD_{0.05}$	0.45	

The balance fertilizer treatment (NPKSZn) showed significantly higher grain yield and yield parameters of rice. The highest panicle m^{-2} was obtained with balanced fertilized (T_1) plot followed by other omission plots. The highest grain yield was obtained in T_1 (8.37 t ha^{-1}) followed by T_5 (8.13 t ha^{-1}). The N and K omission treatment (T_2 and T_4) produced significantly lower yield (6.72-6.87 t ha^{-1}) than the other treatments. From the experiment it may be concluded that besides N, K and NK is the most yield limiting nutrient element in BRRI RS, Habiganj farm (Table 18).

Influence of nitrogen and potassium rates on performance of modern rice.

The objectives of present study are to find out suitable ratio of N and K for MV the rice cultivation, and N and K dynamics in soil and plant. The experiments were conducted at BRRI RS farm, Habiganj during Boro 2020-2021. Five doses of K (0, 50, 100, 150 and 200 kg ha^{-1}) in the main plot and four doses of N (0, 100, 120 and 140 kg/ha) in the subplots were tested with BRRI dhan92. The experimental design was split-plot with three replications. Phosphorus and S was applied as blanket dose. Forty-five-days-old seedlings were transplanted maintaining 20cm × 20cm spacing. Grain yield was recorded at 14% moisture content.

Potassium deficient condition, application of increasing N significantly decreased grain yield whether N deficient condition, K rates were not responsible for increased grain yield. Application of N @ 140 kg ha^{-1} with 50 kg K ha^{-1} produced significantly higher grain yield (8.49 t ha^{-1}) than the other combination of N and K fertilization (Table 19).

Greenhouse gas emission and global warming potential under organic amendment at Kushtia region.

Field experiment was conducted at farmer's field, Kushtia Bangladesh in 2020-2021. The treatments were; chemical fertilizers (NPKSZn), cow dung (CD), poultry manure (PM), and vermicompost (VC) as integrated plant nutrient system (IPNS) based inorganic fertilizations. The static closed-chamber method was used to measure CH_4, CO_2 and N_2O emission rates during Boro rice season, respectively. Results revealed that VC fertilization treatment decreases GHG and GWP than CD and PM treatments. The CD and PM

Table 18. Effects of nutrient element omission from the complete treatment on grain yield of BRRI dhan92, Boro 2020-21, Habiganj.

Treatment	Panicle m^{-2}	Grain yield (t ha^{-1})
T_1 (NPKSZn)	385	8.37
T_2 (-N)	300	6.72
T_3 (-P)	360	7.58
T_4 (-K)	348	6.87
T_5 (-S)	362	8.13
T_6 (-NP)	358	7.80
T_7 (-NK)	326	7.01
T_8 (All missing)	242	6.13
$LSD_{0.05}$	7.70	0.36

T_1= NPKS (Complete), T_2= PKS (-N), T_3= NKS (-P), T_4= NPS (-K), T_5= NPK (-S), T_6= KS (-NP), T_7= PS (-NK) and T_8= All missing (-NPK)

Table 19. Effect of N and K rates on grain yield (t ha^{-1}) of BRRI dhan92, Boro 2020-21, BRRI RS, Habiganj.

K dose (kg ha^{-1})	N dose (kg ha^{-1})			
	0	100	120	140
0	6.13c B	6.56 c A	6.86 c A	6.90 c A
50	6.63 b D	7.36 b C	7.77 a B	8.49a A
100	6.10 c C	7.78 a B	8.32 a A	8.24 a A
150	7.10 a A	7.80 a B	7.09 b A	6.93 b A
200	7.14 a B	7.89 a A	7.87 a A	7.07 b B
CV (%)	4.42			

Means with same lowercase letter in a column and same uppercase letter in a row are not significantly different at the 5% level of probability

significantly increased total CH_4, N_2O (Fig. 1 and 2) and GHGI about 24-38% and GWP around 18-35% of VC fertilization with Boro rice cultivation (Table 20). There was also significant difference of rice yield between organic amendment and chemical fertilization systems in Boro season (Table 20). It can be concluded that the VC organic manure could be useful for soil management strategy to reduce about 31-62 % of GHGI, 21-53% of GWP and increase about 5-7% of rice yield than that of CD and PM.

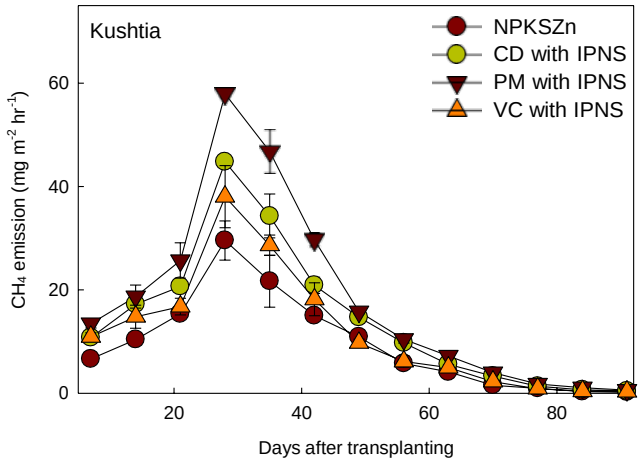

Fig. 1. CH_4 emission pattern as influence by organic amendment under Boro rice cultivation at Kushtia region in rice soil.

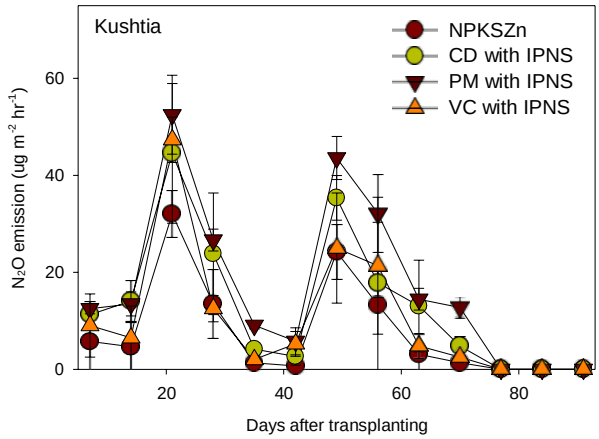

Fig. 2. N_2O emission pattern as influence by organic amendment under Boro rice cultivation at Kushtia region in rice soil.

Table 20. Yield, GHG intensity and GWP with Boro rice season under organic amended rice soil.

Treatment	Yield and GHG intensity (kg ha^{-1})		Global warming potential (kg CO_2 eq. ha^{-1})
	Yield	GHGI	
NPKSZn	6500	0.89	5790
Cowdung with IPNS	7600	1.15	8727
Poultry manure with IPNS	7750	1.42	11031
Vermicompost with IPNS	8200	0.88	7188
$LSD_{0.05}$	210.07	0.14	513

Greenhouse gas emission and global warming potential as influenced by water management during Boro rice cultivation

We hypothesize that vermicompost organic fertilizer under varied water management options greatly influences green house gas (GHG) emission patterns and global warming potential (GWP), which has been evaluated in the present study. The experiment was conducted at the experimental farm BRRI, Gazipur, buring January to May 2021. Incorporation of vermicompost into soil was as integrated plant nutrient system (IPNS) under different water management system We have used RCB design with three replications for imposing treatments in four multiply five-meter plots. BRRI dhan58 was grown as irrigated rice culture. Three water management systems were applied; continuous flooding (CF), alternate wetting and drying (AWD) with 15 cm and irrigation suspension at 20-40 days after transplanting (DAT) with AWD (ISAWD). In CF, plots were kept flooded until harvesting and in AWD, plots were irrigated when water level fell below 15cm. In ISAWD, there was 5-7 cm water up to 20 DAT and no water was applied after 20-40 DAT and then using AWD system before harvesting. Four perforated PVC pipes were installed with 15 cm depth for monitoring water depth in the AWD and ISAWD plots. We have followed standard gas sampling techniques for recording N_2O and CH_4 emission patterns.

GHG and GWP during Boro season.

In Boro season, CH4 emission pattern was significantly lower with AWD and ISAWD treatment than CF the irrigation system (Fig. 3). However, N_2O emission pattern was lower under CF than other water management (Fig. 4). The total CH_4 flux were 253-148-145 kg ha^{-1} under CF-AWD-ISAWD irrigation system and N_2O flux were 0.23-0.66 kg ha^{-1} under different water condition during study period (Table 21). The AWD and ISAWD irrigation system significantly reduced total CH_4 fluxes by 72-75% over CF. The AWD and ISAWD irrigation system was mainly responsible for increased total N_2O fluxes by 148% and 187% over CF system, respectively. The AWD and ISAWD irrigation system significantly reduced about 66-68% of total GWP and 43-63% of GHG intensity than continuous flooding because of reducing CH_4 emission rates (Table 21). Grain yield was not different among the AWD and CF system.

Design and development of fertilizer deep placement mechanism for existing rice transplanter.

A research experiment was conducted to incorporate the fertilizer deep placement mechanism (FDP) with greenhouse gas emission (GHG) determination under different management practices at Kushtia and Gazipur. Different static GHG chambers were made for collection and analysis of GHG during study period under existing

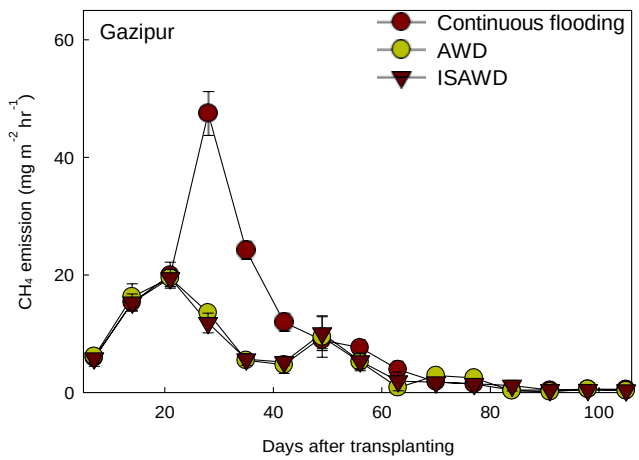

Fig. 3. CH_4 emission under varying irrigation management during Boro, 2020-21 (Note: CF= continuous flooding, AWD= alternate wetting and drying and ISAWD= Irrigation suspension at 20-40 days after transplanting (DAT) with AWD).

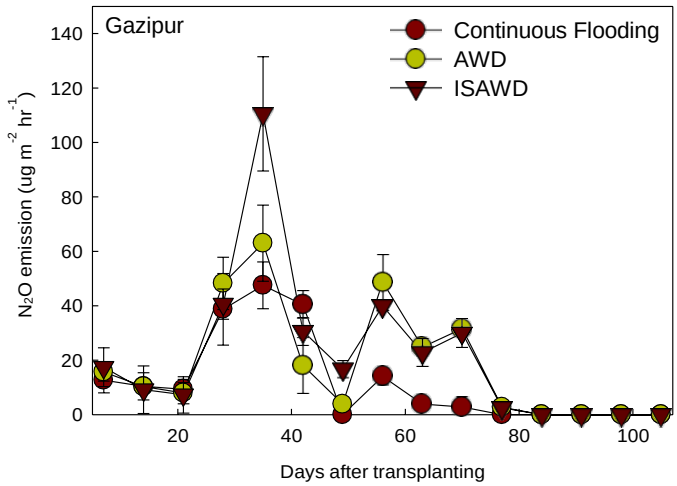

Fig. 4. N_2O emission under varying irrigation management during Boro 2020-21 21 (Note: CF= continuous flooding, AWD= alternate wetting and drying and ISAWD= Irrigation suspension at 20-40 days after transplanting (DAT) with AWD).

Table 21. Total GHG and GWP under varying irrigation management during Boro 2020-21.

Treatment	Greenhouse gas emission (kg ha^{-1})				Yield (kg ha^{-1})
	CH_4	N_2O	GWP	GHGI	
CF	254	0.23	7140	1.19	6000
AWD	148	0.57	4289	0.73	5900
ISAWD	145	0.66	4242	0.83	5100
$LSD_{0.05}$	52	0.21	339	0.08	540

(Note: CF= continuous flooding, AWD= alternate wetting and drying and ISAWD= Irrigation suspension at 20-40 days after transplanting (DAT) with AWD).

and modified fertilization systems during Boro and T. Aman rice cultivation. Static GHG chamber was installed at Kushtia and Gazipur fields for collection of GHG. Randomized complete block design with three replications were applied to evaluate the machine. BRRI dhan87 and BRRI dhan89 were grown as rain-fed and irrigated rice culture, respectively. Treatments of the trials were; T_1 = Mechanical transplanting and top dressing of fertilizer, T_2 = Farmers' practice and T_3 = Mechanical transplanting along with mixed fertilizer deep placement. Mechanical transplanting along with mixed fertilizer deep placement gave significantly higher yield than other treatments (Table 22). There are significant difference of grain yield and GWP among the mechanical transplanting and top dressing of fertilizer and mechanical transplanting along with mixed fertilizer deep placement from rice soil in Kushtia and Gazipur locations (Fig. 5). Nutrient use efficiency was also higher with mechanical transplanter with mixed fertilizer (Fig. 6).

Table 22. Rice yield performance as affected under different transplanting and mode of fertilizer application T. Aman 2020.

Treat	Rice yield (t ha^{-1})		Straw yield (t ha^{-1})	
	Gazipur	Kushtia	Gazipur	Kushtia
T_1	4.66	4.80	4.90	5.25
T_2	4.26	4.34	5.12	5.20
T_3	5.74	5.90	6.30	6.50
CV (%)	3.35	2.45	4.42	5.56
$LSD_{0.05}$	0.23	0.21	0.43	0.53

Note: T_1 = Mechanical transplanting and top dressing of fertilizer, T_2 = Farmers' practice and T_3 = Mechanical transplanting along with mixed fertilizer deep placement.

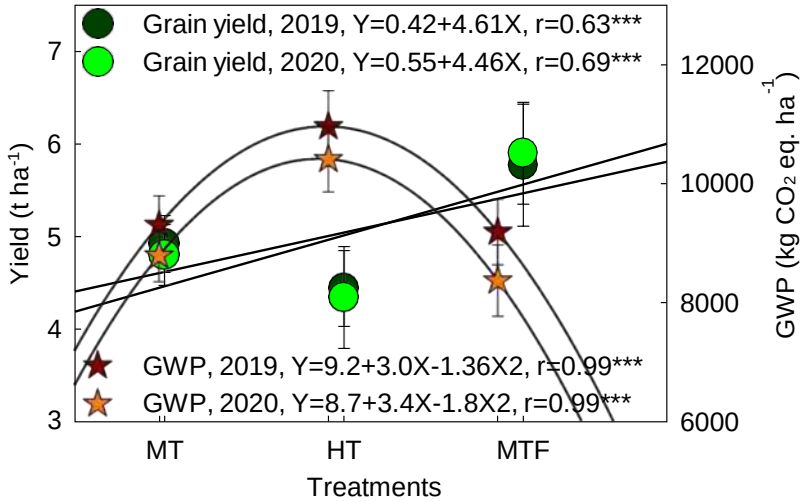

Fig. 5. Relation of global warming potential and yield during T. Aman season at both region. Note: MT = Mechanical transplanting and top dressing of fertilizer, HT = Farmers' practice and MTF = Mechanical transplanting along with mixed fertilizer deep placement.

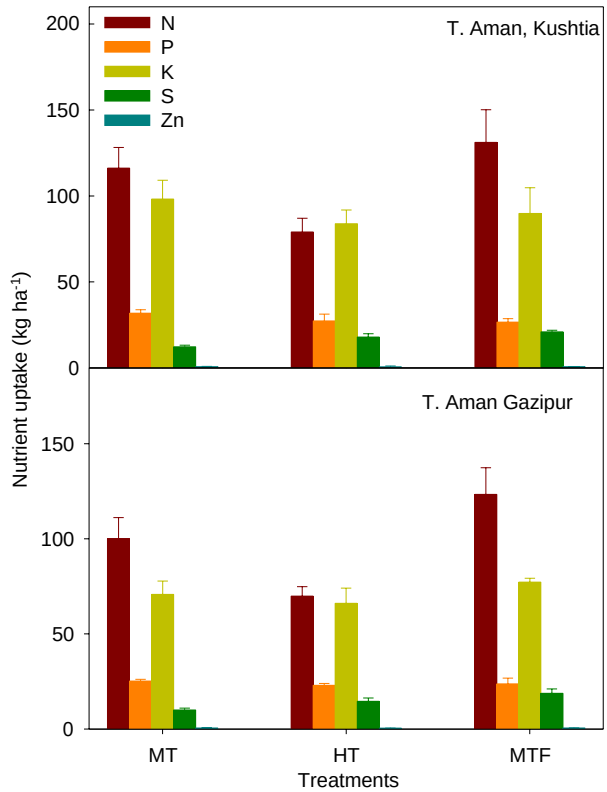

Fig. 6. Nutrient uptake during T. Aman season at both region. Note: MT = Mechanical transplanting and top dressing of fertilizer, HT = Farmers' practice and MTF = Mechanical transplanting along with mixed fertilizer deep placement.

Performance of greenhouse gas emission and grain yield under newly developed rice verities at Sylhet regions.

The experiment was conducted at farmers' filed to determine the grain yield and GHG with newly developed rice varieties compares to the existing rice varieties under different districts of Sylhet region, Bangladesh. Cool farm tools Beta-3 was used for measuring CH_4 emission. The neweueh rice varieties as BRRI dhan84, BRRI dhan88, BRRI dhan96, BRRI dhan89 and BRR dhan92 and existing rice cultivars BRRI dhan28 and BRRI dhan29 were used. Short duration rice varieties BRRI dhan84, BRRI dhan88 and BRRI dhan96 produced significantly higher yield (7.5-8.5 t ha^{-1}) than BRRI dhan28 (7.0-7.5 t ha^{-1}). However, GHG emission was not different during the study period. Long duration BRRI dhan89 and BRRI dhan92 showed higher grain yield (8.5-9.5 t ha^{-1}) than BRRI dhan29. BRRI dhan89 and BRRI dhan92 also reduced about 7-10% CH_4 emission than BRRI dhan29 (Table 23).

Effect of planting time on growth and yield of some BRRI released Boro varieties.

Research activities were done to identify the suitable planting time and variety for Haor areas. Eight Boro varieties were evaluated in a time series of sowing date (T_1 = 1 Nov, T_2 = 10 Nov, T_3 = 20 Nov, T_4 = 1 Dec and T_5= 10 Dec) during Boro 2020-21. Seedlings of 35 days were transplanted in 5.4 m × 12 rows plot using 2-3 seedlings $hill^{-1}$ in RCB design with three replications. Fertilization with P:K:S:Zn @ 20:60:20:3.6 kg ha^{-1} from TSP, MP, gypsum and ZnSO4 ha^{-1} were done at final land preparation. Nitrogen @ 120 kg ha^{-1} from urea was applied in three equal splits at 15 and 30 DAT and five days before PI stage. The results showed that irrespective of variety and sowing time BRRI dhan74 gave highest yield (9.54 t ha^{-1}) in sowing time of 10 December with 140 days growth duration (Table 24 and 25). Besides this BRRI dhan28 and BRRI dhan88 also gave highest yield (8.18 and 8.49 t ha^{-l}) in the sowing time of 10 December whereas, BRRI dhan29, BRRI dhan67, BRRI dhan84 and BRRI dhan89 gave maximum yield when seeded in 1st November where maximum growth duration occurred. BRRI dhan58 produced highest yield in sowing time of 1st December (Table 24).

Table 23. Grain yield and CH_4 emission compare to existing rice varieties and newly release rice varieties

Short duration variety			Long duration variet		
Name of Variety	Yield (t ha^{-1})	CH_4 (kg ha^{-1})	Name of Variety	Yield (t ha^{-1})	CH_4 (kg ha^{-1})
BRRI dhan28	7.0-7.5	62.9	BRRI dhan29	7.5-8.5	72.3
BRRI dhan84	7.5-8.0	60.8	BRRI dhan89	8.5-9.1	67.6
BRRI dhan88	7.8-8.5	60.8	BRRI dhan92	8.6-9.5	65.6
BRRI dhan96	7.6-8.5	60.8			
$LSD_{0.05}$	0.56	0.79	LSD (5%)	0.49	1.0

Table 24. Yield (t ha^{-1}) of different Boro varieties in different sowing time.

Sowing time	BRRI dhan28	BRRI dhan29	BRRI dhan58	BRRI dhan67	BRRI dhan74	BRRI dhan84	BRRI dhan88	BRRI dhan89
T_1	7.12	8.12	7.38	7.93	4.70	7.43	6.22	9.29
T_2	7.07	7.11	7.76	7.58	6.06	6.53	6.84	8.36
T_3	7.24	7.54	8.02	7.16	7.62	6.36	6.95	8.33
T_4	7.68	7.88	8.93	7.64	7.83	7.08	7.33	8.48
T_5	8.18	7.93	7.65	7.94	9.54	7.08	8.49	8.66
$LSD_{0.05}$			1.32					

Sowing date (T_1 = 1 Nov, T_2 = 10 Nov, T_3 = 20 Nov, T_4 = 1 Dec and T_5= 10 Dec)

Table 25. Yield of different Boro varieties in different sowing time.

Sowing time	BRRI dhan28	BRRI dhan29	BRRI dhan58	BRRI dhan67	BRRI dhan74	BRRI dhan84	BRRI dhan88	BRRI dhan89
T_1	155	167	163	156	154	154	154	167
T_2	145	159	156	153	146	145	146	158
T_3	146	159	152	145	143	144	145	157
T_4	134	147	143	135	134	133	136	147
T_5	137	145	140	136	140	137	134	146
$LSD_{0.05}$			1.32					

Sowing date (T_1 = 1 Nov, T_2 = 10 Nov, T_3 = 20 Nov, T_4 = 1 Dec and T_5= 10 Dec)

Seedling raising techniques through polythene covering.

An experiment was conducted at BRRI RS, Habiganj to observe the effect of polythene covering during Boro rice seedling raising. BRRI dhan88 was used to conduct this experiment. Six different treatment was used to raise the seedling. T_1= Fully Polythene cover all time, T_2=Polythene covering only during cold wave (Mean temperature <15^{0}C), T_3= Polythene covering during 11:00 am to sun set, T_4= Polythene covering only at night, T_5= Polythene covering all time with 20 cm diameter opening at the each end of the seedbed cover and T_6= No covering. Weather report showed that the mean maximum and minimum temperature during the experiment period was 24.4^{0}C and 13.44 ^{0}C respectively that means there is such cold period happening during this experimental time. As a result no covering treatment produced good seedling with a highest seedling strength value is 4.56 mg cm^{-1}, (Table 26)). So this experiment will repeat in next Boro season.

PEST MANAGEMENT

Monitoring of insect pest and natural enemy incidence by using light trap.

Rice insect pests and their natural enemies were monitored by using Pennsylvanian light traps from July 2020 to June 2021 at the BRRI RS, Habiganj. The traps were operated with 100 WATT white fluorescent tube light from dusk to dawn and the tube was operated from the nearest electricity sources of the light traps. Insect pests and natural enemies those were attracted to the light of the light trap slipped into the hole of the trap and caught behind in a pot which was attached with the hole of the trap. Then the insect pest and natural enemies were collected, sorted, counted and the numbers were recorded in the data sheet every day.

The abundance of green leafhopper (GLH), white-backed planthopper (WBPH), brown planthopper (BPH), yellow stem borer (YSB), leafroller (LR), caseworm (CW), grasshopper (GH), rice bug (RB) and long horned cricket (LHC) were found in the light trap during the reporting period. Among the insect pests, GLH populations were found highest followed by WBPH, BPH and YSB. Highest peak of GLH and BPH observed in April. Another peak of GLH with BPH and WBPH was found in the month of October. (Fig. 7).

Among the natural enemies green mirid bug (GMB) populations were found highest followed by carabid beetle (CBB) and lady bird beetle (LBB). Two distinct peaks of GMB and CBB were observed November to December. Distinct peak of LBB wasobserved in October to April (Fig. 8).

Table 26. Seedling strength of the seedling of BRRI dhan88 under different seeding raising techniques.

Treatment	Seedling strength (mg cm^{-1})
T_1	2.29
T_2	3.14
T_3	2.62
T_4	3.40
T_5	3.08
T_6	4.56
$LSD_{0.05}$	1.62

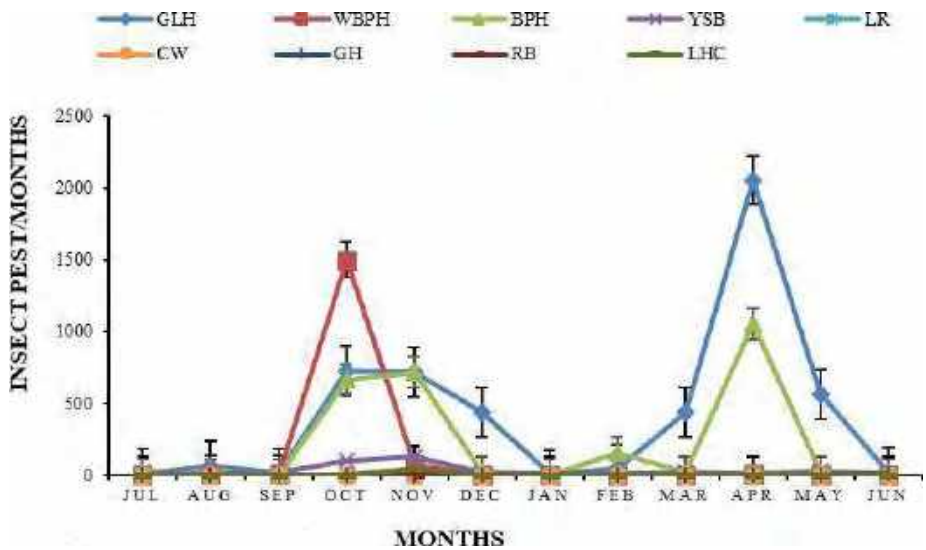

Fig. 7. Incidence patterns of major insect pests in light trap, BRRI RS, Habiganj, July 2020- June 2021.

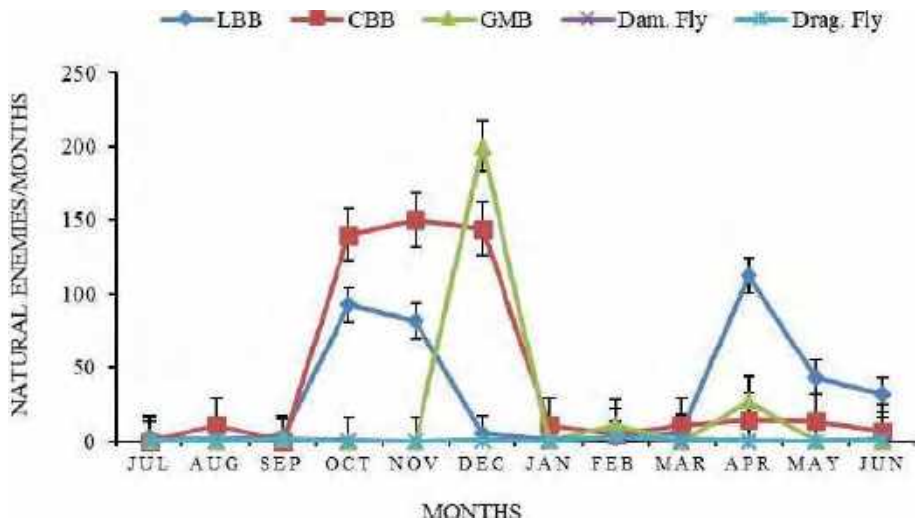

Fig. 8. Incidence pattern of natural enemies of rice insect pests in light trap, BRRI RS, Habiganj, July 2020- June 2021.

Demonstration of wet-direct seeding crop establishment technique.

The demonstration was conducted at BRRI RS, farm Habiganj during Boro 2020-21. Germinated rice seeds of three BRRI varieties i.e., BRRI dhan29 and BRRI dhan92 and sown in line by hand with the help of a rope. The plot size was 33 decimals for each variety. The line to line spacing was 25 cm. Five to six days after sowing pre-emergence herbicide Laser@ 125 g ha^{-1} was applied. Thinning was done 20 days after sowing (DAS) followed by one hand weeding at 30 DAS. BRRI recommended practices were followed for crop production.

The highest grain yield was observed in BRRI dhan29 and BRRI dhan92 (8.64 and 8.85 t

ha^{-1}) in hand seeding at BRRI RS farm, Habiganj with a growth duration 149-153 days (Table 27). The growth duration of the tested varieties reduced 8-10 days in direct seeding than transplanting.

Truthfully labeled and breeders seed production

About 17 tons truthfully labeled seeds (TLS) were distributed and sold to the researchers and local farmers according to their demand. More than 20 tons of TLS were produced during the reporting year.

About 27 tons of breeders seeds (BS) were produced and sent to the Genetic Resource and Seed Division of BRRI.

TECHNOLOGY TRANSFER AND SEED DISSEMINATION

The station conducted one special workshop where high officials from MoA, DAE and different NARS institutes participated. It also conducted training courses on Rice cultivation technology for 400 farmers in which they were trained up with rice production technology in different ecosystems especially on submergence and cold environment. The training courses were conducted at BRRI training center and different upazilas of Sylhet region. Seeds of different varieties were distributed among the participating farmers for dissemination of those varieties.

Table 27. Growth duration and yield of different demonstration during Boro 2020-21, BRRI RS, Habiganj (direct wet seeding).

Variety name	Seeding date	Maturity date	Growth duration (day)	Yield (t ha^{-1})	Remarks
BRRI dhan29	13 Nov. 20	16 Apr. 21	153	8.64	Seeding by hand
BRRI dhan92	21 Nov. 20	18 Apr. 21	149	8.85	Seeding by hand
BRRI dhan29	13 Nov. 20	26 Apr. 21	163	8.38	Transplanting
BRRI dhan92	21 Nov. 20	28 Apr. 21	157	8.80	Transplanting

BRRI RS, Rajshahi

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SUMMARY

In Aus 18 breeding lines from two regional yield trial (RYT) were evaluated of which one entries appeared promising for further evaluation. In OYT Aus, the genotype IR99853-B-B-B-509 produced significantly higher grain yield but 20 days longer growth duration than the check BRRI dhan48. In hybridization program in T. Aman, 2,297 F1 Seeds were produced from 32 crosses. Eleven RYTs were conducted in T. Aman in which me 60 breeding lines were evaluated and six entries were found promising for further advancement. In OYT, T. Aman under Aggri Network Trial, 30 out of 254 entries showed 5.0-6.1 t/ha yield with 95 days to 113 days growth duration. In OYT T. Aman under RCP1.0 core panel, 15 genotypes were selected under stressed condition for further trial. Out of 15 local germplasm, seven landraces showed good field performance in Aman season.

In Boro, A total of 1965 F1 seeds were produced from 25 crosses. In Rapid Generation Advance of Segregating Nursuries, Boro, 34,904 individual progenies from 25 crosses were grown comprising F_2, F_3 and F_4 populations. Overall recovery of the lines across the generations was 86.66%. Twelve RYTs were conducted in Boro in which 63 breeding lines were evaluated against different varieties and 12 entries were found promising for further advancement. None of the zira type landraces produced significantly higher yield than the check varieties in Boro season. In AYT Boro under AGGRi Network trial, the genotype IR17A1293 performed the highest grain yield with a growth duration of 148 days.

Under TRB project, 13 entries out of 110 produced the highest yield compared to the checks in OYT AUS. In OYT Aman, six genotypes out of 127 produced higher grain than the check BRRI dhan87 and the genotype BR11869-5R-16 showed the best performance among six entries and all checks. In PYT Aman, the genotype BR10923-4-1-1 and BR10913-21-1-1) produced the highest grain vield compared than three checks. In OYT Aman, estimation of breeding value of rice elite breeding pool (EBV) trial, two genotypes viz. IR98841-GAZ 8-1-3-1 and Lal Swarna produced the highest yield than the checks. In PYT-DTR Aman, the genotypes BR10535-14-1-3-1-1 and BR10535-5-1-3-3-1 showed better performance on grain yield. In Aman OYT insect resistance rice (BPH and GM), 22 entries out of 460 entries produced higher yield and shorter growth duration than BRRI dhan49. In Aman AYT insect resistant rice (BPH and GM), IRBPHN-SVIN352-18 and BR10422-1-4-1 produced significantly highest yield than BRRI dhan49. In Boro PYT#1, bacterial blight (BB) tolerant rice, the genotype BR11606-4R-142 produced significantly higher grain yield and similar growth duration with BRRI dhan88. In Boro PYT#2), bacterial blight (BB) tolerant rice, the genotype BR11607-4R-153 performed the highest grain yield. In Boro OYT, insect resistant rice (BPH), 35 out of 320 entries produced higher grain compared to the check BRRI dhan88 and BRRI dhan89. In Boro AYT, insect resistant rice (BPH), the highest grain yield was produced by the genotype BR 11593-5 R-55.

Ten advanced breeding lines are found as resistant materials against bacterial blight in Boro season. Six new fungicides were found effective against sheath blight disease in T. Aman season. Sheath blight was found in higher incidence and bacterial blight was found in moderate incidence in Rajshahi region.

Fipronil 50SC and Cartap 50SC were found as most effective fungicides against stem borer control. Bamboo made trap was found highly effective against box and snap type trap in Both Aus and Aman season. The highest number of YSB larvae was found at Paba while the highest number of dark headed borer larvae was found at BRRI RS, Rajshahi as well as tanore upazila of Rajshahi district.

Considering higher productivity, cropping pattern Potato/Pumpkin (relay)-T Aus-T. Aman (BRRI dhan75) found as most promising. Two row potato/two row Maize-T Aus (BRRI dhan82) T. Aman (BRRI dhan75) was also found as a highly productive pattern. Considering cropping system the rice equivalent yield (REY) remained higher in conventional rice transplanting followed by strip tillage maize followed by strip tillage mungbean systems. Yield performance of BRRI dhan89 remained higher in early seeding (upto 15

December) while it was remained higher of BRRI dhan58 in late planting situation (upto 30 January seeding). In late Aus condition, the highest grain yield was found in BRRI dhan75 followed by BRRI dhan48 while the lowest yield was recorded in BRRI dhan28. In on-station and in farmer's field, the highest grain yields were found in BRRI dhan51 and the lowest yields were recorded in BRRI dhan87 in Aman season.

Among the 12 varieties in Aus stability trial, BRRI dhan82 were top in rank followed by BRRI dhan65. In Aman stability trial, BRRI dhan93 ranked top in terms of yield followed by BRRI hybrid dhan4. In Boro stability trial, the highest yield was found in BRRI hybrid dhan5.

BRRI RS, Rajshahi arranged 49 training programmes on modern rice cultivation, farm mechanization, cropping pattern etc. where 1,660 participants 100k part. Around 100 crop cut was done in Aus season and the local 76 Aus variety produced the highest yield closely followed by BRRI dhn48. A total of 149 demonstrations were established in Aman season and 37 crop cut were done where the highest yield was found in BRRI dhan95 followed by BRRI dhan94. In Boro season, around 900 demonstrations were established in farmers' field and 79 crop cut were done where the highest yield was found in BRRI dhan89 followed by BRRI dhan92.

In head to head adaptive trial in Boro season, the highest grain yield was found in BRRI dhan81 in short duration package while the grain yield remained higher in BRRI dhan89 in long duration package. Considering three seasons, 23 tons breeder seed and 14 tons TLS seed were produced in BRRI RS, Rajshahi.

VARIETY DEVELOPMENT

Regional yield trial (RYT), T. Aus 2020-21

Fifteen genotypes along with BRRI dhan48 and Bina dhan19 were evaluated at BRRI Rajshahi farm. Bina dhan19 produced significantly lower grain yield (4.35 t/ha and 111 days) and five days longer growth duration than the check BRRI dhan48 (5.02 t/ha and 106 days.)

Observational yield trial (OYT), T. Aus 2020-21

Eight genotypes along with checks BRRI dhan48 and N22 were evaluated and the genotype IR99853-B-B-B-509 produced significantly higher grain yield (4.15 t/ha and 125 days) but 20 days longer growth duration than the check BRRI dhan48 (3.60 t/ha and 105 days).

Regional yield trial (RYT), T. Aus 2020-21

Three genotypes along with BRRI dhan48 and BRRI dhan82 were evaluated where the entry BR9830-53-3-5-2 produced significantly higher grain (3.49 t/ha and 101 days) than the all check varieties (2.32-2.67 t/ha and 100-103 days).

Hybridization, T. Aman 2020-21

Thirty-two crosses were made using sixteen parents. A total of 2297 F1 seeds were produced.

Confirmation of F_1, T. Aman 2020-21

Fourteen crosses were made grown along with their parents and 11 crosses were selected and confirmed as true F_1s. Seeds of these selected F_1 plants were selfed to produce F_2 seeds.

Regional yield trial (RYT), T. Aman 2020-21

RYT#1-Rainfed lowland rice (RLR#1). Seven genotypes along with two checks BRRI dhan49 and BRRI dhan87 were evaluated and the genotype IR98381-B-B-B-B-71 produced similar grain yield (5.51 t/ha) but 20 days earlier than the check BRRI dhan49 (5.51 t/ha).

RYT#2-Rainfed lowland rice (RLR#2). Seven genotypes along with two checks BRRI dhan49 and BRRI dhan87 were evaluated and two entries BR8492-9-5-3-2-HR1 and BR8492-9-5-3-2 produced significantly higher grain yield (5.28-5.25 t/ha and 117-119 days) than all check varieties (4.88-4.70 t/ha and 121-129 days).

RYT#3-Zinc enriched rice (ZER#1). Two advanced lines were evaluated along with BRRI dhan49, BRRI dhan72 and BRRI dhan87 and none of the entry showed higher grain yield than the check varieties.

RYT#4-Zinc enriched rice (ZER#2). Five genotypes along with three checks BRRI dhan49, BRRI dhan72 and BRRI dhan87 were evaluated and none of the entry performed higher grain yield than the check varieties.

RYT#5- Disease resistant rice (DRR). Six advanced breeding lines along with the checks BRRI dhan49 and BRRI dhan87 were evaluated and none of the entries performed higher grain than the check BRRI dhan49 (5.56 t/ha).

RYT#6- Insect resistant rice (IRR#1). Thirteen breeding lines along with the check varieties BRRI dhan33, BRRI dhan49 and BRRI dhan93 were evaluated. The genotype BR10038-2-12-1 produced significantly higher grain yield (5.86 t/ha) with 8-11 shorter growth duration than all the check varieties (3.33-5.26 t/ha). The other tested entry BR9888-23-5-9-2 produced similar grain (5.37 t/ha) with 6-9 days shorter growth duration with the check variety BRRI dhan49 and BRRI dhan93 (5.10-5.26 t/ha).

RYT#7-Insect resistant rice (IRR#2). Twelve breeding lines along with the checks BRRI dhan33, BRRI dhan49 and BRRI dhan93 were evaluated and none of the tested entries performed higher grain yield than the check varieties.

RYT#8-Premium quality rice (PQR#1). Three advanced lines were evaluated against Krishnobhog type Kalizira and krishnobhog as local check and BINA dhan-13 as standard check at BRRI RS, Rajshahi. BR9590-45-1-3-2-P2 produced higher grain (3.17 t/ha and 140 days) than all the check varieties (1.18-1.85 t/ha and 138-143 days) followed by BR8993-3-5-1-P1 (2.67 t/ha and 135 days)**.**

RYT#9- Premium quality rice (PQR#2). Three advanced breeding lines along with the check variety D. Kataribhog as local check and BRRI dhan37 as standard check were evaluated. The genotype BR9590-45-1-3-2-P2 produced higher grain and 19-37 days shorter growth duration (4.41 t/ha and 100 days) than all the check varieties (1.89-2.12 t/ha and 119-137 days) followed by BR9581-1-16-3-5-3 (4.12 t/ha and 103 days)**.**

RYT#10- Special yield trial. Eight genotypes were evaluated at two locations i.e. BRRI RS, Rajshahi farm and farmers field of Alimganj. Out of eight, the genotype SP02 and SP05 produced higher grain and good field performance at both the locations.

RYT#11- Submergence and drought tolerant rice. Four genotypes were evaluated against three standard check varieties i.e. BRRI dhan56, BRRI dhan71 and BRRI dhan95 at three locations i.e. BRRI RS, Rajshahi farm and farmers field of Alimganj and Tanore. None of the entry performed better than the check varieties.

Aggri network trials for favourable environment, IRRI-Irrigated rice breeding programme, OYT, T. Aman 2019-20

Advanced breeding lines (254) along with six international check varieties and 10 national check varieties were evaluated. Out of 254, thirty entries showed 5.0-6.1 t/ha yield with 95 days to 113 days' growth duration, the two check varieties BRRI dhan49 and BRRI dhan75 yielded 4.3 t/ha and 5.1 t/ha, respectively.

Evaluation of the agronomic performance of RCP1.0 core panel under normal and stress conditions at the selected test locations, OYT, T. Aman 2020-21

A total of 192 advanced lines along with eight national and global checks were evaluated under control and stress conditions at Alimganj, Paba. Totally 15 genotypes (3.09-4.09 t/ha) were selected based on the performance under stressed condition for further trial.

Collection and maintenance of local landraces, T. Aman 2020-21

Around 15 local germplasm were collected from different upazila of Rajshahi region. Out of 15, seven landraces (Swarna Raj-1, Nur Md Variety, Lal dhan Rajshahi, Swarna Raj-2, Shampakatari, Ranjit swarna, Swarna -5) showed good field performance i.e higher grain yield (3.55-5.31 t/ha) with 118-135 days growth duration, 22.6-27 cm panicle length and 31.2-44 cm flag leaf length.

Hybridization, Boro 2020-21

Twenty- five crosses were made using 17 parents.
A total of 1,965 F1 seeds were produced.

Rapid generation advance of segregating nursuries, Boro 2020-21

In total 34,904 individual progenies from 25 crosses were grown comprising F_2, F_3 and F_4 population and 30,247 individual progenies were harvested from rapid generation advanced of

segregating populations of different generations. Overall recovery of the lines across the generations was 86.66%.

Regional yield trial (RYT), Boro 2020-21

Twelve regional yield trials were conducted in Boro season.

RYT#1 (FBR-MD). Seventeen advanced breeding genotypes along with three check varieties BRRI dhan81, BRRI dhan89 and BRRI dhan92 were evaluated at BRRI RS, Rajshahi farm. None of the genotype produced higher grain yield than the check varieties BRRI dhan89 and BRRI dhan92 (7.69 t/ha).

RYT#2 (FBR-Barishal#1). Six advanced lines along with two checks BRRI dhan58 and BRRI dhan92 were evaluated. Among the genotypes, one genotype BRBa1-4-9 produced highest grain yield (9.06 t/ha) with growth duration of 168 days that was significantly similar with the check BRRI dhan9 (9.20 t/ha). But all of the genotypes produced significantly higher grain yield (8.10-9.06 t/ha) than the check BRRI dhan58 (7.43 and 158 days) but 4-10 days longer growth duration.

RYT#3 (FBR-Barishal#2). Seven advanced genotypes were evaluated against two checks, BRRI dhan58 and BRRI dhan92 and none of the tested entry showed higher grain yield than the check variety BRRI dhan92 (8.69 t/ha).

RYT#4 (FBR-Cumilla#1). Six advanced lines along with the check varieties BRRI dhan81, BRRI dhan84 and BRRI dhan88 were evaluated. All the entries produced higher grain yield (7.61-8.95 t/ha) but with 6-18 days longer growth duration than the check varieties (4.29-6.51 t/ha).

RYT#5 (FBR-Cumilla#2). Seven advanced breeding lines were evaluated along with the three check varieties BRRI dhan50, BRRI dhan58 and BRRI dhan89. None of the entries produced higher grain yield than the check BRRI dhan89 (8.49 t/ha).

RYT#6 (CTR). A total of 17 breeding lines along with four checks BRRI dhan28, BRRI dhan67, BRRI dhan69 and BRRI dhan89 were evaluated in three locations. At BRRI RS, Rajshahi farm, none of the entry performed higher grain yield than the check BRRI dhan89 (7.85 t/ha). At Alimganj, the genotype BR10715-5R-1 performed similar grain and growth duration with the check BRRI dhan69 and BRRI dhan89.

RYT#7 (PQR). Five advanced breeding lines were evaluated against three checks BRRI dhan50, BRRI dhan63 and BRRI dhan81 at two locations. At BRRI RS, Rajshahi farm, two entries viz. BR9930-2-3-2-2 and BR9930-2-2-4-3 produced significantly higher grain (6.29-6.50 t/ha) than BRRI dhan81 (5.53 t/ha) but produced similar grain with BRRI dhan50 (6.31 t/ha) in similor growth duration. At Paba, none of the genotype performed better than the checks.

RYT#8 (ZER). Three advanced breeding lines were evaluated along with three check BRRI dhan74, BRRI dhan84 and BRRI dhan89. The tested entries didn't perform higher grain than BRRI dhan89 (8.00 t/ha) but the genotype BR9674-5-6-2-1-7-22 produced significantly higher grain (6.90 t/ha) than the check varieties BRRI dhan74 and BRRI dhan84 (6.17-6.37 t/ha).

RYT#9 (DRR). Five breeding lines along with BRRI dhan58, BRRI dhan89 as susceptible checks and IRBB60 as resistant check were evaluated. The check BRRI dhan89 produced the highest grain (9.21 t/ha). Out of five, four entries produced significantly higher grain (8.22-8.89 t/ha) than the resistant check IRBB60 (7.11 t/ha). Among them, the genotype BR9943-2-2-P1-HR2 produced significantly higher grain (8.81 t/ha) and other three tested entries gave similar grain (8.22-8.29 t/ha) with the check variety BRRI dhan58 (8.34 t/ha).

RYT#10 (GSR). Five genotypes along with two standard checks BRRI dhan58 and BRRI dhan88 were evaluated. The genotype WANXIAN77-P10-P3 produced significantly higher grain (9.66 t/ha and 160 days) than all the check varieties (7.40-9.30 t/ha and 146-158 days). The other genotype FBR336 produced significantly higher grain (8.81 t/ha) but with 14 days longer growth duration than the check BRRI dhan88 (7.40 t/ha).

RYT#11 (YMT). Two advanced lines along with the standard check variety BRRI dhan63 were evaluated. None of the tested entries produced higher grain than the check variety BRRI dhan63 (6.45 t/ha).

RYT#12 (MLT-Blast). In total, 11 genotypes were evaluated against the standard check variety BRRI dhan28. None of the tested entries produced higher grain yield than the check variety BRRI dhan28 (5.50 t/ha).

Evaluation of Zira landraces from different region of Rajshahi, Boro 2020-21

Eleven local germplasm, among them eight landraces were Zira, rest three germplasms were minikit and shuvolata were collected from different region of Rajshahi and evaluated against BRRI dhan63, BRRI dhan81 and BRRI dhan86. None of the landraces produced significantly higher yield than the check varieties.

Establishment of aggri network trials for favourable environment, OYT, Boro 2020-21

This trial was conducted with 270 breeding lines including 10 national check varieties to select the best performing breeding lines with highest genetic merits. The check varieties, BRRI dhan29, BRRI dhan89 and BRRI dhan92 yielded 8.55 t/ha, 8.87 t/ha and 8.64 t/ha, respectively while the tested 16 entries yielded 7.51-8.30 t/ha with growth duration of 148-165 days.

Establisment of aggri network trials for favourable environment, AYT, Boro 2020-21

This trial was conducted with 44 breeding lines including four national check varieties to understand and select the best performing breeding lines with the highest genetic merits. Among the tested entries, the genotype IR17A1293 performed the highest grain (8.01 t/ha) yield with a growth duration of 148 days. The check varieties, BRRI dhan81, BRRI dhan89 and BRRI dhan92 yielded 6.18 t/ha, 8.79 t/ha and 8.89 t/ha, respectively.

Experiments under transform breeding rice (TRB) Project

Observation Yield Trail (OYT) T. Aus 2020

Thirteen entries (5.12-5.91 t/ha and 107-124) out of 110 entries produced the highest yield compared to the two checks (4.28-5.09 t/ha and 106-109 days).

Advanced yield trial (AYT), T. Aus 2020

AYT consisted of Bina dhan19 along with BRRI dhan48 were evaluated where Bina dhan19 produced significantly lower grain yield (4.35 t/ha and 111 days) with five days longer growth duration than the check variety BRRI dhan48 (5.02 t/ha and 106 days).

Observational yield trial (OVT), bacterial blight (BB) tolerant rice, T. Aman 2020

A total 127 fixed lines with two standard checks were evaluated. Among them, six genotypes produced higher grain (5.98-6.26 t/ha) compared to the check BRRI dhan87 (5.93 t/ha and GD 125 days) with GD in between 100-128 days and the genotype BR11869-5R-16 (yield 6.23 t/ha and GD 128 days) showed the best performance among six entries and all checks.

Preliminary Yield Trial (PVT#2), bacterial blight (BB) tolerant rice T. Aman 2020

Out of 17 entries, the genotype BR10923-4-1-1 (yield 4.92 t/ha and GD 133 days) and BR10913-21-1-1 (yield 4.87 t/ha and GD 132 days) produced the highest grain compared to the three checks (yield varies 3-4.71 t/ha and GD 108-138 days) but with GD five to six days earlier the highest yield producing check variety BRRI dhan52 (yield 4.71 t/ha and GD 138 days).

OYT, Estimation of breeding value of rice elite breeding pool (EBV), T. Aman 2020

In total 198 entries were evaluated with standard checks. Out of 198, two genotypes IR98841GAZ-8-1-3-1 (6.42 t/ha) with a growth duration of 108 days and Lal Swarna (6.35 t/ha) with a growth duration of 130 days produced the highest grain yield among all six checks (yield varies 4.10-6.02 t/ha and GD 102-129 days).

Preliminary yield trial (PYT), drought resistant rice (DTR), T. Aman 2020

In total 17 breeding lines were evaluated. The genotypes BR10535-14-1-3-1-1 (5.94 t/ha and 117 days) and BR10535-5-1-3-3-1 (5.57 t/ha and 111 days) showed better performance on grain yield and two days shorter and six days longer GD compared to the check BRRI dhan71 (5.21 t/ha and 113 days).

Observation yield trial (OYT), insect resistant rice (BPH and GM), T. Aman 2020

In total 460 entries along with checks were evaluated. Among them, 22 entries produced higher yield (5.55-6.26 t/ha) with shorter growth duration (98-128 day) compared to the check BRRI dhan49 (5.53 t/ha and 129 days), the genotype BR11869-5R-16 produced 6.26 t/ha yield with 128 days GD.

Preliminary yield trial (PYT), insect resistant rice (BPH and GM), T. Aman 2020

A total of 50 genotypes with standard checks BRRI dhan33, BRRI dhan49, BRRI dhan87 and one resistant check T27A were evaluated at Alimganj, Paba, Rajshahi. Out of 50 genotypes, one entry viz. BR10774-4R-3 produced similar grain (5.44 t/ha and 120 days) to BRRI dhan49 (5.31 t/ha and 133 days) with 13 days earlier GD and the other check BRRI dhan87 (5.28 t/ha and 128 days) with eight days earlier GD.

Advanced yield trial (AYT), insect resistant rice (BPH and GM), T. Aman 2020

Two entries IRBPHN-SVIN352-18 and BR10422-1-4-1 produced significantly the highest yield(5.62-5.66 t/ha) with 6-24 days earlier GD compared to the check BRRI dhan49 (5.22 t/ha and 134 days).

Preliminary yield trial (PYT#1), bacterial blight (BB) tolerant rice, Boro 2020-21

Thirty genotypes were tested against the check variety BRRI dhan88. The genotype BR11606-4R-142 produced significantly higher grain yield (8.33t/ha) and similar growth duration with BRRI dhan88 (7.09 t/ha).

Preliminary yield trial (PVT#2), bacterial blight (BB) tolerant rice, Boro 2020-21

Out of 50, 23 entries produced more than 7.5 t/ha grain (7.50-8.58 t/ha) with growth duration of 152-162 days which were the highest compered to the check BRRI dhan58 (7.33 t/ha and GD 154 days). Among the tested entries, the genotype BR11607-4R-153 performed the highest grain 8.58 t/ha with a growth duration of 158 days.

Observation yield trial (OYT), insect resistant rice (BPH), Boro 2020-21

In OYT-BB, 35 entries out of 320 entries produced higher grain 8.24-9.45 t/ha compared to the check BRRI dhan88 and in between 144-156 GD while the BRRI dhan89 the highest yielding check produced 8.19 t/ha grain with 154 days GD.

Advanced yield trial (AYT), insect resistant rice (BPH), Boro 2020-21

In total 82 genotypes were tested and nine entries produced significantly higher grain yield (7.62-8.50 t/ha) and with more or less similar GD than the check BRRI dhan89 (7.40 t/ha and 157 days). The highest grain yield (8.50t/ha) was produced by the genotype BR 11593-5 R-55 with 156 days growth duration. Heat storm on 4.04.21 caused panicle sterility of the entries

PEST MANAGEMENT

Screening of advanced breeding lines against bacterial blight (BB) disease, Boro 20-21

In Boro, 118 materials including resistant, susceptible and standard checks were screened against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen. Plants were inoculated with a virulent isolate of the major race, BXO97 at maximum tillering stage following leaf clipping method (Kauffman *et al.* 1973). Among 135 genotypes, ten advanced breeding lines are found as resistant materials and 17 as moderately resistants against bacterial blight disease.

Evaluation of effective chemical against Sheath Blight disease of rice, T. Aman 2020

Nineteen new fungicides with disease control and standard check (Nativo) treatment were tested. Among them, six fungicides- Mukti 32.5 SC (Azoxystrobin 20% + Difeconazole 12.5%), Newtec 300 SC (Hexaconazole + Tricyclazol), Opec 32.5 SC (Azoxystrobin 20%+ Difeconazole 12.5%), Clean 75W (Tebuconazole 50%+ Trifloxystrobin 25% WDG) and Famous 60WG (Pyraclostrobin 5%+ Metiram) and Farmbin 32.5EC (Azoxystrobin 20%+ Difeconazole 12.5%) controlled sheath blight disease successfully (equal

or above 80%) in both BRRI, Gazipur and Cumilla farm.

Survey and monitoring of rice diseases in of Rajshahi district

A survey was conducted to know the present status of different rice diseases in three upazilas named Paba, Tanore and Godagari in Rajshahi district during T. Aman 2020 and Boro 2020-21. In Paba upazila, incidence of bacterial blight, sheath blight, brown spot and bacterial leaf streak in average 35%, 10%, 42% and 67% with the severity of 5, 3, 3 and 5 respectively during T. Aman 2020. In Bijoynagar village of Godagari, the incidence of sheath blight and bacterial blight were 89% and 82% respectively with higher severity scale of 9. In Tanore, sheath blight was found in higher incidence 22 to 75% in severity scale 7 during T. Aman season. Prevalence of bacterial blight was the highest incidence (55%) followed by sheath blight (51%) with severity scale 7 and 5, respectively on Swarna and BRRI dhan34 in that season. In Boro season, bacterial blight (45%) and bacterial leaf streak (62%) in higher incidence with severity scale 7. In BRRI Rajshahi farm, brown spot and bacterial blight disease were in medium incidence (equal or above 25%) with severity scale 3 to 5 while other major diseases were found in lower incidence with less severity.

Crop loss assessment of different rice varieties due to major diseases in Rajshahi

Kukhondi, village of Paba, Rajshahi was selected for crop loss assessment experiment. The Experiment was conducted in 50 farmer's field of that village in Boro 2020-21. Two major rice diseases bacterial blight and brown spot were observed in higher incidence (DI 50% and 27.5 % with severity 5 respectively) in all spots. Yield loss was obtained mainly in BRRI dhan28 in one spot about 40 % due to neck blast disease with DI 85 % and DS 7. BRRIdhan86 was also affected by bacterial blight diseases in two spots with higher disease incidence (60%). In this experiment, above 25% disease incidence was considered as disease spots while below 25% as less or non-infected or healthy plot/spot. Yield of BRRI dhan28 was higher in healthy plot compared to the diseased spot those were affected by different diseases like bacterial blight (BB), brown spot (BS), bacterial leaf streak (BLS) and sheath blight (ShB). On the other hand, yield of BRRI dhan86 was also higher in comparison with the diseased plot. Considering all yield and disease data it can be said that disease incidence with severity have negative impact on rice yield.

Effect of selected insecticide for stem borer management

The investigation was conducted at BRRI RS, Rajshahi during Boro 2020-21. Four single molecule insecticides along with control were used in this experiment. Applications were given one at maximum tillering stage and another at before flowering stage. The lowest dead heart infestation was found from Fipronil 50SC treated plot (3.38%) and the highest dead heart damage of 12.41% was found in control plot. The percent white head infestation due to stem borer revealed significant results and Fipronil 50SC (3.44% white head) found superior among all the insecticides but at per with Cartap 50SC (4.45% white head). The highest white head infestation (8.10%) was found in control plot and it was significantly different with other treatments. Significantly the highest yield (7.28 t/ha) was in Fipronil 50SC treated plot and the lowest yield was found in control plot (5.37 t/ha).

Effect of different trap design for the management of rat

The experiment was conducted in the rice field of BRRI RS, Rajshahi farm during Aus and Aman season 2020. Three different types of traps were used for capturing rats such as Bamboo made trap, Snap trap and Box type live trap in this experiment. The rat capture efficacy of different kinds of traps was varied significantly in both the seasons. In Aus season the highest number of rats (16.00 rats /trap) were captured by bamboo made trap and the lowest number of rats (0.60 rat/trap) was captured by box type live. In Aman season, the highest number of rat was captured (20.55 rat/trap) by bamboo made trap and the lowest number of rat was captured by box type live trap and snap trap (0.36 rat/trap).

Species composition of stem borer in Rajshahi region

The experiment was conducted at Paba, Godagari and Tanore upazilas of Rajshahi district as well as BRRI RS, Rajshahi during Aman, 2020 and Boro 2020-21 to document the stem borer species composition in the selected Rajshahi region**.** Among the locations, the highest number of YSB larvae was (60.26%) found at Paba upazila and the lowest was (50.79%) at BRRI RS, Rajshahi. The highest number of dark headed borer larvae was (49.03%) found at BRRI RS, Rajshahi and lowest was (38.46%) at Paba upazila. Among the different locations, the highest number of dark headed borer larvae (50.19%) was found in Tanore upazila and the the lowest number was (40.22%) in BRRI RS, Rajshahi. In case of yellow stem borer, the highest number was (56.76%) found in Paba upazila and the lowest was (48.33%) Tanore upazila Rajshahi district. The highest number of pink borer species was (3.26%) found in BRRI RS, Rajshahi then Paba upazila (2.70%) and the lowest was (1.49%) in Tanore upazila.

RICE FARMING SYSTEMS

Evaluation of crop productivity and soil health under four crops cropping patterns

The trial consisted with six cropping patterns (CP) viz. CP_1. Potato/pumpkin (relay)-T Aus-T. Aman (BRRI dhan75), CP_2. Potato-mungbean-T. Aus-T. Aman (BRRI dhan75), CP_3. Field Pea-Onion-T. Aus-T. Aman (BRRI dhan75). CP_4. Mustard-Onion-T. Aus-T. Aman (BRRI dhan75), CP_5. Mustard-Onion/Maize (relay)-T. Aman (BRRI dhan75), CP_6. Potato-Maize-T. Aman (BRRI dhan95) were evaluated in BRRI RS, Rajshahi farm.

Among the cropping patterns, the rice equivalent yield (REY), yield of 1st crop (Rabi season) remained higher 13.07 t/ha in CP_1 (Potato) followed by CP_6 (12.80 t/ha) (Potato) and CP_2 (12.66 t/ha) (Potato) and that was found lower (5.20 t/ha) in CP_3 (field pea). In 2nd crop, REY (10.45 t/ha) was found higher in CP_5 (Onion) and that was remained lower (3.27 t/ha) in CP_2 (Mungbean). The REY in 3rd crop was found higher in CP_1 (BRRI dhan82) followed by CP_5 (Maize). Considering system yield, the higher REY (27.78 t/ha) was found in CP_1 followed by CP_5 (27.01 t/ha). The lower system yield was found in CP_6 (24.76 t/ha)

Evaluation of crop productivity under four crops cropping patterns in farmers field

The trial consisted with five cropping patterns were evaluated in farmer's field. The cropping patterns were CP_1. Two row potato/Two row Maize-T Aus (BRRI dhan82)-T. Aman (BRRI dhan75), CP_2. Potato/Pumpkin-T Aus (BRRI dhan82)-T. Aman (BRRI dhan75), CP_3. Potato-Mungbean-T. Aus (BRRI dhan82)-T. Aman (BRRI dhan75), CP_4. Potato-Maize-T. Aman (BRRI dhan75), CP_5. Maize-Mungbean-T. Aman (BRRI dhan75).

The rice equivalent yield (REY), yield of 1st crop remained higher in potato of CP_3 (REY 13.91 t/ha) followed by CP_2 (13.30 t/ha) (Potato) and CP_4 (14.11 t/ha) and that was found lower in 8.63 t/ha in CP_5 (Maize). In potato based patterns, the REY in 1st crop was found significantly lower in CP_1 of 10.89 t/ha. In contrast, the REY in 2nd crop (maize) was found significantly higher in CP_1 followed by CP_4 (5.63 t/ha). Considering system yield, the higher REY (29.23 t/ha) was found in CP_1 followed by CP_3 (27.23 t/ha). The lower system yield was found in CP_5 (18.57 t/ha).

Evaluation of crop productivity and soil health under strip tillage system in maize-mungbean-rice cropping pattern

The trial was conducted at BRRI RS, to evaluate the productivity and profitability of strip tillage system. The tillage and crop establishment methods were T_1: Strip tillage dry seeded rice followed by strip tillage maize and mungbean, T_2: Strip tillage un-puddled rice through rice transplanted followed by strip tillage maize and mungben, T_3: Conventional tillage transplanted rice followed by strip tillage maize and mungben, T_4: Conventional transplanted rice followed by conventional maize and mungben.

The higher grain yield of rice was found in T_3 (4.92 t/ha) which was statistically similar with all other treatments except T_1 (4.40 t/ha). In contrast, the highest grain yield of maize was found in T_1 (11.18

t/ha) followed by T_2 (10.77 t/ha). Considering cropping system yield, the rice equivalent yield (REY) remained higher in T_3 (16.69 t/ha) closely followed by T_2 (16.54 t/ha) treatment and that was found lower in T_1 (16.29 t/ha) treatment. The gross margin was found higher in T_2 treatment (Tk 2,18,500/ha) followed by T_3 (Tk 2,12,800/ha. Although the gross return remained higher (Tk 4,10,220/ha) but gross margin remained lower (2,09,190 t/ha) in T_4 (Conventional) treatment.

Effect of time of planting on rice varieties in Boro Season

The trial was conducted at BRRI RS, Rajshahi to identify the suitable planting time of different rice varieties in Boro season. This was two factor experiment and the treatments under factor A were V_1: BRRI dhan28,V_2: BRRI dhan58, V_3: BRRI dhan81, V_4: BRRI dhan89 and the treatments under factor B were S_1: 15 November seeding with 40 day-old seedling, S_2: 15 November seeding with 50 day-old seedling, S_3: 30 November seeding with 40 day-old seedling, S_4: 30 November seeding with 50 day-old seeding, S_5: 15 December seeding with 40 day-old seedling, S_6: 15 December seeding with 50 day-old seedling, S_7: 30 December seeding with 35 day-old seedling, S_8: 15 January seeding with 30 day-old seedling, S_9: 30 January seeding with 30 day-old seedling. The interaction of variety and time of plating affected significantly and the highest yield was found in the combination V_4 x S_5 (8.08 t/ha) followed by V_4 x S_1 (7.61 t/ha) and V_2xS_9 (7.45 t/ha). After that, the other high yielding combinations were V_2 x S_5 (7.27 t/ha), V_4 x S_2 (7.18 t/ha) and V_2 x S_8 (7.05/ha). The yield performance of BRRI dhan89 was remained higher in early seeding (upto 15 December) while the yield performance remained higher in late planting situation (upto 30 January).

Evaluation of rice varieties in late Aus condition under Tomato-Boro-Aus systems

The trial comprised with six rice varieties viz. BRRI dhan28, BRRI dhan4, BRRI dhan71, BRRI dhan75, BRRI dhan82 and local_76 was conducted to identify the suitable variety in late Aus condition for Rajshahi region. The highest grain yield was found in BRRI dhan75 (5.41 t/ha) followed by BRRI dhan48 (5.13 t/ha) and lacal_76 (5.11 t/ha) while the lowest yield was recorded in BRRI dhan28 (4.45 t/ha).

Performance evaluation of Aman rice in Rajshahi region

The trial comprised with six rice varieties viz. BRRI dhan51, BRRI dhan87, BRRI dhan93, BRRI dhan94, BRRI dhan95 and Swarna was established in BRRI RS, Rajshahi farm and farmer's field to identify the suitable variety in Aman season for Rajshahi region. In on-station and in farmers' field, the highest grain yields were found in BRRI dhan51 (5.86 and 5.56 t/ha) and the lowest yields were recorded in BRRI dhan87 (5.12 and 4.76 t/ha).

SOCIOECONOMICS AND POLICY

Stability analysis of BRRI developed Aus varieties

Twelve rice varieties were evaluated at BRRI RS, Rajshahi. Among the 12 varieties, BRRI dhan82 (4.95 t/ha) ranked top followed by BRRI dhan65 (4.88 t/ha). After BRRI dhan65, the next two high yielding varieties were BRRI hybrid dhan7 (4.64 t/ha) and BRRI dhan83 (4.19 t/ha). The grain yield remained lower in BRRI dhan24 (3.35 t/ha) decreasingly followed by BR26 (3.37 t/ha).

Stability Analysis of BRRI developed T. Aman rice varieties

Forty-seven Aman rice varieties were evaluated at BRRI RS, Rajshahi farm. Among them, BRRI dhan93 ranked top in terms of yield (5.81 t/ha) followed by BRRI hybrid dhan4 (5.61 t/ ha). Next to BRRI hybrid dhan4, the rice yields in Aman season remained higher in BRRI dhan66 (5.60 t/ha), BRRI dhan94 (5.55 t/ha) and BRRI dhan95 (5.49 t/ha). BR5, BRRI dhan38, BRRI dhan37, BRRI dhan34 and BR3 were found as low yielding varieties and the yield ranged from 2.58.26 to 3.60 t/ ha).

Stability Analysis of BRRI developed Boro rice varieties

Forty-six varieties were evaluated at BRRI RS, Rajshahi farm during Boro season. Considering the yield performance, top five varieties were hybrid

dhan5 (9.50 t/ha), BRRI hybrid dhan2 (8.24 t/ha), BRRI dhan69 (7.77 t/ha), BRRI dhan99 (7.71), BRRI bybrid dhan3 (7.69 t/ha) and BRRI dhan29 (7.47 t/ha). BR17 (5.50 t/ha), BR1 (5.94 t/ha) and BRRI dhan68 (5.97 t/ha) were the low yielding among the boro varieties.

TECHNOLOGY TRANSFER

Farmers training and seed distribution

Farmers' training is an important tool to train up farmers on updated information for rice cultivation. BRRI RS, Rajshahi arranged 49 training programmes on modern rice cultivation, farm mechanization, cropping pattern etc. at different Upazillas of of Rajshahj region. One thousand six hundred and sixty participants were participated in the training programmes. Seeds of modern rice varieties were distributed to the farmers for variety demonstration.

Demonstration of BRRI released varieties

Field demonstrations were carried out at different locations of Rajshahi region during T. Aus, T. Aman and Boro seasons. Around 100 crop cut was done in Aus season from the demonstration plots and the local 76 Aus variety produced the highest yield (4.99 t/ha) closely followed by BRRI dhn48 (4.95). BINA dhan19 produced the yield of 4.50 t/ha while the local Pariza recorded the lowest grain yield of rice. A total of 149 demonstrations was established in Aman season and 37 crop cut were done where the highest yield was found in BRRI dhan95 (5.94 t/ha) followed by BRRI dhan94 (5.87) and BRRI dhan93 (5.77 t/ha). BRRI dhan87 produced the yield of 5.32 t/ha while the lowest yield was recorded in BRRI dhan2.87 t/ha in BRRI dhan91. In Boro season, around 900 demonstrations were established in farmer's field and 79 crop cut were done where the highest yield was found in BRRI dhan89 (8.46 t/ha) followed by 8.19 t/ha in BRRI dhan92. After that BRRI dhan81 produced the yield of 7.74 t/ha while zira dhan recorded the lowest yield of 7.15 t/ha.

Head to head adaptive trial, Boro 2020-21

Head to head adaptive trial was conducted in six locations with five short duration (BRRI dhan28, BRRI dhan67, BRRI dhan81, BRRI dhan84 and BRRI dhan88) and four long duration varieties (BRRI dhan29, BRRI dhan58, BRRI dhan89, BRRI dhan92). In case of short duration varieties, the highest grain yield was found in BRRI dhan81 (8.48 t/ha) followed by BRRI dhan67 (7.79 t/ha) and the lowest yield was recorded in BRRI dhan88 (6.76 t/ha). In case of long duration varieties, the grain yield remained higher in BRRI dhan89 (8.91 t/ha) followed by BRRI dhn92 (8.42 t/ha) and the grain yield remained lower in BRRI dhan58 (8.02 t/ha).

Truthfully leveled and breeders seed production

Nucleus seed stock was collected from GRS Division of BRRI. Single seedling was transplanted per hill. For breeder seed production, all official formalities with SCA and BRRI authority were performed through proper channel. Breeder seed was produced in T. Aman and Boro seasons but TLS seed was produced in Aus and T. Aman and Boro seasons. Considering three seasons (Aus, T. Aman and Boro), breeder and TLS seeds were produced 23 and 16 tons, respectively.

Advisory services

Any serious problem related to rice production at farmers' field was addressed duly in co-operation with the Department of Extension (DAE), Bangladesh Agricultural Development Corporation (BADC), Barind Multipurpose Development Authority (BMDA), Seed Certification Agency (SCA) and different NGO's. Field visits were done mainly to address different problems on insect and disease attack, seed sterility at flowering time etc.

BRRI RS, Rangpur

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SUMMARY

To develop suitable modern rice varieties for Rangpur region, 56 germplasms were collected from different sources for maintenance breeding. Thirty-one single crosses were made and six F_1s were confirmed. A total of 6,000 progenies from four F_3 and 20 F_5 generations were advanced through field RGA nurseries. In total 250 plants and four genotypes were selected from observational yield trial (OYT). Under TRB programme, 37 genetically fixed lines were selected and BR11863-5R-294 with 110 days growth duration produced the highest grain yield (4.97 t/ha) followed by BR11869-5R-80 produced 4.68 t/ha grain yield with 94 days in T. Aus 2020. In submergence (flash flooding) and medium stagnant water (MSW) stresses tolerant programme 129 genotypes were selected from 1,047 genotypes based on phenotypic acceptance, growth duration, survivability and higher yield performance in T. Aman 2020. BR10534-2-3-2-1-1 with 130 days growth duration produced the highest grain yield (5.54 t/ha) in drought tolerant rice programme. In various yield trials under disease resistance (BB) rice programme, 160 genotypes were tested out of which 40 genotypes were selected based on disease incidence, phenotypic acceptance, growth duration and higher yield performance. Under the programme of favourable Boro and cold tolerant rice, in different yield trials, 662 genotypes were tested out of which 101 genotypes were selected based on cold tolerant (SES), phenotypic acceptance, growth duration, and yield performance. In different yield trials under disease resistant programme, 332 genotypes were tested and out of which 120 genotypes were selected based on disease incidence, phenotypic acceptance at maturity stage, growth duration and yield performance. In PYT#1, BR11607-4R-258 gave 8.615 t/ha grain yield with 152 days growth duration, better phenotypic acceptance (PAcp=3) and no visible symptoms of BLB and blast diseases. In PYT#2, BR11604-4R-35 with 152 days growth duration, 3 PAcp score and with no BLB, blast and other disease symptom. Whereas, standard check BRRI dhan58 gave 7.30 t/ha grain yield with 157 days growth duration. In observational yield trial of insect resistant programme, 42 genotypes were selected out of 332 genotypes based on phenotypic acceptance, growth duration, and yield performance. The highest grain yield (9.60 t/ha) was observed in three genotypes viz. BR12279-4R-146, BR11957-4R-170 and BR12279-4R-187.

In long-term nutrient omission trial has been running in the BRRI RS, farm, Rangpur since 2014-15 in Boro-Fallow-T. Aman cropping pattern. The experiment includes seven treatments [T_1=Fertilizer control, T_2= NPKSZn, T_3= PKSZn (- N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn)] which were designed in RCB with three replications. After sixth cropping year it is found that N is the most limiting nutrient for rice growth and yield followed by phosphorus, potassium and sulphur irrespective of seasons.

In determining minimum irrigation water requirement of rice at different regions of Bangladesh through water balance from on-farm demand and model simulation experiment was conducted for three seasons (T. Aus, T. Aman and Boro) in 2020-21 at the research field of BRRI RS, Rangpur. In T. Aus, BRRI dhan48 was used and this season received enormous rainfall so that no irrigation including the CROPWAT model predicted irrigation could not be applied. In T. Aman season, BRRI dhan71 was transplanted and in later part to meet up the irrigation demand, the control treatment (i.e., continuous standing water in the field) received highest amount among the treatments while CROPWAT treatments required comparatively less irrigation than the other treatments. During Boro season, BRRI dhan58 were used and CROPWAT model treatment had the highest yield among the treatments. Yields of AWD and CROPWAT treatments did not have any significant difference while control treatment yield was significantly different from other two treatments. Following the same trend, irrigation application in control treatment was the highest and significantly varied with the other two treatments. Irrigation application amounts in AWD and CROPWAT treatments did not have significant difference among them.

A total of 419 varietal demonstrations were conducted in Rangpur-Dinajpur region under different projects/programmes during this reporting period. In T. Aus BRRI dhan48 and BRRI dhan82 were used and the highest yield was observed in BRRI dhan48. The highest yield was observed in BRRI hybrid dhan6 in T. Aman and BRRI hybrid dhan5 in Boro season. Ten field days were arranged at different demonstration sites. Approximately 500 farmers, local leaders and DAE personnel attended those field day programmes and showed keen interest about those newly released varieties. Under training programme, 610 farmers, 141 SAAOs and seed dealers were trained on modern rice production technology from different upazilas of Rangpur-Dinajpur region. A total of 1,599 kg, 7,362 kg and 5,840 kg TLS were produced in T. Aus, T. Aman and Boro season, respectively. A total of 2,570 kg breeder seed (BRRI dhan52 and BRRI dhan87) was produced in T. Aman season and 5,750 kg breeder seeds (BRRI dhan58 and BRRI dhan89) was also produced in Boro season. In total 8,320 kg breeder seed was sent to the GRS Division, BRRI HQ, Gazipur. In this reporting period, 6411 kg TLS was distributed among the farmers for dissemination and popularization of the latest BRRI varieties in Rangpur-Dinajpur region.

Table 1. List of crosses made, breeding for standard rice varieties for Rangpur region, 2020-2021.

	F_1 seed	Characteristic
T. Aman, 2020		
BR8470-3-4-Rang2-4-2-2/BRRI dhan34	35	Premium quality
BR8470-3-4-Rang2-4-2-2/BRRI dhan70	24	Premium quality
BR8470-3-4-Rang2-4-2-2/BRRI dhan87	28	High Yield potential
BR8470-3-4-Rang2-4-2-2/BRRI dhan93	19	High Yield potential
BRRI dhan87/ Lata Balam	13	Premium quality
BRRI dhan87/Miniket (Dinajpur)	17	Premium quality
BRRI dhan87/BRH13-2-4-6-4-1	21	High Yield potential
IR16F1081/Swarna5	26	Medium Stagnant Tolerant
BRRI dhan93/BRRI dhan70	27	Premium quality
BRRI dhan93/Black rice	30	Premium quality
BR8415-2-2-Rang1-4-1-1-1/BRRI dhan34	27	Premium quality
BR8415-5-4-Rang5-8-1-1-1/Black rice	30	Premium quality
BRRI dhan90/BRRI dhan70	27	Premium quality
BR8412-5-4-Rang5-8-1-1-1/Black rice	25	Premium quality
Swarna5/Basmati	18	Premium quality
BR8493-3-5-1-P1/Kataribhog (Dinajpur)	19	Premium quality
BRRI dhan34/BR8493-3-5-1-P1	15	Premium quality
BR8493-3-5-1-P1/Krishnibhog	14	Premium quality
Swarna5/Kalizira (Slender)	28	Premium quality
BR8493-3-5-1-P1/ Kalizira (Slender)	50	Premium quality
IR4630/Gainza	54	Moderate photosensetive
Swarna5/Malshira	58	Moderate photosensetive
Swarna5/Gainza	57	Moderate photosensetive
Boro, 2020-2021		
BRRI dhan92/Black rice (GRSD)	10	Premium quality
BRRI dhan92/Basmati (Acc. No. 4905)	15	Premium quality
BRRI dhan92/Miniket (Dinajpur)	19	Premium quality
BRRI dhan29/ Basmati (Acc. No. 4905)	25	Premium quality
BRRI dhan29/ Black rice(GRSD)	30	Premium quality
BR8415-5-4-Rang5-8-1-1-1/ Basmati (Acc. No. 4905)	21	Premium quality
BR8415-5-4-Rang5-8-1-1-1/ Black rice (GRSD)	26	Premium quality
BR8415-5-4-Rang5-8-1-1-1/ Black rice (GRSD)	22	Premium quality

VARIETY DEVELOPMENT

Development of rice varieties suitable for T. Aman and Boro season in Rangpur region

In total 56 germplasm were collected from farmers' field and the genebank of Genetic Resources and Seed Division (GRSD) for maintenance breeding. Thirty one single crosses were made using 36 parents (Table 1). Six F_1s were confirmed (Table 2). Four F_3 and 20 F_5 generations were advanced through field RGA. Totally 6,000 individual plants were selected from field RGA (Table 3).

Observational yield trial (OYT)

Two hundred genotypes were evaluated along with three standard checks viz. BRRI dhan52, BRRI dhan75 and BRRI dhan87. 250 P/S were selected based on phenotypic acceptance and homogeneity and four fixed genotypes were selected (Table 4).

Table 2. List of F_1 confirmed, breeding for standard rice varieties for Rangpur region.

BR no.	Cross	Objective
	Boro 2019-20	
BRrang32	BR8470-3-4-Rang2-4-2-2/BRRI dhan34	Premium quality
BRrang33	BR8415-2-2-Rang1-4-1-1-1/BRRI dhan34	High yield potential
BRrang34	BR8415-5-4-Rang5-8-1-1-1/Black rice	Premium quality
BRrang35	BRRI dhan90/BRRI dhan70	High yield potential
BRrang36	BRRI dhan87/Miniket (Dinajpur)	
BRrang37	BR8412-5-4-Rang5-8-1-1-1/Black rice	

Table 3. List of segregating generation in field RGA, breeding for standard rice varieties for Rangpur region.

BR no.	Cross	Objectives
F_3 Generation		
BRrang28	BRRI dhan87/Shompa katari	Premium quality
BRrang29	BRRI dhan87/Swarna5	High yield potential
BRrang30	BRRI dhan87/Black rice (GRSD)	Premium quality
BRrang31	BR8470-3-4-Rang2-4-2-2/BRRI dhan87	High yield potential
F_5 Generation		
BRrang06	BR9159-8-5-40-13-52/Swarna5	Earliness and high yield
BRrang07	BR9159-8-5-40-13-52/Nania	Earliness and high yield
BRrang08	BR9159-8-5-40-13-52/Guti Swarna	Earliness and high yield
BRrang09	BR9159-8-5-40-13-57/Swarna5	Earliness and high yield
BRrang10	BR9159-8-5-40-13-57/Gooti Swarna	Earliness and high yield
BRrang11	BRRI dhan52/Lal Swarna	Earliness and high yield
BRrang12	BRRI dhan52/ Gooti Swarna	Earliness and high yield
BRrang13	Nania/Swarna5	Earliness and high yield
BRrang14	Nania/Lal Swarna	Earliness and high yield
BRrang15	Swarna5/Minikit	Earliness and high yield
BRrang16	Sonamukhi/BRRI dhan52	Earliness and high yield
BRrang17	Swampa katari/ BR9159-8-5-40-13-52	Earliness and high yield
BRrang20	BRRI dhan58/ Minikit	Earliness and high yield
BRrang21	BRRI dhan75/ Minikit	Earliness and high yield
BRrang22	BRH11-9-11-4-5B/ BRRI dhan68	Premium quality
BRrang23	BRH11-9-11-4-5B/ BRRI dhan69	High yield potential
BRrang24	BRRI dhan58/ BRH11-9-11-4-5B	High yield potential
BRrang25	BRRI dhan61/ BRH11-9-11-4-5B	High yield potential
BRrang26	BR16/BRH11-9-11-4-5B	High yield potential
BRrang27	BRRI dhan29/ BRH11-9-11-4-5B	High yield potential

Table 4. Agronomic parameters of the selected materials from observational yield trial (OYT), T. Aman 2020.

Designation	PHt. (cm)	Mat. (day)	Yield (t/ha)
BRrang13-RGA-5-1-2	110	118	6.3
BRrang13-RGA-5-2-3	105	115	6.5
BRrang13-RGA-5-3-5	112	110	5.8
BR8415-2-3-Rang1-1-1	110	107	6.7
BRRI dhan52 (Ck)	118	142	5.0
BRRI dhan75 (Ck)	108	112	4.8
BRRI dhan87 (Ck)	120	128	5.7

D/S: 10 July, 2020; D/T: 02 August, 2020 & Spacing: 20 cm x 15 cm

Advanced yield trial (AYT), T. Aman 2020

In total two AYTs were conducted in T. Aman season. In AYT#1, six genotypes were tested along with BRRI dhan49, CN6 and BRRI dhan87. In AYT#2, six genotypes were also tested along with BRRI dhan87. None of the tested entries were performed better than standard checks.

Special yield trial (SYT)

Two SYTs were conducted in Rangpur region in the reporting period. One is on-station (BRRI RS, Rangpur) and another is on- farm (Mithapukur-Rangpur). In both the trials eight genotypes were tested viz. SP01 to SP08. In BRRI Rangpur, SP05 (4.29 t/ha & 116 days) performed better followed by SP02 (3.78 t/ha & 112 days) among all the tested entries. In on-farm, SP02 (5.00 t/ha and 118 days) performed better followed by SP05 (4.00 t/ha and 114 days).

Regional yield trial (RYT), T. Aus 2020

One RYT was conducted in T. Aus season.

Three genotypes along with two standard checks; BRRI dhan48 and BRRI dhan82 were evaluated in this trial. None of the tested entries performed better than the check varieties.

RYT, T. Aman 2020

Nine RYTs were conducted under T. Aman season with two rainfed lowland rice (RLR), two zinc enriched rice (ZER), two premium quality rice (PQR), two insect resistant rice (IRR) and, one disease resistant rice (DRR) against the standard check varieties.

RYT-1 (RLR-1). Seven genotypes along with two checks; BRRI dhan49 and BRRI dhan87 were evaluated. None of the tested genotypes were found high yielder over the check variety.

RYT-2 (RLR-2). Seven genotypes along with standard checks; BRRI dhan49 and BRRI dhan87 were evaluated. None of the tested genotypes were found high yielder over the check variety.

RYT-3 (ZER-1). Two genotypes along with three checks BRRI dhan49, BRRI dhan72 and BRRI dhan87 were evaluated. None of the tested genotypes were found high yielder over the check variety.

RYT-4 (ZER-2). Five genotypes along with three checks BRRI dhan49, BRRI dhan72 and BRRI dhan87 were evaluated. None of the tested genotypes were found high yielder over the check variety.

RYT-5 (PQR-1). Three genotypes and four checks viz. Krishnobhog type, Kalizira, BINA dhan13 and Krishnobhog were evaluated. BR8493-3-5-1-P1 (4.77 t/ha) and BR9590-45-1-3-2-P2 (5.38 t/ha) were performed better over all check varieties. BR9590-45-1-3-2-P2 produced 3.2 t/ha high yield over Krishnobhog (2.18 t/ha).

RYT-6 (PQR-2). Three genotypes along with two checks viz. Kataribhog (Dinajpur) and BRRI dhan37 were evaluated. None of the tested genotypes were found high yielder over the check variety.

RYT-7 (IRR-1). Thirteen genotypes were tested along with three checks BRRI dhan33, BRRI dhan49 and BRRI dhan93. BR9888-26-9-14-3 performed better than the three checks.

RYT-8 (IRR-2). Twelve genotypes were tested along with three checks BRRI dhan33, BRRI dhan49 and BRRI dhan93. BR9882-6-2-2-4 performed better than the three checks.

RYT-9 (DRR). Six genotypes were tested along with two checks BRRI dhan49 and BRRI dhan87. None of the tested genotypes were found high yielder over the check variety.

Regional yield trial (RYT), Boro 2020-2021

A total of 19 RYTs were conducted during Boro season: Three cold tolerant rice (CTR), one favourable Boro rice (FBR), one zinc enriched rice (ZER), two premium quality rice (PQR), one green super rice (GSR), one disease resistant rice (DRR), two favourable Boro rice (FBR-Cumilla), two favourable Boro rice (FBR-Barishal) and three BRAUS against standard check varieties.

RYT-1 (CTR-1-Mithapukur). Seventeen genotypes along with four checks BRRI dhan28, BRRI dhan67, BRRI dhan69 and BRRI dhan89 were evaluated. BR8909-B-12-2-CS1-4-CS2-P5-4-5 (7.56 t/ha) were performed better than all checks and 0.39 t/ha yield advantaged over BRRI dhan89 (7.17 t/ha) with similar growth duration.

RYT-2 (CTR-2-Chirribondor, Dinajpur). Seventeen genotypes along with four checks BRRI dhan28, BRRI dhan67, BRRI dhan69 and BRRI dhan89 were evaluated. Among the tested enties, BR10715-5R-9 (8.22 t/ha) produced the highest yield followed by BR10717-5R-82 (7.82 t/ha). BR10715-5R-9 gave 0.62 t/ha yield advantaged over BRRI dhan89 (7.60 t/ha) with four days longer growth duration.

RYT-3 (CTR-3-Dorshona, Rangpur). Seventeen genotypes along with four checks BRRI dhan28, BRRI dhan67, BRRI dhan69 and BRRI dhan89 were evaluated. Among the tested enties, BR10717-5R-82 (7.78 t/ha) produced the highest yield.

RYT-4 (FBR). Seventeen genotypes were tested against BRRI dhan81, BRRI dhan84 and BRRI dhan89. None of the tested entries were performed better than BRRI dhan89.

RYT-5 (ZER). Three genotypes were evaluated along with the three checks BRRI dhan74, BRRI dhan84 and BRRI dhan89. BR8419-4-1-3-8-5 (6.71 t/ha and 162 days) perfomed better than all the check varieties.

RYT-6 (PQR, BRRI Rangpur). Five genotypes were evaluated along with the checks BRRI dhan50, BRRI dhan63 and BRRI dhan81. All genotypes except BR9938-20-1-1-1 performed better than the standard checks. BR9930-2-3-3-1 (8.3 t/ha and 155 days) produced the highest yield followed by BR9930-2-2-4-3 (8.16 t/ha and 154 days) and BR9930-2-2-4-1 (8.11 t/ha and 154 days). BR9930-2-3-3-1 produced 2.26 t/ha yield advantage over BRRI dhan63 (6.04 t/ha and 153 days).

RYT-7 (PQR, Chirirbobdor, Dinajpur). Five genotypes were evaluated along with the checks BRRI dhan50, BRRI dhan63 and BRRI dhan81. BR9930-2-3-2-2 (7.91 t/ha and 157 days) produced the highest yield followed by BR9930-2-2-4-3 (7.81 t/ha and 158 days) and BR9930-2-3-3-1 (7.8 t/ha and 158 days). BR9930-2-3-2-2 produced 2.73 t/ha yield advantage over BRRI dhan63 (5.18 t/ha and 155 days).

RYT-8 (GSR). Five genotypes were tested with check varietis, BRRI dhan58 and BRRI dhan88. FBR336 was selected compared to the standard checks. FBR336 produced the highest yield (10.16 t/ha and 162 days) over all tested entries and produced 0.81 t/ha yield advantage over BRRI dhan58.

RYT-9 (DRR). Six genotypes along with BRRI dhan58, BRRI dhan89 and IRBB50 were evaluated. BR9943-2-2 and BR9943-26-2-3-6 performed better than the standard check varieties.

RYT-10 (FBR-1, Cumilla regional station). Six genotypes were evaluated against BRRI dhan81, BRRI dhan84 and BRRI dhan88. BRC401-1-1-1-1B produced highest yield (7.18 t/ha and 164 days) over all tested materials.

RYT-11 (FBR-2, Cumilla regional station). Seven genotypes were evaluated against BRRI dhan50, BRRI dhan58 and BRRI dhan89. BRC394-1-1-1-5A produced the highest yield (7.42 t/ha and 164 days) followed by BRC335-1-3-2-2-1 (7.40 t/ha and 165 days) and BRC398-4-1-1-1B (6.97 t/ha and 173 days). Whereas, BRRI dhan89 produced 6.91 t/ha with 165 days.

RYT-12 (FBR-1, Barishal regional station). Six genotypes were evaluated against BRRI dhan58 and BRRI dhan92. BRBa 2-5-3 produced highest yield (7.61 t/ha and 160 days) over all tested materials.

RYT-13 (FBR-2, Barishal regional station). Seven genotypes were evaluated against BRRI dhan58 and BRRI dhan92. IR16A2022 produced highest yield (8.25 t/ha and 150 days) followed by IR04A429 (7.77 t/ha and 167 days), IR15A3466

(7.66 t/ha and 157 days), IR15A2854 (7.56 t/ha and 150 days) and BRRI dhan92 (7.45 t/ha and 161) over all tested materials.

RYT-14 (BRAUS-1, Parbortipur, Dinajpur). Three genotypes were evaluated against BRRI dhan28, BRRI dhan58 and BINA dhan14 in late boro. In spite of lower yield than BRRI dhan58, BRRI dhan29-SC3-28-16-10-6-HR6 (Com)-HR1 (Gaz)-P8 (Hbj) (7.3 t/ha and 97 days) is selected due to its yield potential and growth duration in late planting.

RYT-15 (BRAUS-2, Saidpur, Nilphamari). Three genotypes were evaluated against BRRI dhan28, BRRI dhan58 and BINA dhan14 in late Boro. BRRI dhan29-SC3-28-16-10-6- HR6 (Com)-HR1 (Gaz)-P8 (Hbj) (6.81 t/ha and 99 days) produced highest yield followed by BRRI dhan29-SC3-28-16-10-6- HR6 (Com)-HR2 (Gaz)-P11 (Hbj) (6.4 t/ha and 97 days) and BINA dhan14 (5.77 t/ha and 109 days).

RYT-16 (BRAUS-3, Dorshona, Rangpur). Three genotypes were evaluated against BRRI dhan28, BRRI dhan58 and BINA dhan14 in late Boro. In spite of lower yield than BRRI dhan28, BRRI dhan29-SC3-28-16-10-6- HR6 (Com)-HR2 (Gaz)-P11 (Hbj) (4.26 t/ha and 97 days) is performed better considering grain yield and growth duration than BRRI dhan28 (4.5 t/ha and 109 days).

Multilocation Trial (MLT) of blast resistant advanced lines in Boro 2020-21

The main objective to evaluate specific and general ability of the advanced breedling lines with standard checks in two locations in Rangpur and Dinajpur Region.

MLT-1 (Mithapukur, Rangpur)

Eleven advanced breeding lines were tested along with standard blast susceptible check BRRI dhan28 in onfarm condition. BR (Path) 13784-BC3-63-6-4-HR6 produced highest yield 8.49 t/ha with only 146 days followed by BR (Path) 12452-BC6-53-21-11 (8.40 t/ha and 150 days) and BR (Path) 13784-BC3-62-3-5-HR2 (8.10 t/ha and 146 days). Under natural condition, the selected lines were not infected with neck blast whereas, BRRI dhan28 was infected by 80-90% and produced 3.43 t/ha grain yield with 146 days.

MLT-2 (Chirirbondor, Dinajpur)

Nine advanced breeding lines were tested along with standard blast susceptible check BRRI dhan28 in onfarm condition. BR (Path) 13784-BC3-62-3-5-HR2 produced highest yield 8.55 t/ha with only 155 days followed by BR (Path)12452-BC6-53-21-11 (8.25 t/ha and 153 days) and BR (Path)12452-BC4-77-25-11-8-5 (7.59 t/ha and 157 days). In these lines no neck blast was observed whereas BRRI dhan28 was infected by 50-60% and produced 6.06 t/ha grain yield with 153 days.

Advanced line adaptive research trial (ALART)

Fifteen ALARTs were conducted under T. Aus, T. Aman and Boro seasons. In T. Aus, one ALART, in T. Aman nine ALARTs and in Boro season five ALARTs were candueted performed to develop rice varieties. None of the tested genotypes were recommended for PVT.

Proposed variety trial (PVT)

Five PVTs were conducted under T. Aman 20 and Boro 20-21 seasons. In T. Aman season, one PVT (I-018 to I-020) and four PVTs in Boro season (I-021 to I-028) were conducted to develop rice varieties.

TRB project

T. Aus 2020

Development of short duration T. Aus rice varieties. The main objective of the project is development of shorter growth duration high yielding T. Aus rice varieties with better phenotypic acceptance and grain quality. Under this project, a total of 110 fixed lines with the standard checks BRRI dhan48 and BRRI dhan82 were tested in non-replicated OYT. Among the tested genotypes 37 better performing genetically fixed lines were selected for next season PYT. BR11863-5R-294 with 110 days growth duration produced the highest grain yield (4.97 t/ha) followed by BR11869-5R-80 that produced 4.68 t/ha grain yield with 94 days growth duration.

T. Aman, 2020

Development of submergence and water stagnation tolerant rice varieties. The project aims to develop of high yielding rice varieties tolerant to submergence (flash flooding) and medium stagnant water (MSW) stresses. In different yield trials, 1,047 genotypes were tested out of which 129 genotypes were selected based on phenotypic acceptance, growth duration, survivability and higher yield performance.

From OYT-1 Eleven genotypes out of 56 genotypes, from OYT#2, twenty genotypes out of 60 genotypes, from OYT#3, twenty genotypes out of 46, from OYT#4, eight genotypes out of 24, from PYT#2 four genotypes out of eight, from PYT#3, six genotypes out of 12, from PYT#4, three genotypes out of eight, from AYT#1, three genotypes out of eight genotypes, from AYT#2, five genotype out of 14, from PVS#1, two genotypes out of four, from PVS#2, one genotype out of three, were selected.

In OYT-1, the genotype BR11692-5R-345 with 89% survivability produced the highest yield of 6.1 t/ha under stress condition. BR11690-5R-301 produced higher yield (5.3 t/ha) under stress with 71% survivability in OYT#2.

In OYT#3, BR11694-5R-236 produced the highest yield (7.2 t/ha) followed by BR11694-5R-317 (6.4 t/ha) having survivability of 94% and 100 %, respectively. In OYT#4, the highest yield 6.0 t/ha observed in IR100842-B-B RGA-B RGA-B RGA-9 with survivability of 93%.

In PYT#2, BR11185-5R-738-5 produced the highest yield (4.1 t/ha) with survivability of 79% and growth duration of 119 days. In PYT#3, the genotype BR11196-5R-83 produced the highest yield (4.3 t/ha) with 80% survivability and 119 days growth duration. In PYT#4 the genotype IR127152-3-22-18-1-B produced the highest yield of 4.8 t/ha which possessed all four *SUB1* genes along with four BB resistance genes.

In AYT#2, the genotype IR16F1148 produced the highest yield of 4.5 t/ha with 94% survivability and 120 days growth duration under stress. This genotype was also evaluated in PVS#1, where it produced 4.2 t/ha yield under stress which was 1.2 t/ha higher than the check variety BINA dhan11 (3.0 t/ha) with similar growth duration. This genotype was promoted to ALART.

From PVS#2, two genotypes viz. BR9158-19-9-6-50-2-HR1 and IR13F441 produced higher yield under stress (4.5 t/ha and 4.3 t/ha respectively) with survivability of 87% and 86% respectively. Yield and survivability were significantly higher than the check varieties BRRI dhan52 (3.4 t/ha) and BRRI dhan79 (3.5 t/ha). These two genotypes were also promoted to ALART. The genotype BR9158-19-9-6-50-2-HR1 also got the highest preference score in PVS.

The heritability obtained for grain yield under stress of all trials conducted was ranging from 51% to 98%, while that for non-stress trials was ranging from 54% to 89%, indicating acceptable level of precision in this experiment.

Development of drought tolerant rice varieties. The aim of the project is to develop drought tolerant shorter growth duration high yielding T. Aman rice varieties for drought prone area of Bangladesh with better phenotypic acceptance and grain quality. A total of 17 fixed lines with the standard checks BRRI dhan56 and BRRI dhan71 were tested in replicated PYT. BR10534-2-3-2-1-1 with 130 days growth duration produced the highest grain yield (5.54 t/ha). Where, the best performing standard check produced 4.15 t/ha grain yield with 123 days growth duration. Among the tested genotypes four better performing genetically fixed lines were selected for next season SYT.

Development of disease resistance (BB) rice varieties. In different yield trials under this programme, 160 genotypes were tested out of which 40 genotypes were selected based on disease incidence, phenotypic acceptance, growth duration and higher yield performance.

From OYT#1 thirty-three genotypes out of 130, from PYT#1, four genotypes out of 17, from PYT#2, three genotypes out of 12 were selected for further yield conformation. In OYT#1, the genotype BR11864-5R-74 produced highest yield of 8.08 t/ha with 106 days growth duration. Also genotypes BR11994-5R-19 with 107 days growth duration and BR11869-5R-16 with 134 days growth duration produced 7.58 t/ha and 6.29 t/ha

grain yield. Also genotypes produced 5.02 t/ha to 5.92 t/ha grain yield. Where as the best performing check variety BRRI dhan49 produced 5.16 t/ha grain yield with 135 days growth duration.

In PYT#1, none of the genotypes performed better than the check variety BRRI dhan30 (4.69 t/ha). But if we consider growth duration and standard check BRRI dhan49 (4.19 t/ha with 138 days growth duration), the grain yield of best performing genotypes BR10393-4-1-1-6 (4.25 t/ha) with 130 days growth duration is mentionable. In PYT#2, none of the genotypes performme better than the check varieties BRRI dhan87 based on grain yield (5.22 t/ha) and growth duration (127 days).

Boro 2020-2021

Development of favourable Boro and cold tolerant rice varieties. The project aims to develop favorable Boro and cold tolerant rice vareties seedling and reproductive stages for stress prone environment. In different yield trials, 662 genotypes were tested out of which 101 genotypes were selected based on cold tolerant (SES), phenotypic acceptance, growth duration, and yield performance.

From OYT (FBC) thirty-eight genotypes out of 360 genotypes, from AYT (Cold), thirty-five genotypes out of 82 genotypes, from estimation of breeding value trial (EBV) 28 parental germplasm for hybridization out of 220 germplasm were selected. In OYT (FBC), BR11640-5R-42 produced the highest grain yield (10.01 t/ha) with 163 days growth duration and 1 cold (SES) score at seedling stage. Among the tested genotypes, five genotypes produced yield from 9.01 t/ha to 9.85 t/ha and 20 genotypes produced 8.00 t/ha to 8.62 t/ha grain yield.

In AYT (Cold), BR11894-R-R-R-R-110 produced 10.88 t/ha grain yield with 160 days growth duration and 1 Cold (SES) score. Among the tested genotypes, six genotypes produced yield from 9.42 t/ha to 9.91 t/ha and sixteen genotypes produced yield from 8.00 t/ha to 8.96 t/ha.

Development of disease resistance (BB, RTV and Blast) rice varieties. In different yield trials, 332 genotypes were tested out of which 120 were selected based on disease infestation, phenotypic acceptance at maturity stage, growth duration and yield performance.

From OYT eighty-five genotypes out of 252, from PYT#1, 16 genotypes out of 32, from PYT#2, three genotypes out of 12 were selected for further yield conformation.

In OYT (BB), the genotype BR11866-5R-40 produced the highest yield of 10.20 t/ha with 166 days growth duration. Also six genotypes produced more than 9.50 t/ha yield, 13 genotypes gave more than 8.00 t/ha grain yield and 50 genotypes produced more than 7.00 t/ha grain yield. Where the best performing check variety BRRI dhan89 produced 7.96 t/ha grain yield with 167 days growth duration.

In PYT#1 (BB), the best performing genotype BR11607-4R-258 produced 8.615 t/ha grain yield with 152 days growth duration, better phenotypic acceptance (PAcp=3) and no visible BLB and blast infestation. Among the tested genotypes, 8 genotypes produced grain yield from 7.50 t/ha to 8.2 t/ha with no BLB and blast disease symptom. On the other hand best performing standard check variety BRRI dhan88 produced 7.37 t/ha grain yield with 150 days growth duration.

In PYT#2 (BB), the highest grain yield (8.32 t/ha) was found in genotype BR11604-4R-35 with 152 days growth duration, 3 PAcp score and with no BLB, blast and other disease symptom. Where standard check BRRI dhan58 produced 7.30 t/ha grain yield with 157 days growth duration. Among the tested genotypes, three genotypes produced grain yield 7.00 t/ha to 7.50 t/ha with no BLB and blast disease symptom.

Development of insect resistance (BPH) rice varieties. The project aims to develop major insect (BPH) resistance rice varieties for insect affected target region of Bangladesh. In OYT, a total 42 genotypes were selected out of 332 genotypes based on phenotypic acceptance, growth duration, and yield performance. No BPH resistance SES score were considered for this selection. Because no BPH infestation occured in Rangpur region during the reporting year 2020-21. The highest grain yield (9.60 t/ha) was found in three genotypes BR12279-4R-146, BR11957-4R-170 and BR12279-4R-187. It is also mentionable that nine genotypes produced more than 9.0 t/ha grain yield.

International Network for Genetic Evaluation of Rice (INGER)

Two trials (IRLON_SET22 and IRTON_30) were conducted in BRRI RS, Rangpur during this reporting period. In IRLON, 168 entries including checks were tested in T. Aman following augmented design and six genotypes were selected for further use. In IRTON, 64 entries including five checks were evaluated in augmented design during Boro season and four genotypes were selected for using in crossing programme

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CROP-SOIL-WATER MANAGEMENT

1. Long-term missing element trial at BRRI RS,Rangpur

Long-term nutrient omission trial is an effective tool for identifying the contribution of nutrients in crop production. In order to find the role of major macro and micronutrients, a long- term field experiment has been running in the BRRI RS farm, Rangpur since 2014-15 in Rice-Fallow–Rice cropping pattern. The experiment includes seven treatments [T_1=Fertilizer control, T_2= NPKSZn, T_3= PKSZn (-N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn)] which were designed in RCB with three replications. Rice has been growing in Boro-Fallow-T. Aman cropping pattern. After sixth cropping year we found that N is the most limiting nutrient for rice growth and yield followed by phosphorus, potassium and sulphur irrespective of seasons (Tables 5 and 6).

2. Determining minimum irrigation water requirement of rice at different regions of Bangladesh through water balance from on-farm demand and model simulation

The experiment was conducted for three seasons (Aus, T. Aman and Boro) in 2020-2021 at the research field of BRRI RS, Rangpur. Table 7 as well as grain yield of different varieties according to treatments. In Aus 2020, BRRI dhan48 was transplanted when the seedling was 22-day-old. The

Table 5. Effect of long-term missing element on the yield of BRRI dhan87 at BRRI farm, Rangpur in T. Aman 2020.

Treatment	Tiller/m^2	Panicle/m^2	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	(%) Grain yield decreased due to nutrient omission
T_1	182	176	3.64	3.74	-
T_2	235	221	5.02	5.11	-
T_3	193	178	3.95	4.17	27
T_4	205	196	4.86	4.97	3.3
T_5	216	204	4.74	4.87	6
T_6	224	213	4.85	5.02	3.5
T_7	222	212	4.87	5.03	3.1
LSD (0.05)	33	34	0.38	0.41	
CV (%)	5.51	5.95	2.90	3.02	

N.B. T_1= Control, T_2= NPKSZn, T_3= PKSZn (-N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn)

Table 6. Effect of long-term missing element on the yield of BRRI dhan89 at BRRI RS farm, Rangpur in Boro 2020-21.

Treatment	Tiller/m^2	Panicle/m^2	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	(%) Grain yield decreased due to nutrient omission
T_1	136	119	2.70	2.97	-
T_2	238	226	7.93	7.75	-
T_3	155	150	3.21	4.50	147
T_4	230	213	6.48	7.04	22
T_5	231	223	7.21	7.35	10
T_6	239	222	7.11	7.30	12
T_7	245	224	7.74	7.68	2.5
LSD (0.05)	25	23	0.51	0.50	
CV (%)	4.22	4.15	2.96	2.76	

N.B. T_1= Control, T_2= NPKSZn, T_3= PKSZn (-N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn)

season received enormous rainfall so that no irrigation including the CROPWAT model predicted irrigation could not be applied. Overflowing and standing rainwater in the field did not create any irrigation demand. Thus, the irrigation treatments did not have any impact on the irrigation requirement as well as yield. In T. Aman, BRRI dhan71 was transplanted when the seedlings were 25-day-old. The crop did not suffer any water stress during its vegetative stage, but drought occurred at the later part of the season as rain ceased in the middle of September. To meet up the irrigation demand, the control treatment (i.e., continuous standing water in the field) received the highest amount among the treatments while CROPWAT treatments required comparatively less irrigation than other treatments. Both AWD and CROPWAT treatment saved irrigation compared to continuous standing water treatment. Yields were statistically similar in AWD and CROPWAT treatments and yield of control treatment was significantly different than the other two treatments. During Boro 2020-21 season, forty-day-old seedlings of BRRI dhan58 were transplanted in the field. CROPWAT model treatment had the highest yield among the treatments. Yields of AWD and CROPWAT treatments did not have any significant difference while control treatment yield was significantly different than that of the other two treatments. Following the same trend, irrigation application in control treatment was the highest and significantly varied with other two treatments. Irrigation application amounts in AWD and CROPWAT treatments did not have significant difference among them. Irrigation scheduling by CROPWAT model might be a potential approach to save irrigation water, but still needed in depth evaluation in terms of irrigation demand, irrigation received and yields.

Table 7. Treatment wise irrigation applied and average yield in different seasons 2020-2021, Rangpur.

Treatment	Irrigation (mm)			Avg. Yield (t/ha)		
	Aus	T. Aman	Boro	Aus	T. Aman	Boro
Control	0	254a	510a	3.7a	3.45b	6.51b
AWD	0	223b	363b	3.9a	4.20a	7.47a
CROPWAT	0	113c	394b	3.8a	4.43a	7.55a
CV%	0	10.4	11.47	8.69	6.79	1.69
$LSD_{0.05}$	0	28.4	83.80	0.57	0.48	0.21

SOCIO-ECONOMIC

Stability analysis of BRRI varieties at BRRI RS, Rangpur in T. Aus, T. Aman and Boro season during 2020-2021.

A total of 102 BRRI developed varieties were evaluated during T. Aus (11), T. Aman (45) and Boro (46) season at BRRI RS following RCBD with three replications. In T. Aman, BRRI dhan95 (4.43 t/ha) produced the highest yield followed by BRRI dhan71 (4.02 t/ha) in short duration, BR11 (5.14 t/ha) produced the highest yield followed by BRRI dhan49 (5.11 t/ha) and BRRI dhan44 (5.10 t/ha) in medium duration. In long duration, BRRI dhan46 (5.76 t/ha) produced the highest yield followed by BR22 (5.61 t/ha). During Boro season, BRRI hybrid dhan5 showed the highest yield (9.07 t/ha) followed by BRRI hybrid dhan3 (8.8 t/ha) and BRRI dhan74 (8.15 t/ha) in short duration group. In long duration group, BRRI dhan69 produced the highest yield (8.6 t/ha) followed by BRRI dhan58 (8.13 t/ha) and BRRI dhan89 (8.09 t/ha).

TECHNOLOGY TRANSFER

Demonstration. A total of 419 varietal demonstrations were conducted in Rangpur-Dinajpur region under different projects during the reporting period.

RS Rangpur (GOB). A total of 401 varietal demonstrations were conducted at different locations of Rangpur-Dinajpur region. In T. Aus season, BRRI dhan48 and BRRI dhan82 were used and maximum yield was observed 5.92 t/ha in BRRI dhan48 in Kasimpur, Ranisankail, Thakurgaon and minimum yield was observed 3.07 in case of BRRI dhan48 in Fulbari, Kurigram. In T. Aman season, BRRI dhan51, BRRI dhan52, BRRI dhan70, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan95, BRRI hybrid dhan4 and BRRI hybrid dhan6 were used for varietal demonstrations. Maximum yield was observed 6.26 t/ha in BRRI hybrid dhan6 in dolua, Thakurgaon and minimum was also found in BRRI hybrid dhan6 (4.10 t/ha) in Mohespur, Polashbari, Gaibandha. In Boro season, BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan81,

BRRI dhan84, BRRI dhan86, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI hybrid dhan3 as well as BRRI hybrid dhan5 were used. Maximum yield was observed 8.65 t/ha in BRRI hybrid dhan5 and minimum was 4.68 t/ha in BRRI dhan81 in Fulbari, Kurigram.

TRB Project. Twelve head to head adaptive trails were conducted in eleven upazilas under seven districts in Rangpur-Dinajpur region during the reporting period. Six varieties viz BRRI dhan51, BRRI dhan52, BRRI dhan79, IR13F440 and Guti swarna (Local Check) were used in T. Aman season. In Boro, BRRI dhan 28, BRRI dhan29, BRRI dhan58, BRRI dhan67, BRRI dhan81, BRRI dhan84, BRRI dhan89 and BRRI dhan92 were used for adaptive trial. BRRI dhan51, BRRI dhan52, BRRI dhan79 in T. Aman season and the farmers chose BRRI dhan67, BRRI dhan58, BRRI dhan81, BRRI dhan84, BRRI dhan88, BRRI dhan89 and BRRI dhan92 were choosen by the farmers in Boro season due to grain appearance, high yield potential and less disease incidence (Tables 8 and 9).

SPIRA Project. Six demonstrations were conducted in six locations during T. Aman and Boro season. Three varieties viz BRRI dhan87, BRRI hybrid dhan4 and BRRI hybrid dhan6 in T. Aman and three varieties BRRI dhan86, BRRI dhan88 and BRRI dhan92 were also tested in Boro season. In T. Aman, BRRI hybrid dhan6 produced the highest yield (5.78 t/ha) at Bongao-Ranisankail-Thakurgaon with growth duration 119 days (Table 10). On the other hand, yield performance of BRRI dhan92 (8.45 t/ha) was the highest at Kaliganj-Debiganj-Panchagarh with 165 days growth duration in Boro season (Table 11).

Table 8. Grain yield of head to head trials under TRB project in Rangpur region, T. Aman 2020.

Location	Yield (t/ha)					
	BRRI dhan51	BRRI dhan52	BRRIdhan79	BINA dhan11	Guti swarna	IR13F440
Kishoreganj, Nilphamari	4.35	4.43	4.41	3.87	4.18	4.20
Rajarhat, Kurigram	3.95	4.31	4.10	3.70	3.93	4.14
Fulchari, Gaibandha	4.35	4.69	4.79	3.97	4.62	4.52
Birganj, Dinajpur	4.02	4.50	4.31	4.00	4.36	4.09
Ranisankail,Thakurgaon	3.97	5.03	3.92	4.01	4.54	4.43
Kakina, Lalmonirhat	4.99	5.11	5.04	4.09	5.17	4.43

Table 9. Grain yield of head to head trials under TRB project in Rangpur region, Boro 2020-21.

Location	Yield (t/ha)								
	BRRI dhan28	BRRI dhan67	BRRI dhan81	BRRI dhan84	BRRI dhan88	BRRI dhan29	BRRI dhan58	BRRI dhan89	BRRI dhan52
Saidpur, Nilphamari	7.69	7.68	7.07	7.33	7.10	-	-	-	-
Debiganj, panchagarh	5.65	6.88	6.57	6.48	6.59	-	-	-	-
Ranisangkail, Thakurgaon	7.23	5.50	6.32	6.54	6.76	-	-	-	-
Sadar, Kurigram	-	-	-	-	-	7.81	7.70	8.70	8.10
Bochaganj, Dinajpur	-	-	-	-	-	8.54	7.70	8.23	8.33
Ghoraghat, Dinajpur	-	-	-	-	-	9.75	9.25	10.10	10.00

Table 10. Grain yield of varietal demonstration under SPIRA project in Rangpur region, T. Aman 2020-21.

Location	Variety	Growth duration (day)	Yield (t/ha)
Ranisankail, Thakurgaon	BRRI hybrid dhan6	119	5.78
Pirganj, Rangpur	BRRI hybrid dhan4	118	5.27
Gobindoganj, Gaibandha	BRRI dhan87	132	5.26

Table 11. Grain yield of varietal demonstration under SPIRA project in Rangpur region, T. Aman, 2020-2021.

Location	Variety	Growth duration (day)	Yield (t/ha)
Debiganj, Panchagarh	BRRI dhan92	161	8.45
Rajarhat, Kurigram	BRRI dhan88	143	6.87
Gobindoganj, Gaibandha	BRRI dhan86	140	6.87

Training and field day. Nineteen farmers' trainings on modern rice production technology were conducted at different upazilas of Rangpur-Dinajpur region in collaboration with DAE under GOB and SPIRA project. A total of 610 farmers and 141 SAAOs and Seed Dealers were trained through these programmes. A total of 44 womens were present in farmers' training programme. It was very much helpful to minimize knowledge gap on modern rice production technologies. Twelve in-house trainings were arranged at BRRI regional station to improve the capability in office management of the office staff. Ten field days were arranged at different demonstration sites in collaboration with DAE during this reporting period. A total of 500 farmers, local leaders and DAE personnel attended those field day programmes.

Seeds and Seedling distribution among the flood affected farmers. BRRI RS, Rangpur arranged special programmes for the flood affected farmers. Different photosensitive varieties viz. BR22, BRRI dhan34, Nizarsail and Gainza were distributed among the flood affected farmers in Kamarjani-sadar-Gaibandha, sadar-Rangpur, Pairabandh-Mithapukur-Rangpur.

Technologies dissemination workshop. BRRI RS, Rangpur organized two workshops in Rangpur-Dinajpur region for the increasing of Boro rice production during the reporting period. The aim of the workshop was sustainable rice production in these regions through adoption of BRRI developed technologies. Around 200 participants attended the workshop. Secretary and Additional Secretary of MoA, The DG, Directors and senior scientists of BRRI, The DG, Directors of DAE, AD, DDs, UAOs, RSCO, DSCOs and SAAOs of Rangpur-Dinajpur region, scientists from NARS, DDs from BADC and BMDA personnel, different NGOs extension personnel, farmers, electronic and print media personnels also attended the workshop.

Promotional activities for the formers enclaves farmer. BRRI Rangpur conducted 68 demonstration programmes for the dissemination of BRRI developed latest varieties in Dashiarchora-Fulbari-Kurigram (Former enclave) and Dohogram-Patgram-Lalmonirhat (Former enclave). BRRI Rangpur also arranged two fieldday programmes in Dashiarchora-Fulbari- Kurigram in T. Aus and T. Aman season. BRRI dhan48, BRRI dhan71, BRRI dhan75, BRRI dhan74, BRRI dhan87, BRRI dhan89 and BRRI dhan92 are becoming popular in Dashiarchora- Fulbari-Kurigram. Newly released BRRI varieties and other technologies will be disseminated in those deprived and under privilege people for uplifting living standard in future.

Seed production and dissemination in July 2020-June 2021

A total of 1,599 kg, 7,362 kg and 5,840 kg TLS were produced in T. Aus, T. Aman and Boro season, respectively. In total 2,570 kg breeder seed (BRRI dhan52 and BRRI dhan87) was produced in T. Aman season and 5,750 kg breeder seed (BRRI dhan58 and BRRI dhan89) was also produced in Boro season. In total 8,320 kg of breeder seed was sent to the GRS Division, BRRI HQ, Gazipur. In three seasons, 6411 kg TLS was distributed among the farmers for dissemination in Rangpur-Dinajpur region (Table 12).

Table 12. Variety-wise seed production and distribution during T. Aus 2020, T. Aman 2020 and Boro 2020-2021, BRRI RS, Rangpur.

Variety	Amount (kg)		Send to GRS (kg)	Sold TLS (kg)	Distribution of TLS (kg)
	TLS	Breeder seed			
T. Aus, 2020					
BR26	76	-	-	-	25
BRRI dhan48	924	-	-	298	626
BRRI dhan82	305	-	-	80	212
BRRI dhan83	127	-	-	5	100
BRRI dhan85	167	-	-	53	105
BRRI hybrid dhan7	-	-	-	-	100
Total	1599			436	1168
T. Aman, 2020					
BR22	248	-	-	40	177
BRRI dhan34	520	-	-	206	233
BRRI dhan49	90	-	-	81	9
BRRI dhan52	74	1200	1200	64	10
BRRI dhan70	172	-	-	47	125
BRRI dhan71	461	-	-	440	21
BRRI dhan75	478	-	-	327	151
BRRI dhan79	173	-	-	108	65
BRRI dhan87	3566	1370	1370	1911	1655
BRRI dhan90	224	-	-	113	111
BRRI dhan93	347	-	-	229	118
BRRI dhan94	210	-	-	181	29
BRRI dhan95	511	-	-	446	65
Naizarsail	110	-	-	15	85
Gainja	178	-	-		168
BRRI hybrid dhan4					100
BRRI hybrid dhan6					400
Total	7362	2570	2570	4203	3522
Boro, 2020-21					
BR16	18	-	-	14	2
BRRI dhan28	34	-	-		3
BRRI dhan50	40	-	-	35	3
BRRI dhan58	1885	2750	2750	1522	363
BRRI dhan63	23	-	-	-	5
BRRI dhan79	-	3000	3000	-	-
BRRI dhan81	484	-	-	352	132
BRRI dhan84	341	-	-	301	40
BRRI dhan88	600	-	-	423	177
BRRI dhan89	1970	-	-	1540	430
BRRI dhan92	445	-	-	379	66
BRRI hybrid dhan3	-	-	-	-	200
BRRI hybrid dhan5	-	-	-	-	300
Total	5840	5750	5750	4566	1721
Grand Total	14801	8320	8320	9205	6411

BRRI RS, Satkhira

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SUMMARY

In line stage trial (LST), 513 entries were selected from 4068 populations in T. Aman 2020, while in Boro 2020-21, a total of 421 entries were selected from 3,823 populations. Under observational trial (OT), 239 and 103 entries were selected in T. Aman 2020 and Boro 2020-21, respectively.

In T. Aman 2020, three preliminary yield trials (PYT) were conducted. In PYT-1, the entries BR11388-4R-23, BR11395-4R-3, BR11394-4R-35, BR11388-4R-6 performed better than the check varieties. In PYT-2, the entries BR11391-4R-144 and BR11394-4R-157 produced higher yield than the checks. In PYT-3, the entries BR11723-4R-172, BR11715-4R-186, BR11716-4R-102, BR11723-4R-27 produced the highest yield over the checks. In Boro 2020-20, a total of 373 entries were evaluated in four PYTs, from where 117 entries were selected.

In T. Aman 2020, under secondary yield trial (SYT), 47 genotypes were evaluated against the checks BRRI dhan54, BRRI dhan73 and BRRI dhan87. Among them 13 genotypes performed better than the checks.

In T. Aman 2020, under regional yield trial (RYT) for PQR, the entries BR8493-3-5-1-P1, BR9590-45-1-3-2-P2, BR9054-6-1-2-3 and BR9844-7-4-1-2-4-2 produced better than the checks Kalizira and Binadhan-13. In RYT for IRR, the entries BR10039-19-4-5 and BR10039-21-4-3 performed better than the check. In RYT for bacterial blight resistant rice, BR10397-3-2-1-1 and BR10397-3-2-1-3 performed better than the check BRRI dhan49. In RYT for saline tolerant rice, the entries HHZ8-SAL14-SAL3-Y2, IR 87870-6-1-1-1-1-B, TP30649, HHZ18-Y3-Y1-Y1 and IR15T1464 yielded higher than the check BRRI dhan54, BRRI dhan73 and BRRI dhan87.

In Boro 202-21, under RYT for Barishal-1, the entries BRBa2-1-3 and BRBa2-5-3 performed better than the check variety BRRI dhan58 and in RYT for Barishal-2, the entry IR12A329 performed better than the check variety BRRI dhan58. In RYT for Cumilla-1, BRC401-1-1-1-1B performed better than the check of BRRI dhan81 and BRRI dhan84. In case of RYT for Cumilla-2, BRC428-2-2-1, BRC428-3-1-1 and BRC394-1-1-1-2 performed better than BRRI dan50 and BRRI dhan58. In RYT for yield maximization trial, BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B performed better than the check variety of BRRI dhan63. In Boro 2020-21, under RYT for saline tolerant rice 44 genotypes were evaluated and among them a total 27 genotypes were selected based on phenotype. The entries BR9620-4-3-2-2, BR9620-2-4-1-5, BR11723-4R-48, BR11712-4R-227, BR11716-4R-123, BR11716-4R-102 produced higher yield against their respective check varieties.

Under advanced yield trial (AYT), BR10187-1-5-11, BR10188-4-1-4 and BR9926-7-7-6 performed better over the check varieties in Boro 2020-21.

In T. Aman 2020, none of the tested entries performed better than their respective check varieties in ALARTs for RLR, IRR and ZER. In Boro 202-21, under ALART for FBR-Bhanga, the entry SVINO63-Boro-18-Bhanga gave higher yield than the check BRRI dhan29 and BRRI dhan89. In ALART for BBRR-Bio, both the tested entries produced similar yields to their respective check.

Nitrogen is the most critical yield limiting nutrient and balanced fertilizer application needed for getting maximum yield as well as maintain soil health.

Combined application of ash and manure (1:1) @ 5 t ha^{-1} + 70% BRRI recommended fertilizer (RF) could be a good fertilizer management option for increasing rice yield in saline soil. In another study, application of increased N (20%) and K (60%) from the recommended dose of N (124 kg ha^{-1}) and K (60 kg ha^{-1}) increased rice yield in saline soil. Foliar application of Flora did not show any yield advantage on BRRI dhan92 at Satkhira.

In T. Aman, BRRI hybrid dhan6, BR11 and BRRI dhan54 and in Boro season, BRRI hybrid dhan2, BRRI hybrid dhan5, BR8, BRRI dghn29, BRRI dhan47, BRRI dhan58, BRRI dhan69, BRRI dhan89 and BRRI dhan97 appeared as good yielder in stability analysis at BRRI RS, farm, Satkhira.

BRRI developed hybrid rice varieties performed better than the company hybrid rice varieties at Assasuni, Satkhira district in Boro 2020-21 season.

In T. Aus 2020, BRRI dhan48 performed better than the other Aus varieties and under water stagnant condition, BR23 produced the highest yield followed by BR10, BRRI dhan30, BRRI dhan79 and BRRI dhan49, respectively.

In T. Aman 2020, under HHAT for coastal ecosystem BRRI dhan73 and BRRI dhan78 performed better and in RLR long duration, BRRI dhan95 produced the highest yield followed by BRRI dhan94 and BRRI dhan80. In Boro 2020-21, under HHAT for coastal ecosystem, RLR long duration and RLR short duration BRRI dhan67, BRRI dhan92 and BRRI dhan88 produced the highest yield.

At seedling stage, maximum seedling height and seedling strength were observed when seedlings were covered with polythene sheet keeping a round shape opening.

A total of 26.57 tons of breeder seed of different T. Aman and Boro rice varieties were produced and sent to the GRS Division. In addition, 21.93 tons of truthfully labelled seed of different Aus, Aman and Boro rice varieties were produced, stored, sold and distributed to the farmers, NGOs and DAE as well.

Over all 116 demonstrations (Aus, Aman and Boro) were conducted during 2020-21 under SPDP program. Thirteen farmer's training (444 farmers) and thirteen field days were arranged and attended one agricultural fair during this year as well as participated in different respective and technical activities.

Climate resilient farming systems research and development activities under PBRG, NATP-2 project conducted at Bishnupur union, Kaliganj, Satkhira to improve the system productivity of standing resources. For homestead area, higher yield was obtained from cucumber (670 kg/65 dec) followed by bitter gourd (629 kg/65 dec.), while in nearby homestead areas had maximum yield from potato (1615 kg/93 dec) followed by cabbage (1450 kg/93 dec). In crop and cropping system component, most of the farmers followed Boro (BRRI dhan28)-Fallow- T. Aman (BRRI dhan49) cropping pattern, which was successfully replaced by Mustard (BARI Sharisa 14)–Boro (BRRI dhan81)-T. Aman (BRRI dhan75) and Boro (BRRI dhan81) - Jute (NSC) – T. Aman (BRRI dhan75) cropping pattern. The existing cropping pattern had a REY of 11.98 t/ha, which was increased by 16.76 t/ha and 20.75 t/ha in the improved patterns respectively. Improved technology has increased productivity of gher system proved worthwhile with average gross return of 7,51,676 Tk/ha from five ghers. In poultry system, Sonali chicken, Khaki Campbell duck and Turkey rearing under scavenging system seems to be a good option to increase farmers' income. In goat rearing, 13 kids were produced from seven farm families with in 11 months. From fish poly-culture system in mini pond, partial harvesting has been done. Three activities were done in plantation of fruit tree and management system.

VARIETY DEVELOPMENT

Line stage trial (LST)

In T. Aman 2020, a total of 513 entries were selected from 4,068 tested populations at BRRI RS, Satkhira farm based on their phenotypic appearance and salt tolerance ability. In Boro 2020-21, a total of 3823 entries from 18 crosses were evaluated in the field of BRRI RS farm, Satkhira to select suitable genotypes having salt tolerance ability and out of them 421 entries were selected.

Observational yield trial (OT)

In T. Aman 2020, a total of 239 entries were selected from 874 tested entries under OYT conducted at different locations of Satkhira and Khulna. In Boro 2020-21, a total of 292 entries of OYT (STR), 118 entries of OYT (IRSSTN) and 320 entries of OYT (IRR) were evaluated in non-replicated trial against standard checks. From OYT (STR) at Debhata, 12 genotypes were selected comparing with the checks BRRI dhan67, BRRI dhan89, BRRI dhan97and BINA dhan10. From OYT (IRSSTN) at Assasuni, 26 genotypes were selected comparing with the checks BRRI dhan67, BRRI dhan89. From OYT (IRR) at BRRI RD farm, Satkhira, 65 genotypes were selected comparing with the checks BRRI dhan88, BRRI dhan89, BR3 (S. ck).

Preliminary yield trial (PYT) in T. Aman 2020

A total of 24, 24, and 25 genotypes were evaluated in PYT-1, PYT-2, and PYT-3, respectively at different sites in Satkhira and Khulna districts against three checks BRRI dhan54 and BRRI dhan73 and BRRI dhan87 during T. Aman 2020.

PYT-1. At Debhata site, BR11388-4R-23(6.25 t ha^{-1}), BR11395-4R-3 (6.31t ha^{-1}) and BR11394-4R-35 (6.00t ha^{-1}) yielded higher than the check varieties BRRI dhan73 and BRRI dhan87, but statistically similar to BRRI dhan54 (6.05t ha^{-1}). At Assasuni site, BR11388-4R-6 (5.47 t ha^{-1}) yielded higher than the check varieties BRRI dhan54 (2.97t ha^{-1}), BRRI dhan73 (5.04t ha^{-1}) and BRRI dhan87 (4.89 t ha^{-1}). At Koyra site, BR11395-4R-3 (5.03 t ha^{-1}) yielded higher than the check varieties BRRI dhan54 (4.23 t ha^{-1}) BRRI dhan73 (4.12 t ha^{-1}) but similar to the check BRRI dhan87.

PYT-2. At Koyra site, BR11391-4R-144 (5.95t ha^{-1}) produced the highest yield than the check varieties BRRI dhan54 (4.10 t ha^{-1}), BRRI dhan73 (4.41 t ha^{-1}) and BRRI dhan87 (4.27 t ha^{-1}). This entry had shorter growth duration (112 days) than the checks BRRI dhan54 (117 days) and BRRI dhan87 (119 days) but similar to BRRI dhan73 (112 days). At Debhata site, BR11394-4R-157 (5.50 t ha^{-1}) yielded higher than the check varieties BRRI dhan54 (4.80 t ha^{-1}), BRRI dhan73 (4.99 t ha^{-1}) and BRRI dhan87 (4.82 t ha^{-1}) with 111 days growth duration, which was shorter than that of BRRI dhan54 and BRRI dhan87. At Assasuni, none of the entries performed better than the check varieties.

PYT-3. In PYT-3, the entries BR 11723-4R-172 (7.18 t ha^{-1}), BR11715-4R-186 (7.01 t ha^{-1}), BR11716-4R-102 (7.11 t ha^{-1}) and BR11723-4R-27 (7.39 t ha^{-1}) produced significantly higher yield than the checks of BRRI dhan54 (5.77 t ha^{-1}), BRRI dhan73 (5.98 t ha^{-1}), BRRI dhan87 (5.85 t ha^{-1}) and BR23 (5.83 t ha^{-1}) at Koyra site. At Tala, the entry BR11716-4R-102 gave the highest yield (7.11 t ha^{-1}) over the checks of BRRI dhan54 (6.13t ha^{-1}), BRRI dhan73 (6.19 t ha^{-1}), BRRI dhan87 (7.12 t ha^{-1}) and BR23 (5.60 t ha^{-1}). The entries BR 11723-4R-172 (7.34 t ha^{-1}), BR1172-4R-218 (7.46 t ha^{-1}), BR11715-4R-186 (7.08 t ha^{-1}) and BR11723-4R-27 (7.61 t ha^{-1}) also yielded higher than checks of BRRI dhan54 BRRI dhan73 and BR23 but similar to BRRI dhan87.

Preliminary yield trial (PYT) in Boro 2020-21

A total of 38, 107, 109, and 119 genotypes were evaluated in PYT-1, PYT-2, PYT-3 and PYT-4, respectively at different sites of Satkhira and Khulna districts. BRRI dhan67 and BRRI dhan89, BRRI dhan97and Binadhan-10 were used as checks. From PYT-1, a total of 13 and 8 entries were selected at BRRI farm and Assasuni, respectively. From PYT-2, a total of 17 and 22 entries were selected at BRRI farm and Assasuni, respectively. From PYT-3, a total of 14 and 30 entries were selected at BRRI farm and Assasuni, respectively. From PYT-4, a total of 13 entries were selected at BRRI farm. No entries could be selected from any PYT at Kaliganj and Koyra and from PYT-4 at Assasuni due to crop damage with high salinity after 5-6 weeks of transplanting.

Secondary yield trial (SYT) during T. Aman, 2020

In SYT, 47 genotypes were evaluated against BRRI dhan54 and BRRI dhan73 as tolerant checks and BRRI dhan87 as sensitive check at different sites of Satkhira and Khulna districts.

SYT-1. At Assasuni site, IRSSTN-SVIN361-18 (5.91 t ha^{-1}) and IRSSTN-SVIN362-18 (5.67 t ha^{-1}) yielded higher than the checks of BRRI dhan54 (3.87 t ha^{-1}), BRRI dhan73 (3.54 t ha^{-1}) and BRRI dhan87 (4.16 t ha^{-1}), respectively. No entry yielded better than the check varieties in Koyra.

SYT-2. At Koyra site, the entries BR10425-1-2-4 (4.33 t ha^{-1}), BR10426-1-5-1 (4.20 t ha^{-1}), BR10426-1-5-2 (4.20 t ha^{-1}) and BR10440-1-1-1 (4.03 t ha^{-1}) gave the higher yield than the resistant check BRRI dhan54 (3.40 t ha^{-1}). At Assasuni, the entry BR10440-1-1-1(4.89 t ha^{-1}) yielded higher than the resistant checks BRRI dhan54 (3.60 t ha^{-1}) and BRRI dhan73 (4.03 t ha^{-1}). At Debhata site, the entry BR10423-1-1-1 (5.39 t ha^{-1}) yielded higher than BRRI dhan54 (4.06 t ha^{-1}), BRRI dhan73 (4.94 t ha^{-1}) and BRRI dhan87 (5.03 t ha^{-1}).

SYT-3. At Koyra site, the entries BR10401-20-5-6B1 (5.18t ha^{-1}), BR10430-7-4-5B2 (5.63t ha^{-1}) and BR10440-412-5 (7.0t ha^{-1}) yielded higher

than the checks BRRI dhan54 (4.0t ha^{-1}), BRRI dhan73 (4.4t ha^{-1}) and BRRI dhan87 (3.8t ha^{-1}). At Assasuni site, the entry BR10425-1-3-4 (5.02 t ha^{-1} produced higher yield than the checks BRRI dhan54 (4.48 t ha^{-1}), BRRI dhan73 (4.50 t ha^{-1}) and BRRI dhan87 (3.33 t ha^{-1}). At Debhata site, the entries BR10401-20-5-6B1**(**5.02 t ha^{-1}) and BR10425-1-3-4 produced higher yield than the resistant checks BRRI dhan54 (3.81 t ha^{-1}) BRRI dhan73 (3.91 t ha^{-1}).

SYT-4. At Koyra site, the entry BR10440-2-9-3 (7.15 t ha^{-1}) produced higher yield than the checks of BRRI dhan54 (3.94 t ha^{-1}), BRRI dhan73 (3.61 t ha^{-1}) and BRRI dhan87 (4.23 t ha^{-1}). At Assasuni site, the entry BR10477-16-13-9 (6.04 t ha^{-1}) gave the highest yield than the checks BRRI dhan54 (4.72 t ha^{-1}) and BRRI dhan73 (37.6 t ha^{-1}) and BRRI dhan87 (3.87 t ha^{-1}). At Debhata, BR10426-9-5-3B1 (5.78 t ha^{-1}) yielded higher than the resistant checks BRRI dhan54 (4.92 t ha^{-1}) and BRRI dhan73 (4.51 t ha^{-1}).

Regional yield trial (RYT) during T. Aman, 2020

In T. Aman 2020, RYT were conducted for rainfed lowland rice (RLR), zinc enriched rice (ZER), premium quality rice (PQR), insect resistance rice (IRR), bacterial blight resistant rice (BBRR) following RCB design at BRRI, Satkhira (Table 1). No entries performed better than checks in RYT for RLR and ZER. In case of RYT for PQR-1, BR8493-3-5-1-P1 and BR9590-45-1-3-2-P2 entries performed better than the checks Kalizira and Binadhan-13, whereas for PQR-2, BR9054-6-1-2-3 and BR9844-7-4-1-2-4-2 performed better than the checks. In RYT for IRR-1, no entries performed better than the checks, BRRI dhan33, BRRI dhan49 and BRRI dhan93 whereas in IRR-2, BR10039-19-4-5 and BR10039-21-4-3 entries performed better over the checks. In RYT for bacterial blight resistant rice, BR10397-3-2-1-1 and BR10397-3-2-1-3 performed better than the check BRRI dhan49 and statistically similar with BRRI dhan87.

Regional yield trial (RYT) for saline tolerant rice in T. Aman 2020

Fifteen genotypes suitable for saline prone areas for RLR ecosystem was evaluated against BRRI dhan54, BRRI dhan73, BRRI dhan87. The trials were conducted at different sites of Satkhira and Khulna districts following RCB design (Table 2). At Koyra, the entries HHZ8-SAL14-SAL3-Y2 (4.19 t ha^{-1}), IR 87870-6-1-1-1-1-B (4.30 t ha^{-1}), and TP30649 (4.05 t ha^{-1}) yielded higher than the checks of BRRI dhan73 (3.63 t ha^{-1}). At Assasuni, the entry TP30649 (5.38 t ha^{-1}) produced more yield than BRRI dhan54 (4.70 t ha^{-1}), BRRI dhan73 (4.59 t ha^{-1}) and BRRI dhan87(3.98 t ha^{-1}). At Tala site, the entries HHZ18-Y3-Y1-Y1 (5.62 t ha^{-1}) and IR15T1464 (5.26 t ha^{-1}) yielded higher than the checks BRRI dhan73 (4.73 t ha^{-1}) and BRRI dhan87(4.69 t ha^{-1}).

Regional yield trial (RYT) during Boro, 2020-21

In Boro 2020-21, different entries of Barishal, bacterial blight resistant rice (BBRR), green super rice (GSR), Cumilla, yield maximization (YM), zinc enriched rice (ZER) and premium quality rice (PQR) were assessed in regional yield trial (RYT) (Table 3). The field trials were conducted at BRRI, Satkhira following RCB design. Among the different entries of Barishal-1, two entries BRBa2-1-3 and BRBa2-5-3 performed better over the check variety BRRI dhan58, but statistically similar with BRRI dhan92. In case of RYT for Barishal-2, IR12A329 performed better the check variety BRRI dhan58, but it was statistically similar with BRRI dhan92. No entries performed better than the check varieties for GSR and BBRR. In RYT for Cumilla-1, BRC401-1-1-1-1B performed better than the checks of BRRI dhan81 and BRRI dhan84 but statistically similar with BRRI dhan88. In case of RYT for Cumilla-2, BRC428-2-2-1, BRC428-3-1-1 and BRC394-1-1-1-2 performed better over BRRI dan50, BRRI dhan58 but statistically similar with BRRI dhan89. In RYT for yield maximization trial, BRH11-9-11-4-5B-HR3 and BRH13-2-4-6-4B performed better than the check variety BRRI dhan63. No entries performed better than the check varieties for ZER and PQR over the check varieties.

Regional Yield Trial (RYT) for saline tolerant rice in Boro 2020-21

A total of 13 genotypes in RYT-1, 13 genotypes in RYT-2 AND 18 genotypes in RYT-3 were

evaluated against BRRI dhan67, BRRI dhan89, BRRI dhan97 and Bina dhan10 at different locations of Satkhira and Khulna. The salinity data of the study locations are presented in Fig. 1 and Fig. 2.

RYT-1. At BRRI farm, Satkira and Assasuni no entries produced higher yield than the checks (Table 4). However, from RYT-1, at BRRI farm and Assasuni eight and four entries, respectively were selected based on phenotype. At Kaliganj and Koyra, all entries were damaged after 5 -6 weeks of transplanting due to high salinity.

RYT-2. At BRRI farm, four entries were selected out of 13 entries in RYT-2 trial. The entry BR9620-4-3-2-2 (7.92 t ha^{-1}) yielded higher than Bina dhan10 (6.83 t ha^{-1}), BRRI dhan67 (6.76 t ha^{-1}) and BRRI dhan97 (6.58 tha^{1}) in BRRI-farm. At Assasuni site, eight entries were selected out of 13 entries. The entry BR9620-2-4-1-5 (3.082t ha^{-1}) yielded higher than BRRI dhan89 (0.652 t ha^{-1}) and BRRI dhan67 (2.678 t ha^{-1}) at Assasuni (Table 4). At Kaliganj and Koyra, all entries were damaged after 5-6 weeks of transplanting due to high salinity.

RYT-3. At BRRI farm, best four entries were selected out of 18 entries for further ALART. The entries BR11723-4R-48(10.07 t $ha^{-1,}$), BR11712-4R-227 (9.40 t $ha^{-1,}$), BR11716-4R-123 (9.16 t $ha^{-1,}$), BR11716-4R-102 (9.11 t $ha^{-1,}$) yielded higher than BRRI dhan67 (6.63 t ha^{-1}), BRRI dhan 89 (6.60t ha^{-1}), BRRI dhan97(7.74 t ha^{-1}) and Bina dhan10(8.02 t ha^{-1}) (Table 4). At Koyra and Rampal all entries were damaged after 6-9 weeks of transplanting due to high salinity.

Advanced yield trial (AYT) in Boro 2020-21

A total of 36 genotypes were evaluated in AYT -1 and AYT -2 against BRRI dhan67, BRRI dhan97 and Bina dhan10.

AYT-1. At BRRI RS farm, Sathkira, six entries were selected from total 18 entries of AYT-1 and the entry BR10187-1-5-11 (7.06 t ha^{-1}) yielded higher than BRRI dhan67 (6.29 t ha^{-1}), Bina dhan10 (6.26 t ha^{-1}) and BRRI dhan97 (5.48 t ha^{-1}). At Assasuni, out of 18 entries five entries were selected and the entry BR10188-4-1-4(4.01 t ha^{-1}) produced more yield than all the three checks BRRI dhan67 (2.81 t ha^{-1}), BRRI dhan97 (3.21 t ha^{-1}) and Bina dhan10 (3.78 t ha^{-1}). At Debhata, five entries were selected from 18 evaluated entries. Among them the entry BR9926-7-7-6 (6.96 t ha^{-1}) yielded higher than BRRI dhan67 (3.095 t ha^{-1}) and Bina dhan10 (4.052 t ha^{-1}). At Kaliganj and Koyra all entries were damaged due to high salinity.

AYT-2. At BRRI RS farm, Sathkira, five entries were selected from total 18 entries of AYT-2 on the basis of phenotypic appearance. In this trial no entries produced higher yield than the checks. At Assasuni, out of 18 entries three entries were selected on the basis of phenotypic appearance. But no entries produced more yield than the checks.

Advanced line adaptive research trial (ALART) during T. Aman 2020

In T. Aman 2020, three ALARTs were conducted for rainfed lowland rice (RLR), insect resistance rice (IRR) and zinc enriched rice (ZER) (Table 5). None of the tested entries performed better against their respective check varieties in ALARTs for RLR, IRR and ZER.

Advanced line adaptive research trial (ALART) during Boro 2020-21

Four ALARTs of premium quality rice (PQR), zinc enriched rice (ZER), favourable boro rice (FBR-Bhanga), and bacterial blight resistant rice (BBRR-Bio) were conducted during Boro 2020-21 at farmers' field in Satkhira (Table 6). In ALART for PQR and ZER none of the tested entries performed better than their respective check varieties. In ALART for FBR-Bhanga, the entry SVINO63-Boro-18-Bhanga produced higher yield than the checks BRRI dhan29 and BRRI dhan89. In ALART for BBRR-Bio, both the tested entries produced similar yields to their respective check varieties with 5-7 days shorter growth duration.

CROP-SOIL-WATER MANAGEMENT

Missing element trial

The experiment was carried out at BRRI RS farm, Satkhira using BRRI dhan87 and BRRI dhan67

during T. Aman 2020 and Boro 2020-21, respectively to study the effect of nutrient omission on rice growth and yield. The treatment consisted of omission of different nutrients (N, P, K, S and Zn) form the complete fertilizer. The omission of N from complete fertilizer (NPKSZn) appeared as the most yield limiting nutrient, while the complete fertilizer produced the highest yield of rice in both T. Aman 2020 and Boro 2020-20 seasons (Table 7). The yield reduction due to N omission from complete fertilizer was 27% and 75% in T. Aman 2020 and Boro 2020-20 seasons, respectively.

Increasing fertilizer use efficiency and resilience in problem soils (saline)

With the objective of managing saline soil and improving rice yield by application of micronutrients, customized compound fertilizers and organic amendments, two field experiments were carried out at Kaliganj, Satkhira and at BRRI RS farm, Satkhira (Table 8) during Boro 2020-21. There was a positive effect of fertilizer sources on the grain yield, although the magnitudes of yield varied with varieties and locations. Combination of ash and manure (1:1) @ 5 t ha^{-1} + 70% RF significantly increased rice yield compared to farmer's practice (FP) and OCP fertilizer in BRRI farm Satkhira, while it produced significantly higher yield than Ash 3 (t ha^{-1}) + 100% NPKSZn in Kaliganj. There was significant variation between the varieties of BRRI dahn67 (salinity tolerant) and BRRI dhan88 in both locations. However, control treatment produced the lowest yield in both Kaliganj and BRRI RS farm, Satkhira.

Evaluation of increased nitrogen rates for Boro rice cultivation in saline areas

The experiment was conducted at the farmer's field at Kaliganj, Satkhira to study the effect of increased N rates on rice yield (Table 9). Application of 20% extra N from the recommended N dose (124 kg ha^{-1}) significantly increased the grain yield of BRRI dhan67. Fig. 2 presents the data related to water salinity of the experimental plot.

Evaluation of increased potassium rates for Boro rice cultivation in saline areas

The experiment was conducted at the farmer's field at Kaliganj, Satkhira to study the effect of increased K rates on rice yield (Table 9). Application of 40% extra K from the recommended K dose (60 kg ha^{-1}) significantly increased the yield of BRRI dhan67. Fig. 2 presents the data related to water salinity of the experimental plot.

Effect of FLORA on growth and rice yield

Application of FLORA (Nitrobenzene) at different rates in combination with chemical fertilizer showed no significant yield advantage over the recommended chemical fertilizer.

SOCIO-ECONOMIC AND POLICY

Stability analysis of BRRI varieties during 2020-20

In T. Aman 2020, among the short duration varieties, BRRI hybrid dhan6 produced the highest yield (5.53 t ha^{-1}). Among the medium duration rice varieties, BR 11(5.36 t ha^{-1}) and BRRI dhan54 (5.38 t ha^{-1}) produced the highest yield than the other varieties. Among the long duration rice varieties, BR10 produced the highest yield (4.82 t ha^{-1}) than the other varieties. In Boro 2020-20 season, among the long duration rice varieties BR8, BRRI dghn29, BRRI dhan47, BRRI dhan58, BRRI dhan69, BRRI dhan89 and BRRI dhan97 produced higher yield than the other varieties. Among the short duration varieties, BRRI hybrid dhan2 (7.701 t ha^{-1}) and BRRI hybrid dhan5 (7.57 t ha^{-1}) produced performed better than the other varieties.

Selection of suitable hybrid rice genotypes under saline prone areas

Eight BRRI developed hybrid rice varieties and promising hybrid lines (BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6, BRRI hybrid dhan7, BRRI99A/BRRI31R and BRRI99A/EL254R) were evaluated against five company released hybrid varieties (Gold, Janokraj, Heera, Tejgold and SL-8) and three salinity tolerant inbreed rice varieties

(BRRI dhan67, IT and Bina dhan10) in three salt affected locations of Satkhira and Khulna district. The objective was to find out produced the hybrid rice genotypes suitable for saline prone areas in Boro season. At Assasuni, Satkhira, all the BRRI hybrid rice varieties performed better than the company hybrid varieties. Among the genotypes, BRRI hybrid dhan5 produced highest yield (8.55 t ha^{-1}) followed by BRRI hybrid dhan4 (8.30 ha^{-1}), BRRI hybrid dhan3 (8.09 t ha^{-1}), BRRI hybrid dhan6 (7.96 t ha^{-1}), BRRI hybrid dhan7 (6.81 t ha^{-1}) (Table 10). At Kaliganj, Satkhira and Koyra, Khulna the crop was damaged due to high salinity. Fig. 3. presents water salinity situation of the experimental plots.

TECHNOLOGY TRANSFER

Validation of BRRI developed rice varieties

In T. Aus 2020, newly released varieties Binadhan-19, BRRI dhan82 and BRRI dhan83 of T. Aus were evaluated against the existing variety BRRI dhan48 at BRRI RS, Satkhira. None of the new varieties produced higher yield than BRRI dhan48, but the growth duration of the tested varieties were 10-12 days less than BRRI dhan48.

In T. Aman 2020, a validation trial was conducted at BRRI RS, Satkhira to evaluate the performance of five entries under stagnant water condition following RCBD. BR23 was the highest yielder followed by BR10, BRRI dhan30, BRRI dhan79 and BRRI dhan49, respectively.

Head-to-head adaptive trial

T.Aman 2020. In T. Aman, HHATs were conducted for coastal ecosystem and two HHATs for rainfed lowland rice (RLR) long duration at farmers' fields of Satkhira and Jashore districts. In HHATs for coastal ecosystem, conducted at Assasuni and Kaliganj of Satkhira districts, BRRI dhan73 (4.60 t ha^{-1}) and BRRI dhan78 (4.45 t ha^{-1}) performed better than BRRI dhan72 (3.50 t ha^{-1}) and BRRI dhan79 (3.93 t ha^{-1}). In HHATs for RLR long duration, conducted at Assasuni, Satkhira and Keshabpur, Jashore, BRRI dhan95 (5.08 t ha^{-1}), BRRI dhan94 (4.85 t ha^{-1}) and BRRI dhan80 (4.43 t ha^{-1}) performed better than BRRI dhan72 (3.50 t ha^{-1}) and BRRI dhan79 (4.35 t ha^{-1}).

Boro 2021-21. In Boro, four HHATs for coastal ecosystem, two HHATs for RLR long duration and two HHATs for sort duration were conducted at farmers' field of Satjhira and Jashore districts. In HHATs for coastal ecosystem, conducted at Assasuni and Kaliganj of Satkhira district, BRRI dhan67 (5.39 t ha^{-1}) produced the highest yield followed by Bina dhan10 (5.11 t ha^{-1}), BRRI dhan97 (4.61 t ha^{-1}), BRRI dhan99 (3.94 t ha^{-1}) and BRRI dhan28 (3.57 t ha^{-1}). In HHATs for RLR long duration, conducted at sadar, Satkhira, BRRI dhan58 (6.69 t ha^{-1}) produced the highest yield followed by BRRI dhan92 (6.12 t ha^{-1}), BRRI dhan29 (5.95 t ha^{-1}) and BRRI dhan89 (5.66 t ha^{-1}). In HHATs for RLR short duration, conducted at sadar, Satkhira and Keshabpur, Jashore, BRRI dhan88 (6.53 t ha^{-1}) produced the highest yield followed by BRRI dhan84 (6.52 t ha^{-1}), BRRI dhan67 (6.51 t ha^{-1}), BRRI dhan81 (6.30 t ha^{-1}) and BRRI dhan28 (6.12 t ha^{-1}).

Effect of polythene covering on rice seedling raising in Boro season

The experiment was conducted to identify the most effective way of polythene covering to protect Boro rice seedling from cold injury. The experiment was consisted of different techniques of polythene covering following RCB design with three replications at BRRI RS farm, Satkhira during Boro 2020-21 season. At seedling stage, maximum seedling height (50.23 cm) was observed when seedlings were covered with polythene sheet keeping a round shape opening, which is statistically similar with control. The highest seedling strength (31.85) was observed when seedlings were covered with polythene keeping round shape opening followed by polythene covering from 11.00 am to sun set (25.40). From field trial, no significant difference was found in case of plant height, growth duration and grain yield.

Seed production and dissemination

A total of 26.57 tons of breeder seed of different Aman and Boro rice varieties were produced and

sent to GRS division. In addition, 21.93 tons of truthfully labelled seeds of different Aus, Aman and Boro rice varieties were produced, stored, sold and distributed to the farmers, NGOs and DAE.

Training, Field Day and Fair

Thirteen farmers' trainings on rice production technology, quality seed production & preservation were conducted to train up 444 farmers of Satkhira, Khulna and Jashore districts. A total of thirteen field days were arranged during the reporting period we. Attended agricultural fair as well as participated in various workshops, seminars, regional and district agricultural coordination committee meetings, district coordination committee meetings, discussion meetings, farmers' field visits with advisory activities in field level and on-line basis.

Climate resilient farming systems research and development for the coastal ecosystem

Climate resilient farming systems research and development activities under PBRG, NATP-2 project conducted at Bishnupur union, Kaliganj, Satkhira to improve the system productivity of standing resources. For homestead area, higher yield was obtained from cucumber (670 kg/65 dec.) followed by bitter gourd (629 kg/65 dec.), while in nearby homestead areas had maximum yield from potato (1615 kg/93 dec.) followed by cabbage (1450 kg/93 dec.). In crop and cropping system component, total seven activities were done. Most of the farmers followed Boro (BRRI dhan28)-Fallow- T. Aman (BRRI dhan49) cropping pattern, which was successfully replaced by Mustard (BARI Sharisa 14) – Boro (BRRI dhan81) – T. Aman (BRRI dhan75) and Boro (BRRI dhan81) - Jute (NSC) – T. Aman (BRRI dhan75) cropping pattern. The existing cropping pattern had a REY of 11.98 t/ha, which were increased by 16.76 t/ha and 20.75 t/ha in the improved patterns respectively. In the production programme of BRRI developed Boro rice varieties, BRRI dhan89 and BRRI dhan81 showed higher yield with 6.51 t/ha and 6.41 t/ha respectively. Improved technology has been increased productivity of gher system proved worthwhile with average gross return of 751676 Tk/ha from five ghers.

In poultry system, Sonali chicken, Khaki Campbell duck and Turkey rearing under scavenging system seems to be a good option to increase farmers' income. In goat rearing, 13 kids were produced from seven farm families within 11 months. From fish poly-culture system in mini pond, partial harvesting has been done. Three activities were done in plantation of fruit tree and management system. Fruit sapling distribution included mango, litchi and wood apple tree sapling. Mini orchards of mango and litchi were established in homestead with integration of vegetables. During Feb-Dec 2020, the average pumpkin yield was almost 151 kg among the farmers and average cucumber yield was 160 kg/25 dec. Planted drumstick trees were growing fast.

Table 1. Performance of different entries under RYT at BRRI, Satkhira during T. Aman 2020.

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
		RYT (RLR-1)	
BR9857-7-6-5-1	114	116	3.6
IR100122-B-B-B-B-2	121	113	4.5
IR103352-B-B-205	114	118	4.7
IR 98377-B-B-B-B-24	111	119	5.3
IR98381-B-B-B-B-71	111	116	4
IR98386-B-B-B-B-33	103	120	5.6
IR98396-B-B-B-B-40	103	117	4.3
BRRI dhan49 (ck.)	103	130	4.6
BRRI dhan87 (ck.)	123	122	5.1
LSD (5%)	5.1	2.46	1.01
CV (%)	2.64	1.2	12.6
		RYT (RLR-2)	
BR9840-52-1-2-1	125	111	4.98
BR9840-52-1-4-2	109	120	5.3
BR9857-4-2-3-5	107	113	4.1

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
BR8492-9-5-3-2-HR1	118	125	4.96
BR8492-9-5-3-2	115	125	4.78
Kanaihati 4	116	117	4.41
Kanaihati 9	113	109	3.22
BRRI dhan49 (ck.)	105	131	4.79
BRRI dhan87 (ck.)	122	124	5.4
LSD (5%)	4.94	4.07	0.69
CV (%)	2.49	1.97	8.51
		RYT (ZER-1)	
IR101757-46-1	117	124	5.38
IR101756-146-1	98	109	4.43
BRRI dhan49 (ck.)	104	127	5.32
BRRI dhan72 (ck.)	117	121	5.7
BRRI dhan87 (ck.)	123	123	5.8
LSD (5%)	5.76	1.87	0.64
CV (%)	2.73	0.82	6.35
		RYT (ZER-1)	
BR9674-1-1-5-2-P4	102	122	4.65
BR9674-1-1-5-4-P4	109	116	3.65
BR9674-3-2-4-2-P3	100	117	3.89
BR9674-3-3-1-1-P3	108	119	4.57
BR7528-2R-HR16-2-24-1-HR1	126	115	4.31
BRRI dhan49 (ck.)	103	127	4.51
BRRI dhan72 (ck.)	118	122	5.12
BRRI dhan87 (ck.)	124	123	5.25
LSD (5%)	3.8	2.84	0.72
CV (%)	1.95	1.35	9.14
		RYT (PQR-1)	
BR8493-3-5-1-P1	133	136	2.97
BR9590-45-1-3-2-P2	136	140	3.06
BR8515-28-1-1-3-HR3(Com)	183	132	2.21
Kalizira (L. ck)	159	139	1.4
BINA dhan-13 (std. ck)	163	142	2.07
LSD (5%)	5.45	2.64	0.29
CV (%)	4.87	2.02	8.49
		RYT (PQR-2)	
BR9054-6-1-2-3	115	116	3.81
BR9844-7-4-1-2-4-2	113	104	4.24
BR9581-16-3-5-3-3	105	117	3.21
D. Kataribhog	163	118	2.75
BRRI dhan37 (std. ck)	124	136	2.9
LSD $_{(5\%)}$	9.64	3.39	0.79
CV (%)	4.13	1.52	12.46
		RYT (IRR-1)	
BR10039-11-3-2	102	126	5.29
BR10039-13-3-4	113	124	5.08
BR10039-21-7-2	107	123	5.01
BR10039-5-5-5	124	123	4.43
BR9888-15-3-7-2	125	126	5.46
BR9888-23-5-9-2	118	121	5.03
BR9888-26-9-14-2	129	119	5.18
BR9888-26-9-14-3	123	122	5.26
BR9888-4-3-17-2	118	120	5.02
BRRI dhan33 (ck.)	106	116	4.39
BRRI dhan49 (ck.)	100	131	4.86
BRRI dhan93 (ck.)	116	130	5.37
LSD (5%)	6.39	1.99	0.95

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
CV (%)	3.32	0.97	11.81
		RYT (IRR-2)	
BR10039-19-4-5	116	123	5.14
BR10039-21-4-3	117	123	5.18
BR9143-25-7-2-2	131	123	4.23
BR9880-24-2-1-14	106	125	4.73
BR9881-33-4-2-39	102	123	4.52
BR9882-17-2-2-32	104	125	4.59
BR9882-6-2-2-4	103	125	4.54
BR9888-26-9-14-3	122	119	4.27
BR9889-11-6-16-3	133	120	3.5
BRRI dhan33 (ck.)	103	111	4.56
BRRI dhan49 (ck.)	103	131	4.60
BRRI dhan93 (ck.)	116	130	5.06
LSD (5%)	4.89	1.98	0.63
CV (%)	2.57	0.96	8.41
		RYT(BBRR)	
BR10397-3-2-1-1	116	121	5.69
BR10397-3-2-1-3	105	117	5.58
BR10401-5-1-3-4	102	119	4.77
BR10401-5-3-3-2	112	115	4.21
BR10392-B-B-12-P2	111	122	3.96
BR10393-4-1-1-1	120	123	4.65
BRRI dhan49 (ck.)	105	125	4.73
BRRI dhan87 (ck.)	126	123	5.48
IRBB60 (Res. ck.)	92	124	4.2
LSD (5%)	6.72	2.01	0.89
CV (%)	3.53	0.95	10.71

Table 2. Performance of different genotypes in RYT salinity breeding in T. Aman 2020.

Designation	GD	Yield (t/ha)		
	(day)	Koyra	Assasuni	Tala
BR10045-15-23-5	115	3.42	3.94	4.32
BR10061-B-1-2-1	120	3.16	1.74	4.27
BR9536-2-1-7	113	2.66	2.02	4.11
HHZ11-DT7-SAL1-SAL1	110	1.94	3.47	4.18
HHZ15-SAL13-Y3	108	1.96	2.14	3.36
HHZ18-Y3-Y1-Y1	106	3.67	2.75	5.62
HHZ8-SAL14-SAL3-Y2 (	108	4.19	3.31	4.63
IR 87870-6-1-1-1-1-B	116	4.30	3.74	4.19
IR103499-B-2-AJY1	110	3.49	3.51	4.01
IR108128-B-1-AJY2-B-1	117	3.14	3.39	4.28
IR108158-B-2-AJY1-1	109	3.29	1.95	3.68
IR15T1451	120	4.26	4.55	3.76
IR15T1464	115	3.98	4.72	5.26
TP30649	112	4.05	5.38	4.97
TP30656	118	2.08	1.74	5.10
BRRI dhan54 (Tol.ck)	110	4.16	4.70	5.71
BRRI dhan73 (Tol.ck)	115	3.63	4.59	4.73
BRRI dhan87 (Sus.ck)	120	4.49	3.98	4.69
LSD (5%)	8.1	0.50	0.25	0.41
H	0.80	0.84	0.86	0.94

Table 3. Performance of different entries under RYT at BRRI, Satkhira during T. Aman 2020.

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
		RYT (Barishal1)	
BRBa1-4-9	109	152	7.57
BRBa2-1-3	103	151	8.57
BRBa2-5-3	93	150	7.93
BRBa3-1-7	86	153	7.50
BRBa3-2-4	94	154	7.91
BRBa3-3-1	93	154	7.56
BRRI dhan58	93	148	7.13
BRRI dhan92	108	154	8.35
LSD (5%)	5.80	1.86	0.72
CV (%)	3.39	0.70	5.27
		RYT (Barshal-2)	
IR04A429	101	155	7.01
IR12A329	102	152	7.73
IR13A515	101	154	7.12
IR15A2820	NG	NG	NG
IR15A2854	100	146	7.45
IR15A3466	101	151	6.04
IR16A2022	100	146	6.98
BRRI dhan58	98	146	6.88
BRRI dhan92	101	154	7.74
LSD (5%)	8.3166	1.4739	0.76
CV (%)	4.71	0.56	6.09
		RYT-BBRR	
BR9943-2-2	101	146	5.98
BR9650-108-2-3	106	147	5.90
BR9942-1-2-1-1-B1	97	140	5.70
BR9943-35-2-1-2-B2	103	141	7.48
BR9943-26-2-3-6	110	145	6.61
BRRI dhan58	101.	138	7.07
BRRI dhan89	112	149	7.37
IRBB60	88	145	3.87
$LSD_{0.05}$	4.06	1.17	1.46
CV (%)	2.26	0.47	13.35
		RYT-GSR	
FBR189	102	143	7.20
FBR336	98	148	7.60
FBR350	96	143	6.02
FBR355	105	146	6.80
WANXIAN7777-P10-P3	104.33	152	8.08
BRRI dhan88	84.67	143.33	6.73
BRRI dhan58	94	146	7.64
LSD (5%)	4.61	3.69	1.36
CV (%)	2.65	1.42	10.71
		RYT-Cumilla#1	
BRC426-4-2-1	93	146	6.64
BRC366-2-2-4-2-1	91	148	7.13
BRC427-9-1-3	99	147	6.35
BRC389-4-2-4-2	93	143	7.11
BRC401-1-1-1-1B	93	147	7.48
BRC366-2-2-4-2-3	88	151	5.79
BRRI dhan81	93	137	6.43
BRRI dhan84	96	136	6.40
BRRI dhan88	83	137	6.88
LSD (5%)	ns	2.3	0.87
CV (%)	6.03	0.93	7.54

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
		RYT-Cumilla#2	
BRC398-4-1-1-1B	102	150	6.62
BRC428-2-2-1	85	149	7.12
BRC428-3-1-1	97	147	7.20
BRC428-3-1-2	94	148	6.75
BRC394-1-1-1-2	95	149	7.40
BRC394-1-1-1-5A	90	149	6.74
BRC335-1-3-2-2-1	108	149	7.15
BRRI dhan50	94	149	6.15
BRRI dhan58	90	146	6.87
BRRI dhan89	102	150	7.71
LSD (5%)	10.03	1.59	0.75
CV (%)	6.09	0.62	6.3
		RYT-YM	
BRH11-9-11-4-5B-HR3	94	141	7.63
BRH13-2-4-6-4B	96	143	7.66
BRRI dhan63	79	141	6.29
LSD (5%)	3.54	1.51	0.37
CV (%)	2.74	0.87	3.33
		RYT-ZER	
BR8419-8-2-1-4-1-3-8-5	90	140	5.86
BR8913-12-4-8-9-2-3-11-22	90	140	6.50
BR9674-5-6-2-1-7-22	88	142	6.00
BRRI dhan74	92	140	6.82
BRRI dhan84	96	139	6.56
BRRI dhan89	104	148	7.30
LSD (5%)	7.81	1.68	NS
CV (%)	4.62	0.66	6.74
		RYT-PQR	
BR9930-2-2-4-1	97	146	6.47
BR9930-2-2-4-3	103	143	5.67
BR9930-2-3-2-2	105	146	6.67
BR9930-2-3-3-1	107	145	5.94
BR9938-20-1-1-1	99	145	6.00
BRRI dhan50	87	146	6.05
BRRI dhan63	83	143	6.45
BRRI dhan81	89	144	6.16
LSD (5%)	4.56	2.1	0.88
CV (%)	2.67	0.81	7.5

Table 4. Performance of different genotypes in RYT salinity breeding in Boro 2020-21.

Entry/Variety	Growth duration (day)	Plant height (cm)	Yield (t/ha)
		RYT - 1 (BRRI RS farm, Satkhira)	
BR9156-4-1-7-9	155	106	6.68
BR9620-2-4-1-5	156	89	6.10
BR9621-B-2-3-22	156	98	6.33
BR9625-4-1-2-8	161	104	5.40
BR9625-B-2-4-6	162	112	4.94
BR9625-B-2-4-8	158	113	6.33
BR9625-B-2-4-9	157	113	5.79
BR9626-1-2-12	160	107	5.52
BR9626-B-2-3-15	152	119	6.81
BRRI dhan 89 (2 line)	160	116	2.19
BRRI dhan67	152	113	6.78
BRRI dhan97	158	115	6.08
Bina dhan10	151	121	7.13
IR 103499-B-2-AJY 1	156	100	5.33

Entry/Variety	Growth duration (day)	Plant height (cm)	Yield (t/ha)
IR 103512-B-AJY 2-2	147	103	5.60
IR 103599-B-67-AJY 3	153	116	6.68
IR 106466-30-CMU 3	162	96	6.38
IR 96184-24-1-1-AJY 2	156	106	6.05
LSD (5%)	1.36	0.21	0.21
H	0.99	1	1
		RYT - 1 (Assasuni)	
BR9156-4-1-7-9	130	87	0.59
BR9620-2-4-1-5	134	74	0.65
BR9621-B-2-3-22	138	84	0.85
BR9625-4-1-2-8	131	79	0.94
BR9625-B-2-4-8	139	87	0.63
BR9625-B-2-4-9	139	89	0.72
BR9626-1-2-12	139	92	0.75
BR9626-B-2-3-15	139	87	0.34
BRRI dhan 89	139	80	0.64
BRRI dhan67	140	87	1.73
BRRI dhan97	139	86	1.93
Bina dhan10	137	91	1.75
IR 103499-B-2-AJY 1	137	103	0.84
IR 103499-B-87-AJY 3	138	88	0.55
IR 103512-B-AJY 2-2	136	95	1.02
IR 106466-30-CMU 3	136	79	0.82
IR 96184-24-1-1-AJY2	137	88	0.64
LSD	1.34	1.50	0.71
H	0.98	0.99	0.83
		RYT-2 (BRRI RS farm, Satkhira)	
BR9154-2-7-1-2	149	91	6.11
BR9156-4-1-7-9	155	93	6.60
BR9620-2-4-1-5	152	89	6.06
BR9620-2-7-1-1	163	108	6.65
BR9620-4-3-2-2	152	89	7.92
BR9621-B-1-2-11	161	106	2.91
BR9625-3-1-12	157	107	6.16
BR9625-B-1-4-6	160	112	5.91
BR9627-1-3-1-10	156	108	6.29
BRRI dhan 89 (5LINE)	155	112	0.70
BRRI dhan67	152	114	6.76
BRRI dhan97	156	114	6.58
Binadhan-10	154	114	6.83
IR 100638-6-CMU 3-CMU 1	163	107	5.71
IR 103854-8-3-AJY 1	162	105	5.21
IR 104002-CMU 28-CMU 1-CMU 3	149	100	5.01
IR 93915-82-CMU2-2-CMU3-AJYB	156	109	5.95
IR92860-33-CMU1-1-CMU2-AJYB	156	109	6.30
LSD (5%)	1.36	0.21	0.21
H	0.99	1	1
		RYT-2 (Assasuni)	
BR9154-2-7-1-2	133	85	2.25
BR9156-4-1-7-9	137	96	0.84
BR9620-2-4-1-5	136	87	3.08
BR9620-2-7-1-1	135	94	2.24
BR9620-4-3-2-2	136	102	2.20
BR9621-B-1-2-11	138	99	0.96
BR9625-3-1-12	134	84	2.36
BR9625-B-1-4-6	139	100	1.83
BR9627-1-3-1-10	139	99	1.51
BRRI dhan 89	139	97	0.65

Entry/Variety	Growth duration (day)	Plant height (cm)	Yield (t/ha)
BRRI dhan67	134	103	2.68
BRRI dhan97	140	97	3.09
Binadhan-10	134	111	3.07
IR 103854-8-3-AJY 1	139	95	0.80
IR92860-33-CMU1-1-CMU2-AJYB	139	98	1.65
LSD (5%)	1.69	1.24	0.27
H	0.94	1	0.99
	RYT- 3 (BRRI RS farm, Satkhira)		
BR11723-4R-172	171	106	8.04
BR11716-4R-102	172	106	9.11
BR11715-4R-186	170	100	8.38
BR11716-4R-108	170	110	7.84
BR11716-4R-120	171	102	8.88
BR11712-4R-218	170	107	7.89
BR11723-4R-27	169	106	9.10
BR11716-4R-129	171	101	8.64
BR11723-4R-48	171	102	10.07
BR11716-4R-105	152	104	8.75
BR11723-4R-12	170	108	8.09
BR11716-4R-147	170	106	8.69
BR11712-4R-227	170	109	9.40
BR11716-4R-123	170	105	9.16
BR11716-4R-114	171	100	7.76
SVIN355	153	104	6.96
SVIN415	151	98	6.37
BR10672-1-3-7-12	153	104	7.34
BRRI dhan67	147	116	6.63
BRRI dhan 89	157	105	6.60
BRRI dhan97	152	110	7.74
Binadhan-10	154	115	8.02
LSD (5%)	1.19	1.91	0.90
H	0.98	0.97	0.89

Table 5. Performance of different genotypes under ALART during T. Aman 2019.

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t/ha)
	ALART (RLR)		
BR9571-13-1-9-1-1	121	142	3.07
BR9574-9-5-3-1-1	122	134	3.81
BRRI dhan49 (ck)	108	132	4.02
BRRI dhan87 (ck)	122	124	4.09
LSD (5%)	2.45	1.49	0.51
CV (%)	2.76	0.56	6.77
	ALART (IRR)		
BR9880-40-1-3-34	108.67	135	3.80
BR9881-24-2-2-25	107.67	134	3.72
BR9880-27-4-1-18	114.47	132	3.79
BR9880-2-2-2-1	114.07	135	3.58
BRRI dhan93 (ck)	118.4	138	4.43
T27A (R. ck)	157.27	152	1.23
LSD (5%)	2.45	1.49	0.51
CV (%)	2.76	0.56	6.77
	ALART (ZER)		
1 V1=BR10001-94-2-B	127	129	2.98
2 V2=BRRI dhan72 (Ck)	117	127	3.51
3 V3=BRRI dhan87 (Ck)	123	128	4.05
LSD (5%)	NS	NS	0.80
CV (%)	0.88	0.82	10.15

Table 6. Performance of different genotypes under ALART during Boro 2020-21.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
	ALART (PQR)		
BR8526=38-2-1-HR1	99	152	5.57
Lata Balam	98	147	5.72
BRRI dhan50 (ck)	85	149	6.41
BRRI dhan63 (ck)	85	140	6.68
BRRI dhan81 (ck)	98	137	6.07
$LSD_{0.05}$	4.0	1.0	0.68
CV (%)	2.11	0.22	5.94
	ALART (ZER)		
BR8912-12-6-1-1-1-1	99	144	6.35
IR105837-8-95-2-1	107	150	6.20
BRRI dhan74 (ck)	92	141	7.65
BRRI dhan89 (ck)	102	150	7.90
$LSD_{0.05}$	3.0	2.0	0.80
CV (%)	1.66	0.73	5.70
	ALART (FBR-Bhanga)		
SVINO63-Boro-18-Bhanga	118	151	7.76
SVINO76-Boro-18-Bhanga	105	149	6.49
BRRI dhan29 (ck)	103	153	6.07
BRRI dhan89 (ck)	112	148	6.32
$LSD_{0.05}$	4.0	2.0	0.89
CV (%)	1.77	0.51	6.68
	ALART (BBRR-Bio)		
BR(Bio)11447-1-28-14-3	105	143	7.79
BR(Bio)11447-3-10-17-1	105	142	7.69
BRRI dhan28 (Std. and sus ck)	104	138	6.84
$LSD_{0.05}$	2.0	1.0	1.04
CV (%)	1.0	0.37	6.22

Table 7. Effect of missing element on grain yield and panicle number of BRRI dhan87 during T. Aman 2020 and BRRI dhan67 in Boro 2020-21.

Treatment	T. Aman 2020			Boro 2020-21		
	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})	Yield decrease (%) due to missing nutrient	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})	Yield decrease (%) due to missing nutrient
PKSZn (-N)	4.27	4.39	22	3.28	3.26	75
NKSZn (-P)	5.13	5.04	10	5.63	5.48	4
NPSZn (-K)	5.47	5.21	7	5.60	5.35	7
NPKZn (-S)	5.28	5.27	6	5.58	5.27	8
NPKS (-Zn)	5.56	5.56	1	5.80	5.55	3
NPKSZn	5.54	5.61	-	5.85	5.71	-
Control	4.30	4.11	27	2.98	2.83	102
CV (%)	1.34	0.98		0.82	0.88	
LSD (5%)	9.21	6.87		5.78	6.45	

Table 8. Effects of fertilizers sources and varieties on grain yield in Kaliganj and BRRI RS farm, Satkhira during Boro season 2020-21.

Fertilizer	GY (t/ha) of Kaliganj, Satkhira		GY (/ha) of BRRI RS farm, Satkhira	
	BRRI dhan67	BRRI dhan88	BRRI dhan67	BRRI dhan88
Farmers' practice	5.09	3.85	3.87	2.17
UDP	5.55	4.13	4.19	2.45
OCP fertilizer	4.86	3.78	4.13	2.28
Recommended fertilizer	5.04	4.01	3.98	2.20
Ash 3 (t ha^{-1}) + 100% NPKSZn	5.52	3.95	3.45	2.37
Ash & Manure (1:1) @ 5 t ha^{-1} +70% NPKSZn	5.66	4.22	4.32	2.48
Control	1.98	1.66	1.80	1.42
LSD (5%)	0.738	0.686	0.819	0.385
CV (%)	5.37	6.57	7.81	6.14

Table 9. Evaluation of increased nitrogen and potassium rates for Boro rice cultivation in saline areas of Kaliganj during Boro 2020-21.

For N experiment		For K experiment	
Treatment	Grain yield (t/ha)	Treatment	Grain yield (t/ha)
N_{124} (RD)	5.52	K_{60} (RD)	4.95
N_{149} (20 % more of RD)	6.12	K_{72} (20 % more of RD)	5.16
N_{174} (40 % more of RD)	5.44	K_{84} (40 % more of RD)	6.21
N_{200} (60 % more of RD)	5.30	K_{96} (60 % more of RD)	5.09
$LSD_{(5\%)}$	*0.47*		*0.53*
CV (%)	*4.24*	CV (%)	*4.95*

Table 10. Performance of different hybrid rice genotypes under saline prone area of Assasuni, Satkhira during Boro 2020-21 season.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRRI hybrid dhan2	108.23	138	5.47
BRRI hybrid dhan3	99.13	138	8.09
BRRI hybrid dhan4	105.52	139	8.30
BRRI hybrid dhan5	101.01	138	8.55
BRRI hybrid dhan6	103.18	137	7.96
BRRI hybrid dhan7	101.33	140	6.81
BRRI99A/BRRI31R	100.68	137	6.09
BRRI99A/EL254R	102.76	138	7.20
Gold (Lal teer)	94.50	140	5.60
Heera (Supreme)	111.63	137	5.46
Tejgold (Bayer)	69.13	139	6.51
SL-8 (BADC)	109.59	141	4.26
Janokraj	100.38	259	4.84
BRRI dhan67	86.77	137	5.85
IT	119.69	140	7.58
Binadhan-10	89.18	138	6.03
CV (%)	12.75	16.08	5.13
$LSD_{0.05}$	21.28	NS	0.55

DS: 10 Dec 2020 DT: 10 Jan 2021

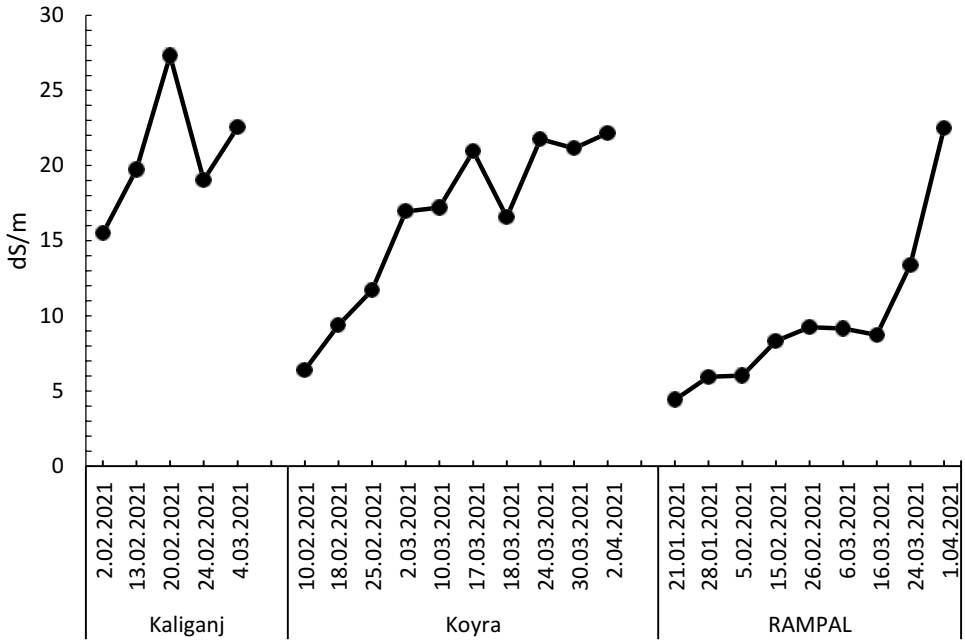

Fig. 1. Soil water salinity of RYT experimental plots at Kaliganj, Koura and Rampal.

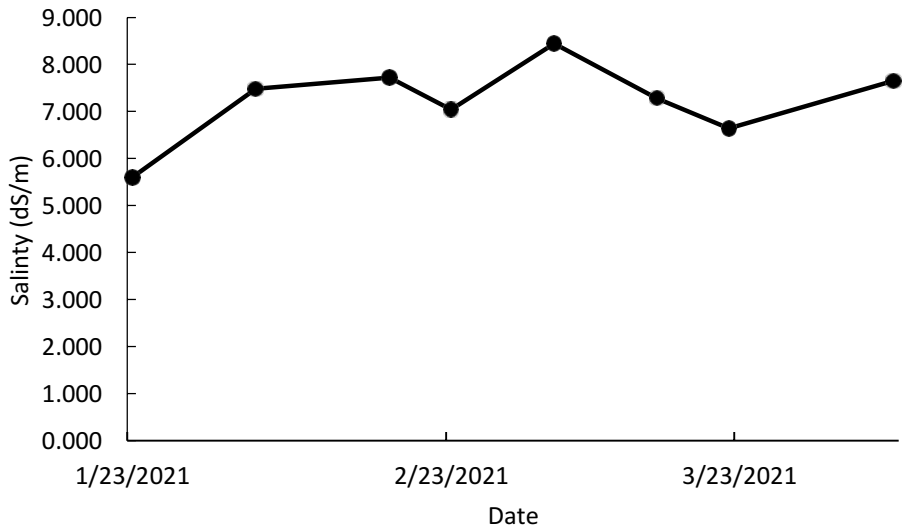

Fig. 2. Soil water salinity of the experimental plots at Kaliganj, Satkhira during Boro 2020-21.

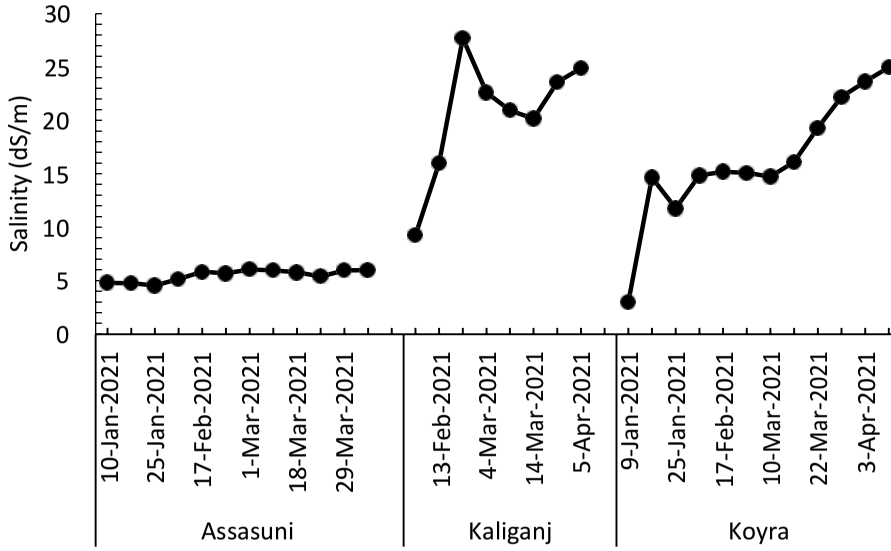

Fig. 3. Soil water salinity of the experimental plots at Assasuni and Kaliganj, Satkhira and Koyra, Khulna during Boro 2020-21.

BRRI RS, Sonagazi

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SUMMARY

Eighteen Regional Yield trials (RYT) and one advanced yield trial (AYT) were conducted at experimental field of BRRI, Sonagazi, Feni to investigate the performance of advanced breeding lines. A total of 127 breeding lines supplied by Plant breeding and Biotechnology divisions were tested under these trials during the reporting period from which eight lines were found better than check varieties in respect of grain yield, growth duration and yield components. Two advanced lines BR9829-80-2-2-1& BR9829-78-1-2-1 gave higher yield than BR27, BRRI dhan48 and BRRI dhan82 tested during Aus 2020. Forty Seven lines along with standard checks BRRI dhan49, BRRI dhan72, BRRI dhan73 and BRRI dhan87 were tested during T. Aman 2020. Two advanced lines from RLR-1 (IR98396-B-B-B-B-40) & DRR (BR10397-3-2-1-1) were found better compared to standard check varieties. Seventy three lines along with standard checks BRRI dhan58, BRRI dhan63, BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88, BRRI dhan89, BRRI dhan92, BRRI dhan97 and BINA dhan10 were tested in the RYTs during Boro 2020-21. Four advanced lines from STR-2 (IR93915-82-CMU2-2-CMU3-AJYB, BR9620-2-4-1-5), DRR-BB Barishal (BR9650-108-2-3) & GSR (FBR336) were found better compared to the check varieties to be recommended for further advanced trial.

Eleven nutrient enriched breeding lines were tested with a check BRRI dhan28 under a confined field trial (CFT) at BRRI Sonagazi in Boro 2020-21 with 3 replications following RCBD. Out of 11 lines, the entries IR 133904 TR-B-B 3-B-28 (6.71 t ha^{-1}) and IR 133904 TR-B-B 1-B-3 (6.80 t ha^{-1}) produced higher grain yield compared to check variety BRRI dhan28 (6.48 t ha^{-1}) but it was not statistically higher.

A total of nine advanced lines adaptive research trials (ALART) were conducted where 19 advanced rice genotypes were evaluated along with 15 check varieties at Chattogram region by BRRI Sonagazi during the reporting period 2020-2021. Unfortunately, none of the genotypes performed better than the check varieties. Accordingly, none of the genotypes recommended for proposed trial (PVT).

Two fertilizer trials were conducted during Boro 2020-21 which were effect of potassium (K) and Sulphur (S); and effect of Zinc (Zn) on modern rice varieties where different combinations fertilizers treatments were applied. Among the K and S treatments, the highest grain yield 6.62 and 6.51 t ha^{-1} at Guimara and Sonagazi, respectively. The treatment T4 (STB + 40 % more K and S) gave in an average 1 t ha^{-1} higher than farmer's practice (5.59 and 5.50 t ha^{-1} at Guimara and Sonagazi, respectively). Grain yield of T4 was also significantly higher than recommended practice (6.10 t ha^{-1}). Another trial was conducted with eight different doses of Zn. Irrespective of variety, the treatment T5 (STB + 100% Zn) was gave the highest mean grain yield (6.27 t ha^{-1}) followed by T4 (T1 + 50% Zn) and the lowest (3.00 t ha^{-1}) was in T8 (Control). Both the nutrient management trials need to be repeated for better understanding and conclusive findings.

Pest incidence surveys were carried out at farmers' fields of Feni, Noakhali, Laxmipur, Cox'sbazar, Chattogram and Khagrachari districts in Aman 2020 and Boro 2020-21 seasons. Rice yellow stem borer, Leaf folder, Rice bug, Grasshopper, Green leaf hopper were found as major insects. Bacterial Leaf Blight (BLB), Sheath blight, Blast, Sheath rot, False smut and infestation were observed in different scores.

Stability analysis trial was conducted during Aus 2020, Aman 2020, and Boro 2020-21 at BRRI Sonagazi. A total of 99 BRRI varieties were evaluated during reporting period from which 11 in, 42 in n and 46 varieties tested in Aus, Aman and Boro season, respectively. Three varieties BRRI dhan48, BRRI dhan87 and BRRI hybrid dhan3 gave highest grain yield in Aus, Aman and Boro season, respectively.

A total of 185 seed production and dissemination program (SPDP)/demonstrations were executed in 215 bigha land at farmer's field during 2020-2021 finacial year (Aus 2020, Aman 2020 and Boro 2020-21). Total grain production of the SPDP was 173.75 ton and 29.06 ton (16.7%) was preserved as seed. From the SPDPs, 10619

farmers gained knowledge on rice technologies and 2022 farmers (19.0%) were motivated.

A total of 35 trainings on rice technologies were executed and trained up 1100 participants having 1010 farmers (784 male and 226 female); and 90 extension personnel (male 79 and female 11). Fourteen field days were organized in selected demonstration sites at crop maturity stage where nearly 2250 progressive farmers, local leaders, extension personnel (DAE and NGO personnel), were participated.

A total of 14.07 ton breeder seed produced by BRRI Sonagazi during the reporting period (3.57 ton in in Aman 2020 () and 10.5 ton in Boro 2021).. All the Breeder seeds of different varieties were sent to Genetic Resource and Seed Division, BRRI, Gazipur. BRRI Sonagazi produced 18.3 ton quality seed (TLS) of modern rice varieties; from which 1.5, 11.5, and 5.3 ton were produced during Aus, Aman, and Boro season, respectively.

VARIETAL DEVELOPMENT PROGRAM AREA

Regional Yield Trial (RYT-1) in Aus 2020

Three advanced lines BR9829-80-2-2-1, BR9830-53-3-5-2 and BR9830-74-4-3-1 along with two standard check BRRI dhan48 and BRRI dhan82 were evaluated at BRRI, Sonagazi, Feni during Aus 2020. The advanced lines BR9829-80-2-2-1, BR9830-53-3-5-2 and BR9830-74-4-3-1 produced 4.87, 5.52 and 5.83 t/ha, respectively (Table 1). The advanced lines BR9829-80-2-2-1 produced higher yield with shorter growth duration than standard checks that may be recommended for further trial.

RYT-2 Plant Breeding in Aus 2020

Four advanced lines BR9829-78-1-2-1, BR9829-78-1-3-2, BR9830-5-2-2-3 and BR9830-44-1-8-2 along with two standard check BRRI dhan48 and BRRI dhan27 were evaluated at BRRI, Sonagazi, Feni during Aus 2020. The advanced lines BR9829-78-1-2-1, BR9829-78-1-3-2, BR9830-5-2- 2-3 and BR9830-44-1-8-2 produced 6.58, 5.44, 5.38 and 4.95 t/ha, respectively (Table 2). The advanced lines BR9829-78-1-2-1 produced higher yield than standard checks.

Advanced Yield Trial (AYT) in Aus 2020

BRRI dhan48 along and Bindhan-19 were evaluated at BRRI, Sonagazi, Feni during Aus 2020. BRRI dhan48 produced 5.77 t/ha grain yield while Bindhan-19produced 4.91 t/ha grain yield (Table 3) but BINA dhan19 was found about 4 to 5 days earlier than BRRI dhan48.Therefore, BRRI dhan48 showed better performance than Binadhan-19 in respect of yield.

Table 1. Results of Regional Yield Trial (RYT-1) during T. Aus 2020 at BRRI Sonagazi

SN.	Designation	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)
1	BR9829-80-2-2-1	5.87	114	104
2	BR9830-53-3-5-2	5.52	113	103
3	BR9830-74-4-3-1	5.83	115	111
4	BRRI dhan48 (Ck.)	5.61	112	104
5	BRRI dhan82 (Ck.)	4.90	103	110
$LSD_{0.05}$		0.18	2.24	4.74
CV (%)		1.71	1.07	2.37

Table 2. Results of Regional Yield Trial (RYT-2) in T. Aus 2020 at BRRI Sonagazi

SN.	Designation	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)
1	BR9829-78-1-2-1	6.58	114	128
2	BR9829-78-1-3-2	5.44	113	125
3	BR9830-5-2-2-3	5.38	115	114
4	BR9830-44-1-8-2	4.95	112	110
5	BRRI dhan48 (CK)	5.63	111	107
6	BRRI dhan27 (CK)	4.24	117	131
$LSD_{0.05}$		0.29	1.879	3.97
CV(%)		3.04	0.91	1.83

Table 3. Advanced Yield Trial (AYT) in T. Aus 2020 at BRRI Sonagazi

SN.	Designation	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)
1	BRRI dhan48	5.77	107	104
2	BINA dhan19	4.91	102	98
$LSD_{0.05}$		NS	NS	1.43
CV(%)		4.71	NS	0.40

RYT Zinc Enriched Rice-1 (ZER-1) during T. Aman 2020

Two advanced lines IR101757-46-1 and IR101756-146-1 along with three standard check BRRI dhan49, check BRRI dhan72 and BRRI dhan87 were evaluated at BRRI, Sonagazi, Feni during Aman 2020. The advanced lines IR101757-46-1 and IR101756-146-1 produced 5.58 and 4.69 t/ha, respectively (Table 4). None of the tested lines showed better performance than standard checks.

RYT Zinc Enriched Rice-2 (ZER-2) during T. Aman 2020

Five advanced lines BR9674-1-1-5-2-P4, BR9674-1-1-5-4-P4, BR9674-3-2-4-2-P3, BR9674-3-3-1-1P3 and BR7528-2R-HR16-2-24-1-HR1 along with three standard check BRRI dhan49, check BRRI dhan72 and BRRI dhan87 were evaluated at BRRI, Sonagazi, Feni during Aman 2020. The advanced lines BR9674-1-1-5-2-P4, BR9674-1-1-5-4-P4, BR9674-3-2-4-2-P3, BR9674-3-3-1-1P3 and BR7528-2R-HR16-2-24-1-HR1 produced 5.71, 4.67, 4.40, 4.78 and 4.59 t/ha, respectively (Table 5). None of the tested lines showed better performance than standard checks.

RYT-1 Rainfed Lowland Rice in T. Aman 2020

Seven advanced lines BR9857-7-6-5-1, IR100122-B-B-B-B-2, IR1003352-B-B-205, IR98377-B-B-B-B-24, IR98381-B-B-B-B-71, IR98386-B-B-B-B-33 and IR98396-B-B-B-B-40 along with two standard check BRRI dhan49 and BRRI dhan87 were evaluated at BRRI, Sonagazi, Feni during Aman 2020. The advanced lines BR9857-7-6-5-1, IR100122-B-B-B-B-2, IR1003352-B-B-205, IR98377-B-B-B-B-24, IR98381-B-B-B-B-71, IR98386-B-B-B-B-33 and IR98396-B-B-B-B-40 produced 5.60, 5.69, 5.82, 5.71, 6.14, 6.13 and 6.52 t/ha, respectively (Table 6). The advanced line

Table 4: Results of RYT (ZER-1) during T. Aman 2020 at BRRI Sonagazi.

SN.	Designation	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)
1	IR101757-46-1	5.58	128	125
2	IR101756-146-1	4.69	121	110
3	BRRI dhan49 (CK)	5.28	131	106
4	BRRI dhan72 (CK)	5.66	126	128
5	BRRI dhan87 (CK)	5.93	128	125
$LSD_{0.05}$		0.35	1.59	3.83
CV(%)		3.44	0.67	1.72

Table 5: Results of RYT (ZER-2) during T. Aman 2020 at BRRI Sonagazi.

SN.	Designation	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)
1	BR9674-1-1-5-2-P4	5.71	120	126
2	BR9674-1-1-5-4-P4	4.67	113	119
3	BR9674-3-2-4-2-P3	4.40	119	118
4	BR9674-3-3-1-1P3	4.78	117	130
5	BR7528-2R-HR16-2-24-1-HR1	4.59	115	125
6	BRRI dhan49 (ck)	5.10	133	112
7	BRRI dhan72 (ck)	6.01	123	128
8	BRRI dhan87 (ck)	6.15	129	126
$LSD_{0.05}$		0.50	1.51	5.08
CV(%)		5.48	0.71	2.36

IR98396-B-B-B-B-40 produced greater yield and showed shorter growth duration than standard checks. Based on the yield performance the above line may be recommended for advanced trial.

RYT-2, Rainfed Lowland Rice (RLR) in T. Aman 2020

Seven advanced lines BR9840-52-1-2-1, BR9840-52-1-4-2, BR9857-4-2-5-5, BR8492-9-5-3-2 HR1, BR8492-9-5-3-2, Kanihati-4 and Kanihati-9 along with two standard check BRRI dhan49 and BRRI dhan87 were evaluated at BRRI, Sonagazi, Feni during Aman 2020. The advanced lines BR9840-52-1-2-1, BR9840-52-1-4-2, BR9857-4-2-5-5, BR8492-9-5-3-2 HR1, BR8492-9-5-3-2, Kanihati-4 and Kanihati-9 produced 4.95, 4.45, 4.59, 4.78, 4.44, 4.58 and 3.52 t/ha, respectively (Table 7). None of the tested lines showed better performance than standard checks.

RYT Development of Disease resistant Rice (DRR) in T. Aman 2020

Seven advanced IRBB60 (R. Ck), BR10401-5-1- 3-4, BR10397-3-2-1-1, BR10392-B-B-12-P2, BR10393-4-1-1-1, BR10401-5-3-3-2 and BR10397-3-2-1-3 along with two standard check BRRI dhan49 and BRRI dhan87 were evaluated at BRRI, Sonagazi, Feni during Aman 2020. The advanced lines IRBB60 (R. Ck), BR10401-5-1-3-4, BR10397-3-2-1-1, BR10392-B-B-12-P2, BR10393-4-1-1-1, BR10401-5-3-3-2 and BR10397-3-2-1-3 produced 4.40, 5.26, **6.42**, 5.41, 5.03, 4.99 and 5.10 t/ha, respectively (Table 8). The advanced line BR10397-3-2-1-1 produced higher yield than standard checks. Based on the yield performance the above line may be recommended for advanced trial.

Table 6: Results of RYT-1 (RLR) during T. Aman 2020 at BRRI Sonagazi.

SN	Designation	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)
1	BR9857-7-6-5-1	5.60	115	115
2	IR100122-B-B-B-B-2	5.69	118	123
3	IR1003352-B-B-205	5.82	118	119
4	IR98377-B-B-B-B-24	5.71	119	112
5	IR98381-B-B-B-B-71	6.14	119	109
6	IR98386-B-B-B-B-33	6.13	120	112
7	IR98396-B-B-B-B-40	6.52	118	115
8	BRRI dhan49(ck)	5.38	133	103
9	BRRI dhan87(ck)	6.17	126	120
$LSD_{0.05}$		0.42	0.94	4.78
CV(%)		4.12	0.45	2.42

Table 7: Results of RYT-2 (RLR) during T. Aman 2020 at BRRI Sonagazi.

SN	Designation	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)
1	BR9840-52-1-2-1	4.95	118	123
2	BR9840-52-1-4-2	4.45	125	120
3	BR9857-4-2-5-5	4.59	114	104
4	BR8492-9-5-3-2 HR1	4.78	126	119
5	BR8492-9-5-3-2	4.44	128	115
6	Kanihati-4	4.58	118	117
7	Kanihati-9	3.52	113	112
8	BRRI dhan49(ck)	5.28	134	104
9	BRRI dhan87(ck)	6.07	125	125
$LSD_{0.05}$		0.43	0.98	4.15
CV(%)		5.24	2.08	2.08

Table 8: Results of RYT-DRR during T. Aman 2020 at BRRI Sonagazi.

SN	Designation	Grain yield (t/ha)	Growth duration (days)
1	IRBB60 (R. Ck)	4.40	117
2	BR10401-5-1-3-4	5.26	130
3	BR10397-3-2-1-1	6.42	130
4	BR10392-B-B-12-P2	5.41	123
5	BR10393-4-1-1-1	5.03	134
6	BR10401-5-3-3-2	4.99	125
7	BR10397-3-2-1-3	5.10	124
8	BRRI dhan49 (Ck)	5.32	133
9	BRRI dhan87 (Ck)	6.18	127
$LSD_{0.05}$		0.32	1.63
CV(%)		3.44	0.74

RYT Salinity tolerant Rice-1 (STR-1) in T. Aman 2020

Nine advanced lines BR9536-2-1-7, IR103499-B-2-AJY1, IR15T1349, R15T1464, IR108128-B-1-AJY2-B-1, IR15T1305, IR15T1376, TP30656 and IR108158-B-2-AJY1-1 along with three standard check BRRI dhan73 (T. ck), BRRI dhan54 (Tol. Ck) and BRRI dhan87 (Sus. Ck.) were evaluated at farmers field of Chakoria, Cox'sbazar during Aman 2020.

The advanced lines BR9536-2-1-7, IR103499-B-2-AJY1, IR15T1349, R15T1464, IR108128-B-1-AJY2-B-1, IR15T1305, IR15T1376, TP30656 and IR108158-B-2-AJY1-1 produced 5.51, 5.70, 5.77, 5.54, 5.38, 5.43, 5.57, 4.43, 4.63, 5.19, 4.54 and 6.03 t/ha, respectively (Table 9). None of the tested lines showed better performance than standard checks.

RYT Salinity tolerant Rice-2 (STR-2) in T. Aman 2020

Nine advanced lines IR15T1408, BR 10061-B-1-2-1, IR87870-6-1-1-1-1-B, TP30649, BR10045-15-23-5, IR15T1451, HHZ15-SAL13-Y3, HHZ18-Y3-Y1-Y1, HHZ11-DT7-SAL1-SAL1 and HHZ8-SAL14-SAL3-Y2 along with three standard check BRRI dhan73 (T. ck), BRRI dhan54 (Tol. Ck) and BRRI dhan87 (Sus. Ck) were evaluated at farmers field of Chakoria, Cox'sbazar during Aman 2020. The advanced lines IR15T1408, BR 10061-B-1-2-1, IR87870-6-1-1-1-1-B, TP30649, BR10045-15-23-5, IR15T1451, HHZ15-SAL13-Y3, HHZ18-Y3-Y1-Y1, HHZ11-DT7-SAL1-SAL1 and HHZ8-SAL14-SAL3-Y2 produced 4.64, 5.83, 3.96, 5.67, 4.50, 4.91, 4.60, 4.48, 5.41 and 5.65 t/ha, respectively (Table 10). None of the tested lines showed better performance than standard checks.

Table 9: Results of RYT (STR-1 during T. Aman 2020 at BRRI Sonagazi.

SN	Designation	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)
1	BR9536-2-1-7	5.51	121	118
2	IR103499-B-2-AJY1	5.70	122	113
3	IR15T1349	5.77	124	110
4	R15T1464	5.54	123	107
5	IR108128-B-1-AJY2-B-1	5.38	123	108
6	IR15T1305	5.43	121	115
7	IR15T1376	5.57	120	121
8	TP30656	4.43	122	115
9	IR108158-B-2-AJY1-1	4.63	125	114
10	BRRI dhan73 (T. ck)	5.19	124	121
11	BRRI dhan54 (Tol. Ck)	4.54	134	119
12	BRRI dhan87 (Sus. Ck)	6.03	121	119
$LSD_{0.05}$		0.42	2.26	6.12
CV(%)		4.64	1.08	3.14

Table 10: Results of RYT (STR-2 during T. Aman 2020 at BRRI Sonagazi.

SN	Designation	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)
1	IR15T1408	4.64	119	111
2	BR 10061-B-1-2-1	5.83	122	121
3	IR87870-6-1-1-1-1-B	3.96	118	114
4	TP30649	5.67	124	112
5	BR10045-15-23-5	4.50	125	120
6	IR15T1451	4.91	122	111
7	HHZ15-SAL13-Y3	4.60	119	102
8	HHZ18-Y3-Y1-Y1	4.48	118	106
9	HHZ11-DT7-SAL1-SAL1	5.41	119	114
10	HHZ8-SAL14-SAL3-Y2	5.65	119	127
11	BRRI dhan73 (T.ck)	5.22	124	121
12	BRRI dhan54 (T.ck)	4.83	134	123
13	BRRI dhan87 (Sus.ck)	6.14	126	117
$LSD_{0.05}$		0.35	1.06	4.20
CV(%)		4.16	0.52	2.16

RYT Favorable Boro Rice-Medium Duration (FBR-MD) in Boro 2021

A total of 17 breeding lines of favorable Boro rice along with three check varieties (BRRI dhan81, BRRI dhan84 and BRRI dhan89) were tested at BRRI Sonagazi in Boro 2020-21. Among the tested 17 entries, none of the entries were found better than BRRI dhan89 in respect of yield, however but six lines (IR108000-B-BRGA-BRGA-185-1, SVIN069, IR15A3500, IR106236-B-B-B-B-PRN-B-PRNB-PRN261, IR16A1135 and SVIN109 gave significantly higher grain yield than the check BRRI dhan81. Moreover, the entry SVIN109 showed significantly higher grain yield than BRRI dhan81 and BRRI dhan84 (Table 11).

Table 11. Results of RYT Favorable Boro rice (FBR-MD) in Boro 2021 at BRRI Sonagazi.

SN	Designation	Grain Yield (t/ha)	Growth duration (days)	Plant Height (cm)
1	IR108000-B-BRGA-BRGA-185-1	6.42	143	86
2	SVIN069	6.00	144	98
3	BR8899-14-4-1-2-2-1	5.56	146	84
4	IR15A3500	6.12	143	87
5	IR15A2874	5.70	145	93
6	IR16A2011	5.63	145	92
7	IR106236-B-B-B-PRN-B-PRN50	5.32	145	95
8	IR106236-B-B-B-B-PRN-B-PRNB-PRN261	5.85	148	95
9	TP30610	5.57	146	90
10	SVIN266	5.36	149	85
11	IR16A1135	5.84	147	89
12	BRC297-15-1-1-1	5.71	146	83
13	BRC302-1-4-4-4	5.55	149	88
14	IR15A3768	5.31	153	98
15	IR9982-B-B-B-B-18	5.75	144	87
16	SVIN109	6.84	143	93
17	TP21654	5.73	144	84
18	BRRI dhan81 (Ck.)	5.42	143	96
19	BRRI dhan84 (Ck.)	6.40	140	94
20	BRRI dhan89 (Ck.)	7.37	157	103
$LSD_{0.05}$		0.37	0.74	2.65
CV(%)		7.78	0.62	3.54

RYT Favorable Boro Rice-Yield Maximization (FBR-YM) in Boro 2020-21

Two breeding lines of favorable Boro rice were tested at BRRI Sonagazi experimental field with one check variety (BRRI dhan63) in Boro 2020-21. Among the two entries, no lines were found better than BRRI dhan63 (Table 12).

RYT Zinc Enrich Rice (ZER) in Boro 2020-21

Three breeding lines of zinc enriched rice (ZER) were tested at BRRI Sonagazi with three check varieties (BRRI dhan74, BRRI dhan84 and BRRI dhan89) in Boro 2020-21. Out of three lines, no lines were found better than BRRI dhan74 (7.31 t/ha) and BRRI dhan89 (8.42 t/ha), however, one line BR9674-5-6-2-1-7-22 was produced significantly higher grain yield (7.15 t/ha) than BRRI dhan84 (Table 13).

RYT Favorable Boro Rice (FBR) Barisal-1 in Boro 2020-21

Six breeding lines of Favorable Boro Rice (FBR) Barisal-1 were tested at BRRI Sonagazi experimental field with two check varieties (BRRI dhan58 and BRRI dhan92) in Boro 2020-21. Out of six lines, none of the entries were found better than BRRI dhan92 (8.52 t/ha) but two lines BRBa1-4-9 (8.15 t/ha), BRBa3-1-7 were observed significantly higher grain yield (than BRRI dhan58 (Table 14).

RYT Favorable Boro Rice (FBR) Barisal-2 in Boro 2020-21

Seven breeding lines of Favorable Boro Rice (FBR) Barisal-2 were tested at BRRI Sonagazi

Table 12. Results of RYT FBR-YM in Boro 2021 at BRRI Sonagazi, Feni

SN	Genotype	Grain yield (t/ha)	Growth duration (day)	Plant height (cm)
1	BRH11-9-11-4-5B-HR3	6.76	146	87
2	BRH13-2-4-6-4B	6.56	145	86
3	BRRI dhan63 (ck)	6.74	144	86
$LSD_{0.05}$		NS	NS	NS
CV(%)		2.76	1.08	6.76

Table 13. Results of RYT ZER in Boro 2021 at BRRI Sonagazi, Feni

SN	Genotype	Grain yield (t/ha)	Growth duration (day)	Plant height (cm)
1	BR8419-8-2-1-4-1-3-8	5.84	148	91
2	BR8913-12-4-8-9-2-3-11-22	5.67	145	93
3	BR9674-5-6-2-1-7-22	7.15	148	92
4	BRRI dhan74(ck)	7.31	148	98
5	BRRI dhan84(ck)	6.25	140	97
6	BRRI dhan89(ck)	8.42	156	108
$LSD_{0.05}$		0.36	0.7	1.53
CV(%)		6.51	0.58	1.95

Table 14. Results of RYT FBR Barisal-1 in Boro 2021 at BRRI Sonagazi, Feni

SN	Genotype	Grain yield (t/ha)	GD (day)	PHT (cm)	Pan/hill	Grains/Pan	1000-grain wt (g)	Sterility %
1	BRBa1-4-9	8.15	157	107	13	196	22.4	15
2	BRBa2-13	7.16	159	106	12	171	22.9	20
3	BRBa2-5-3	7.03	156	93	13	137	22.8	19
4	BRBa3-1-7	7.60	155	97	13	139	23.3	21
5	BRBa3-2-4	7.31	154	96	14	140	22.1	20
6	BRBa3-3-1	7.22	159	102	13	139	23.3	19
7	BRRI dhan58(Ck)	7.10	151	89	12	150	23.6	20
8	BRRI dhan92(Ck)	8.52	160	101	14	169	23.7	15
$LSD_{0.05}$		0.31	0.6	2	1	4	0.4	2
CV(%)		5.14	0.5	2.4	9.6	3.36	1.97	14.1

experimental field with two check varieties (BRRI dhan58 and BRRI dhan92) in Boro 2020-21. Out of seven lines, no lines were found better than BRRI dhan92 (8.21 t/ha) but three lines IR04A429 (8.04 t/ha), IR12A329 (7.93 t/ha) and IR13A515 (7.80 t/ha) were produced significantly higher grain yield than BRRI dhan58 (Table 15).

RYT Salinity Resistant Rice-1 (STR-1) in Boro 2021

A total of 14 breeding lines of Salinity Resistant Rice **(STR-1)** were tested at BRRI Sonagazi experimental field with four check varieties (BRRI dhan67, BRRI dhan89, BRRI dhan97 and BINA dhan10) in Boro 2020-21. None of the entries were found better than BRRI dhan89 (8.04 t/ha) but four lines BR9625-B-2-4-6, BR9625-B-2-4-8, IR96184-24-1-1-AJY2 and IR9156-4-1-7-9 were gave significantly higher grain yield than BRRI dhan67 (6.81 t/ha). On the other hand, seven lines BR9625-B-2-4-6, BR9625-B-2-4-8, BR9626-1-2-12, IR96184-24-1-1-AJY2, IR103512-B-AJY2-2, IR9156-4-1-7-9 and BR9625-4-1-2-8 were found significantly higher grain yield than BRRI dhan97. In addition, eight lines BR9625-B-2-4-6, BR9625-B-2-4-8, BR9626-1-2-12, IR96184-24-1-1-AJY2, IR106466-30-CMU3, IR103512-B-AJY2-2, IR9156-4-1-7-9 and BR9625-4-1-2-8 were obtained significantly higher grain yield than Binadhan-10 (Table 16).

Table 15. Results of RYT FBR Barisal-2 in Boro 2021 at BRRI Sonagazi, Feni

SN	Genotype	Grain yield (t/ha)	GD (day)	PHT (cm)	Panicles/hill	Grains/ Panicle	1000-grain wt (g)	Sterility %
1	IR04A429	8.04	156	107	14	143	24.31	17
2	IR12A329	7.93	156	105	15	143	21.13	20
3	IR13A515	7.80	155	107	13	144	23.60	18
4	IR15A2820	7.32	156	94	15	133	22.42	20
5	IR15A2854	6.86	154	97	14	135	23.92	23
6	IR15A3466	7.03	155	99	12	133	24.18	19
7	IR16A2022	6.99	151	94	13	131	23.06	21
8	BRRI dhan58(Ck)	7.27	151	97	13	138	23.82	19
9	BRRI dhan92(Ck)	8.21	160	104	15	163	23.63	16
$LSD_{0.05}$		0.30	1	2	1	2	1	1
CV(%)		5.00	0.6	3	11	2	5.2	9

Table 16. Results of RYT STR-1 in Boro 2020-21 at BRRI Sonagazi

SN	Genotype	Grain yield (t/ha)	Growth duration (day)	Plant height (cm)
1	BR9620-2-4-1-5	6.61	146	93
2	BR9625-B-2-4-6	7.66	149	99
3	BR9625-B-2-4-8	7.12	149	92
4	BR9625-B-2-4-9	6.40	154	101
5	BR9626-1-2-12	6.88	147	103
6	IR96184-24-1-1-AJY2	7.23	145	104
7	IR106466-30-CMU3	6.68	153	98
8	IR103499-B-87-AJY3	6.32	146	100
9	IR103512-B-AJY2-2	6.93	144	96
10	IR9156-4-1-7-9	7.80	153	105
11	BR9621-B-2-3-22	6.28	149	98
12	BR9626-B-2-3-15	6.02	144	101
13	IR103499-B-2-AJY1	6.59	153	99
14	BR9625-4-1-2-8	7.04	147	96
15	BRRI dhan67 (ck)	6.81	147	97
16	BRRI dhan89 (ck)	8.04	153	102
17	BRRI dhan97 (ck)	6.53	150	98
18	Binadhan-10 (ck)	6.33	138	97
$LSD_{0.05}$		0.30	1	2
CV(%)		5.4	0.9	2.2

RYT Salinity Resistant Rice-2 (STR-2) in Boro 2020-21

A total of 14 breeding lines of Salinity Resistant Rice (STR-2) were tested at BRRI Sonagazi experimental field with four check varieties (BRRI dhan67, BRRI dhan89, BRRI dhan97 and BINA dhan10) in Boro 2020-21. Among the tested entries, BR9620-2-1-1, IR103854-8-3-AJY1, BR9625-3-1-1-2, IR100638-6CMU3-CMU1, IR92860-33-CMU1-1CMU2-AJYB, BR9620-4-3-2-2, BR9625-B-14-6, BR9627-1-3-1-10, IR93915-82-CMU2-2-CMU3-AJYB, IR104002-CMU28-CMU1-CMUB and BR9620-2-4-1-5 were produced significantly higher grain yield than BRRI dhan67 and Binadhan-10 (Table 17). The entry IR93915-82-CMU2-2-CMU3-AJYB (8.62 t/ha) performed better than BRRI dhan89 (8.10 t/ha) in respect of yield. Similarly eight lines BR9620-2-1-1, IR103854-8-3-AJY1, BR9625-3-1-1-2, IR100638-6CMU3-CMU1, BR9627-1-3-1-10 a), IR93915-82-CMU2-2-CMU3-AJYB, IR104002-CMU28-CMU1-CMUB and BR9620-2-4-1-5 were attained significantly higher grain yield than BRRI dhan97.

RYT Drought Resistant Rice (DRR-BB) Barisal-2 in Boro 2020-21

Five of Drought Resistant Rice (DRR-BB Barisal-2) breeding lines were tested at the research field of BRRI Sonagazi with two susceptible check varieties (BRRI dhan58 and BRRI dhan89) and one resistant check variety (IRBB60) in Boro 2020-21. Among the entries, none were found better than BRRI dhan89 (8.10 t/ha), however, the entry BR9650-108-2-3 gave significantly higher grain yield than BRRI dhan58 (Table 18). Similarly two lines BR9650-108-2-3 (8.31 t/ha) and BR9943-26-2-3-6 (7.75 t/ha) were found better than IRBB60 (7.04 t/ha).

Table 17. Results of RYT STR-2 in Boro 2020-21 at BRRI Sonagazi

SN	Genotype	Grain yield (t/ha)	GD (day)	Plant ht (cm)
1	BR9620-2-1-1	7.87	149	92
2	IR103854-8-3-AJY1	7.51	144	100
3	BR9625-3-1-1-2	7.43	147	99
4	IR100638-6CMU3-CMU1	7.69	156	101
5	BR9154-2-7-1-2	6.70	146	95
6	IR92860-33-CMU1-1CMU2-AJYB	6.92	151	103
7	BR9620-4-3-2-2	7.35	146	104
8	BR9625-B-14-6	7.12	151	103
9	BR9627-1-3-1-10	7.28	147	99
10	**IR93915-82-CMU2-2-CMU3-AJYB**	**8.62**	153	105
11	IR104002-CMU28-CMU1-CMUB	7.37	147	96
12	**BR9620-2-4-1-5**	**8.15**	145	100
13	BR9621-B-1-2-11	5.93	146	106
14	BR9156-4-1-7-9	6.21	146	91
15	BRRI dhan67 (ck)	6.47	146	99
16	BRRI dhan89 (ck)	8.10	154	103
17	BRRI dhan97 (ck)	6.82	148	101
18	Binadhan-0 (ck)	6.17	136	100
$LSD_{0.05}$		0.37	1	2
CV(%)		6.33	0.9	2.15

Table 18. Results of RYT DRR-BB Barisal-2 in Boro 2020-21 at BRRI Sonagazi

SN	Genotype	Grain yield (t/ha)	GD (day)	Plant ht (cm)
1	BR9943-2-2	6.92	155	97
2	**BR9650-108-2-3**	**8.31**	152	94
3	BR9942-1-2-1-1-B1	7.39	151	99
4	BR9943-35-2-1-2-B2	7.21	152	98
5	BR9943-26-2-3-6	7.75	156	99
6	BRRI dhan58 (Sus Ck)	7.43	150	97
7	BRRI dhan89 (Sus Ck	8.10	153	101
8	IRBB60 (Res Ck)	7.04	154	90
$LSD_{0.05}$		0.40	1	2
CV(%)		6.59	0.81	2.5

RYT Green Super Rice (GSR) in Boro 2020-21

Five breeding lines of Green Super Rice (GSR) were tested at BRRI Sonagazi with two check varieties (BRRI dhan58 and BRRI dhan88) in Boro 2020-21. Among the five lines, FBR336 produced better yield (8.17 t/ha) than Standard checks but three lines FBR189, FBR350 and WANHAN7777 were showed significantly higher grain yield than BRRI dhan88 (Table 19).

Confined Field Trial (CFT) of High Iron and Zinc Rice (HIZR) in in Boro 2020-21

A confined field trial (CFT) was conducted at BRRI Sonagazi in Boro 2020-21 season. Eleven breeding lines were tested with a check BRRI dhan28 with 3 replications following randomized complete block design (RCBD). The unit plot size was 5 m^2. Standard, uniform and prescribed management practices were followed for all the entries. Out of 11 lines, none of the line gave statistically higher yield than the check BRRI dhan28, The lines IR 133904 TR-B-B 3-B-28 (6.71 tha^{-1}) and IR 133904 TR-B-B 1-B-3 (6.80 tha^{-1}) were showed statistically similar grain yield with check variety BRRI dhan28 (6.48 tha^{-1}) but IR 133904 TR-B-B 3-B-28 (108 cm) and IR 133904 TR-B-B 1-B-3 (102 cm) were found shorter plant height than check variety BRRI dhan28 (114 cm) which was statistically significant (Table 20). None of the lines was found better than check in respect of tillers and panicles per hill, panicle length, flag leave length, flag leave width and spiklets fertility. Nevertheless, the lines IR 135161 TR-4-B-6 (22.44 g) and IR 133904 TR-B-B 2-B-25 (22.12 g) were found higher thousand grain weight than the check variety BRRI dhan28 (20.73 g) (Table 20).

Table 19. Results of RYT GSR in Boro 2021 at BRRI Sonagazi, Feni

SN	Genotype	Grain yield (t/ha)	GD (day)	Plant ht (cm)
1	FBR189	7.29	144	100
2	**FBR336**	**8.17**	149	90
3	FBR350	6.54	150	89
4	FBR355	6.83	147	90
5	WANHAN7777	7.67	147	95
6	BRRI dhan58(Ck.)	7.88	152	97
7	BRRI dhan88(Ck.)	6.72	145	93
$LSD_{0.05}$		0.33	1	1
CV(%)		5.58	0.74	1.84

Table 20. Performances of Zinc and Iron enriched rice genotypes under confined field trial (CFT) in Boro 2020-21 at BRRI Sonagazi.

Rice Genotype	GYTPHA	PH (cm)	TNPP	PNPP	PL (cm)	FLL (cm)	FLW (cm)	Fertility (%)	TGW (g)
IR 135161 TR-4-B-35	6.47	101	392	292	22.90	26.47	1.29	83	20.96
IR 135161 TR-4-B-23	5.56	99	392	300	23.91	27.91	1.32	87	21.43
IR 135161 TR-4-B-2	5.12	95	392	292	21.79	25.25	1.24	84	20.56
IR 135161 TR-4-B-6	6.06	107	400	317	21.70	26.78	1.28	80	22.44
IR 135161 TR-4-B-4	5.64	97	383	325	21.61	25.63	1.30	80	21.10
IR 135160 TR-3-B-19	6.02	101	400	300	22.22	25.61	1.31	81	20.52
IR 135160 TR-3-B-14	5.85	106	408	350	23.06	26.31	1.34	84	20.96
IR 133904 TR-B-B 2-B-25	6.14	102	375	300	22.77	28.40	1.37	83	22.12
IR 133904 TR-B-B 3-B-17	6.09	111	400	317	22.43	27.28	1.33	82	20.69
IR 133904 TR-B-B 3-B-28	6.71	108	392	308	22.52	27.34	1.39	83	21.04
IR 133904 TR-B-B 1-B-3	6.80	102	408	292	22.60	25.63	1.33	82	21.53
BRRI dhan28(CK)	6.48	114	392	300	23.29	28.26	1.35	83	20.73
$LSD_{0.05}$	0.37	4.64	38.83	23.41	0.98	1.78	0.09	4.41	0.84
CV(%)	7.55	5.49	12.06	9.32	5.34	8.2	8.33	6.54	4.9

Advanced Lines Adaptive Research Trial (ALART)

A total of nine ALARTs were conducted by BRRI Sonagazi during the reporting period 2020-2021. Recommended management practices were followed in all the trials. Data were collected on yield and yield contributing characters, phenotypic acceptance at vegetative and reproductive stage, insect and disease reaction and lodging records. All the data and detailed reports were submitted to Adaptive Research Division of BRRI, Gazipur for combined reporting.

ALART Aus 2020

Two ALART Favorable Environment (FE) and Non Saline Tidal Environment (NSTE) trials were conducted during T. Aus 2020 at Mirsarai, Chattogram.

ALART FE: Two advanced lines BR9005-53-1-1 & BR9006-40-2-3-1 along with two standard checks BRRI dhan48 & BRRI dhan82 were tested. None of the tested lines performed better than standard checks.

ALART NSTE: Two advanced line BR8784-4-1-2-P2 & BR8781-16-1-3-P2 along with two standard checks BRRI dhan48 & BRRI dhan27. None of the tested line performed better than standard checks.

ALART Aman 2020

Three categories of ALART trials such as, Rainfed Lowland Rice (RLR), Zinc Enriched Rice (ZER) and Insect resistant rice (IRR-BPH) were conducted during T. Aman 2020 at Sonagazi, Feni.

ALART RLR: Two advanced lines BR9571-13-1-9-1-1 & BR9574-9-5-3-1-1 along with two standard checks BRRI dhan49 & BRRI dhan87 were tested. None of the tested line performed better than standard checks.

ALART ZER: The advanced line BR10001-94-2-B along with two standard checks BRRI dhan72 & BRRI dhan87 were tested. None of the tested line performed better than standard checks.

ALART IRR-BPH: Four advanced lines BR9880-40-1-3-34, BR9881-24-2-2-25, BR9880-27-4-1-18 & BR9880-2-2-2-1 along with one standard checks BRRI dhan93 & one resistant check T27A (R. Ck) were tested. None of the tested lines performed better than standard checks.

ALART Boro 2020

Four categories of ALARTs were conducted during Boro 2020-21 such as, Premium quality Rice (PQR), Zinc Enriched Rice (ZER), Favorable Boro Rice (FBR-Bhanga) and Bacterial blight resistant rice (BBRR-Bio) Biotechnology at Fulgazi, Feni.

ALART PQR: Two advanced line BR8526-38-2-1-HR1 & Lata Balam along with three standard checks BRRI dhan50, BRRI dhan63 &

BRRI dhan81 were tested. None of the entries performed better than standard checks.

ALART ZER: Two advanced line BR8912-12-6-1-1-1-1 & IR225837-8-95-2-1 along with two standard checks BRRI dhan74 & BRRI dhan89 were tested. None of the tested line performed better than standard checks.

ALART FBR-Bhanga: Two advanced lines SVIN063-BORO-18-BHANGA & SVIN076-BORO-18-BHANGA along with two standard checks BRRI dhan29 & BRRI dhan89 were tested. None of the tested line performed better than standard checks.

ALART BBRR Biotechnology: Two advanced lines BR(Bio)11447-1-28-14-3 & BR(Bio)11447-3-10-7-1 along with one standard checks BRRI dhan28 were tested. None of the tested line performed better than standard checks.

CROP SOIL AND WATER MANAGEMENT

Effect of Potassium and Sulphur on the performance of modern rice varieties during Boro season

Two field experiments were conducted at BRRI Sonagazi, Feni; and farmer's field at Guimara Upazila of Khagrachari. These experiments were done in RCB design with three replications. BRRI dhan67 and BRRI dhan88 were used as test variety at Khagrachari and Feni, respectively. Six different fertilizer dose were applied in the experiments. Data on yield, yield components, nutrient status of soil, grain and straw were collected. Standard and Uniform management practices except fertilizer doses were followed in all the plots. .

The field trial was conducted at Guimara, Khagrachari district with 6 different fertilizer treatments in Boro 2020-21 season. In this trial BRRI dhan88 was used. The results showed that the treatment Soil test based (STB) + 40% more potassium (K) and Sulphur (S) (6.59 tha^{-1}) gave maximum grain yield which was statistically similar with the treatment STB dose but significantly higher than other treatments. The lowest grain was found in the treatment absolute control (3.39 tha^{-1}) followed by farmer's practice (5.59 tha^{-1}), STB+ 20% more K and S (5.90 tha^{-1}), and BRRI recommended rate (6.10 tha^{-1}) respectively (Table 21). The field trial was conducted at BRRI farm SonagazI with 6 different fertilizer treatments in Boro 2020-21 season. In this trial BRRI dhan88 was used. The results showed that the treatment Soil test based (STB) (6.27 tha^{-1}), and STB + 40% more potassium (K) and Sulphur (S) (6.27 tha^{-1}) gave maximum grain yield which was statistically similar with the treatment STB dose + 20% more K & S (6.19 tha^{-1}) and BRRI recommended rate (6.19 tha^{-1}) but significantly higher than other treatments. The lowest grain was found in the treatment absolute control (3.60 tha^{-1}) followed by farmer's practice (5.57 tha^{-1}), respectively (Table 22).

Table 21. Yield and yield components of BRRI dhan67 under fertilizer trial in Boro 2021 at Guimara, Khagrachari.

Treatments	GYTPHA	SYTPHA	HI	TPM	PPM	TGW (g)	GPP	% Sterility
T_1=Absolute control (No fertilizer)	3.39	3.86	0.47	248	206	21.50	94	21
T_2=STB dose fertilizer	6.33	6.66	0.49	344	307	22.65	67	14
T_3=STB dose fertilizer + 20% more K and S	5.90	6.33	0.48	309	267	21.91	88	20
T_4=STB dose fertilizer + 40% more K and S	6.62	6.88	0.49	301	269	21.93	96	16
T_5=BRRI recommended rate	6.10	6.38	0.49	315	279	21.12	68	26
T_6=Farmers practice	5.59	5.67	0.50	292	255	22.40	82	18
$LSD_{0.05}$	0.29	0.39	0.017	19	17	0.69	7	2
CV(%)	6.44	8.04	4.37	7.54	7.97	3.87	10.28	12.53

Table 22. Yield and yield components of BRRI dhan88 under fertilizer trial in Boro 2021 at Sonagazi, Feni.

Treatments	GYTPHA	SYTPHA	HI	TPM	PPM	TGW (g)	GPP	% Sterility
T_1=Absolute control (No fertilizer)	3.60	4.18	0.46	259	227	20.78	127	17
T_2=STB dose fertilizer	6.27	6.54	0.49	456	404	20.90	100	12
T_3=STB dose fertilizer + 20% more K and S	6.19	6.71	0.48	448	407	19.19	118	14
T_4=STB dose fertilizer + 40% more K and S	6.51	6.78	0.48	449	405	19.70	97	12
T_5=BRRI recommended rate	6.19	6.56	0.49	433	397	19.60	123	12
T_6=Farmers practice	5.50	6.66	0.46	423	404	19.68	108	14
CV								
$LSD_{0.05}$	0.24	0.34	0.012	31	32	0.77	6	0.89
CV(%)	5.22	6.67	2.96	9.11	10.45	4.72	6.94	8.07

Effect of micronutrient Zinc on the performance of modern rice varieties

A field trial was conducted at BRRI Sonagazi farm during Boro 2020-21. Eight treatments having Zinc (Zn) and without Zn were applied in three varieties BRRI dhan74, BRRI dhan84 and BRRI dhan88 to investigate the effect of Zinc on the performance of the rice varieties. The trial was conducted following split-plot design with three replications. All the intercultural activities and data collection were done following standard methods. Among the treatments, irrespective of variety, the treatments T5 (STB + 100% Zn) was gave the highest mean grain yield (6.27 t ha-1) followed by T4 (T1 + 50% Zn) and the lowest (3.00 t ha-1) was in T8 (Control). Among the varieties, BRRI dhan74 (5.56 tha^{-1}) gave significantly higher grain yield followed by BRRI dhan84 (5.36 tha^{-1}) and BRRI dhan88 (5.15 tha^{-1}) respectively (Table 24). BRRI dhan74 (5.72 tha^{-1}) and BRRI dhan84 (5.45 tha^{-1}) gave significantly highest grain yield in T5 Recommended rate + 100% higher Zn) while and BRRI dhan88 produced the highest grain yield in T4 (Recommended rate + 50% Zn). This is one year season results. Both the nutrient management trials need to be repeated for better understanding and conclusive findings.

PEST MANAGEMENT

Survey and monitoring of rice diseases

Surveys was carried out at farmers' fields of Feni, Noakhali, Laxmipur, Cox'sbazar, Chattogram and Khagrachari districts in T. Aman, 2020 and Boro, 2020-21. Sites were selected with the suggestion and collaboration of Department of Agricultural Extension (DAE). Bacterial Leaf Blight (BLB), Bacterial Leaf Streak (BLS), Sheath rot, False smut and Sheath blight infestation were observed in different scores during T. Aman season. BRRI dhan49 were affected by false smut disease in

Table 23. Response of different Zn levels on grain yield of the varieties

Treatments	BRRI dhan74	BRRI dhan84	BRRI dhan88	Treatment mean
T1 = Recommended rate	6.38	5.41	5.66	5.82AB
T2 = T1-50% Zn	4.37	6.12	5.49	5.33B
T3 = T1 –100% Zn	5.85	5.75	5.12	5.57AB
T4 = T1 + 50% higher Zn	6.21	5.89	5.91	6.00AB
T5 = T1 + 100% higher Zn	6.72	6.45	5.65	6.27 A
T6 = T1 but Zn by spraying	6.09	5.03	5.48	5.53 AB
T7 = Soil test based (STB)	5.58	5.39	5.09	5.35 B
T8 = Absolute Control	3.26	2.83	2.90	3.00 C
Variety Mean	5.56A	5.36AB	5.15B	

different locations due to fluctuation of environmental conditions during Aman season. BRRI dhan28 and BRRI dhan29 were affected moderately by blast during Boro season. The farmers were suggested for preventive measures using fungicide.

Monitoring of insect pests and natural enemies by using light trap

Rice insect pests and their natural enemies were monitored throughout the reporting period by Pennsylvanian light traps at the research farm of BRRI Sonagazi from July 2020 to June 2021. The abundance of leaf folder, stem borer, rice bug, green leafhopper, grasshopper, mole cricket, field cricket, and stink bug were found in the light trap during the reporting period. Some beneficial insects like lady bird beetle, spider, damsel fly, carabid beetle, staphynilid beetle were also found.

SOCIO-ECONOMIC AND POLICY

Three trials on Stability analysis of BRRI developed rice varieties were conducted in Aus 2020, Aman 2020 and Boro 2021 season. A total of 99 rice varieties were evaluated in the trials.

Stability analysis of BRRI developed rice varieties in Aus 2020

Eleven rice varieties were evaluated during Aus 2020 at BRRI Sonagazi farm. Among the varieties, BRRI Hybrid dhan48 ranked the top in terms of yield (5.71 t ha^{-1}) followed by BRRI dhan82 (4.69 t ha^{-1}). The variety BR21, BRRI dhan24, BRRI dhan42 were found low yielding varieties having grain yield 3.16, 3.52 and 3.35 t ha^{-1} , respectively (Fig 1).

Stability analysis of BRRI developed rice varieties in T. Aman 2020

Forty two Aman rice varieties were evaluated during Aman 2020 at BRRI Sonagazi farm. Among the rice varieties, BRRI dhan87 produced the highestgrain yield (6.55 t ha^{-1}) followed by BRRI hybrid dhan4 (6.49 t ha^{-1}). The variety BR3, BR5, BRRI dhan37, BRRI dhan40, BRRI dhan57 were found low yielding varieties and the yield ranging from 3.29 to 4.41 t ha^{-1}(Fig 2).

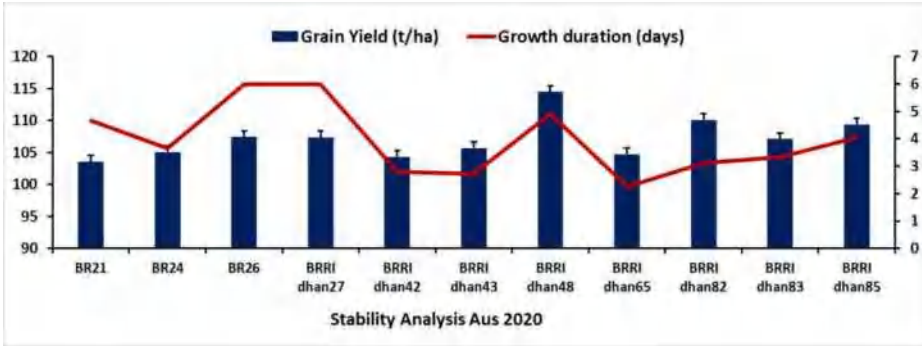

Fig 1. Stability analysis of BRRI developed rice varieties in Aus 2020

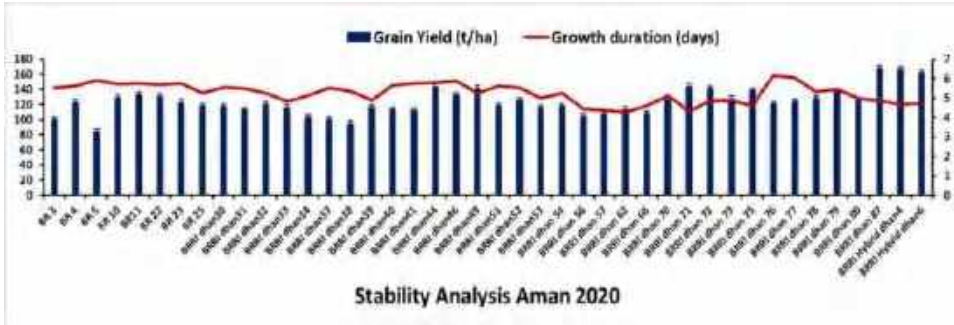

Fig 2. Stability analysis of BRRI developed rice varieties in Aman 2020

Stability analysis of BRRI developed rice varieties in Boro 2021

Forty Six Boro rice varieties were evaluated at BRRI Sonagazi farm during Boro 2020-21. Among the rice varieties, BRRI hybrid dhan3 ranked the top in terms of yield (8.99 t ha^{-1}) followed by BRRI hybrid dhan5 (8.33 t ha^{-1}). The variety BR6, BR7, BRRI dhan26, BRRI dhan27, BRRI dhan36 were found low yielding varieties and the yield ranging from 3.83 to 4.86 t ha^{-1} (Fig 3).

TECHNOLOGY TRANSFER

Head to Head Adaptive trial (HHAT) under TRB Project during Aman, 2020

Three HHAT (Long duration-2 & Short duration-1) were conducted at Sonagazi & Fulgazi Upazila of Feni districts during Aman 2020 (Fig. 4 & 5). For long duration five varieties *viz* BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan94 and BRRI dhan95 were used and for short duration six varieties *viz* BRRI dhan57, BRRI dhan71, BRRI dhan75, BINA dhan16, BINA dhan17 and BINA dhan22 were used in those adaptive trial. In case of long duration BRRI dhan87 yielded highest in both locations (Sonagazi 6.42 t ha^{-1} & Fulgazi 6.53 t ha^{-1}). In case of short duration BRRI dhan71 yielded highest 5.43 t ha^{-1} than other short duration varieties at Sonagazi Feni.

Seed Production and Dissemination Program (SPDP)

SPDP during T. Aus 2020 under GOB

A total of 54 SPDPs were executed in 54 bigha land under nine Upazila of four districts (Feni, Noakhali, Chattogram, and Khagrachari) during Aus 2020 in collaboration of Department of Agricultural Extension (DAE). BRRI dhan48, BRRI dhan82, BRRI dhan83 and BRRI dhan85 were used in the SPDPs. BRRI provided input support like quality seeds, fertilizer and signboard while crop managements were done by the farmers under the supervision of DAE and BRRI. BRRI dhan48 gave the highest mean grain yield (5.07 tha^{-1}) followed by BRRI dhan85 (4.43 tha^{-1}) and the lowest grain yield was found in BRRI dhan83 (3.95 tha^{-1}). Mean growth duration BRRI dhan48, BRRI dhan82, BRRI dhan83 and BRRI dhan85 was 109, 102, 104 and 108 days, respectively. Total production of all the varieties was 34155 kg from which 4303 kg was retained as seeds (12.6% of total production) by the farmers for next season cultivation. About 1409 farmers gained awareness and knowledge about the varieties and 237 farmers (16.8% of total farmers) were motivated to cultivate the varieties.

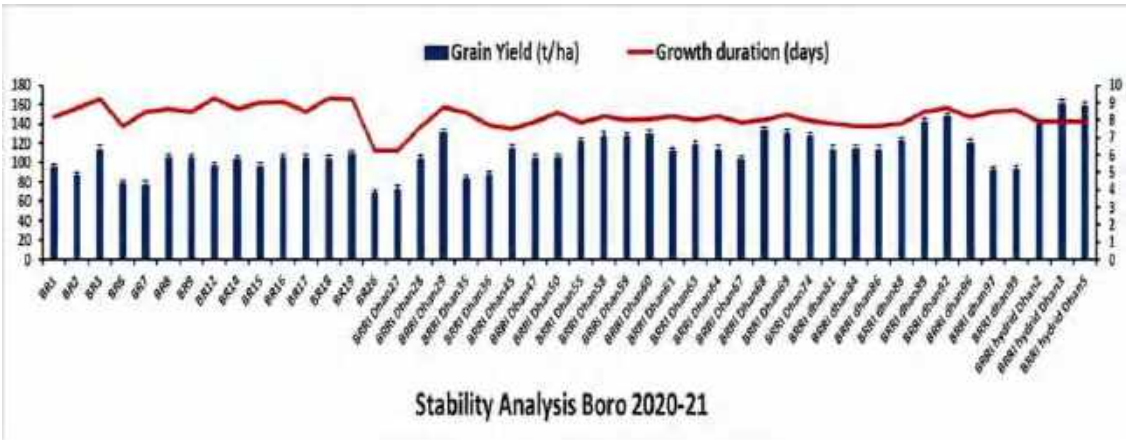

Fig 3. Stability analysis of BRRI developed rice varieties in Boro 2021

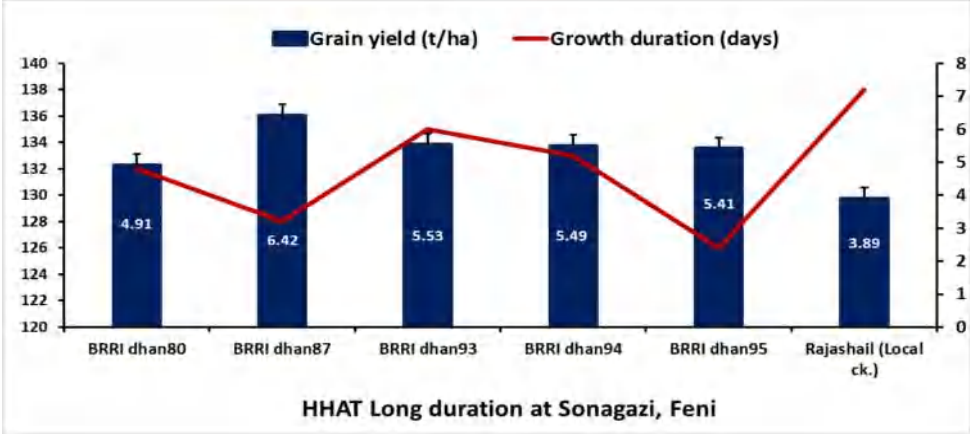

Fig 4. HHAT (LD) of modern rice varieties in Aman 2020

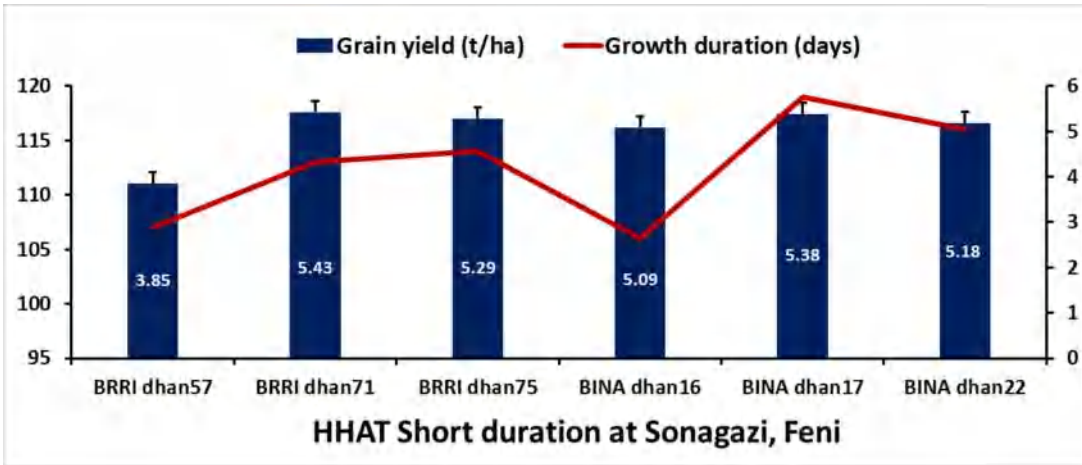

Fig. 5. HHAT (SD) of modern rice varieties in Aman 2020

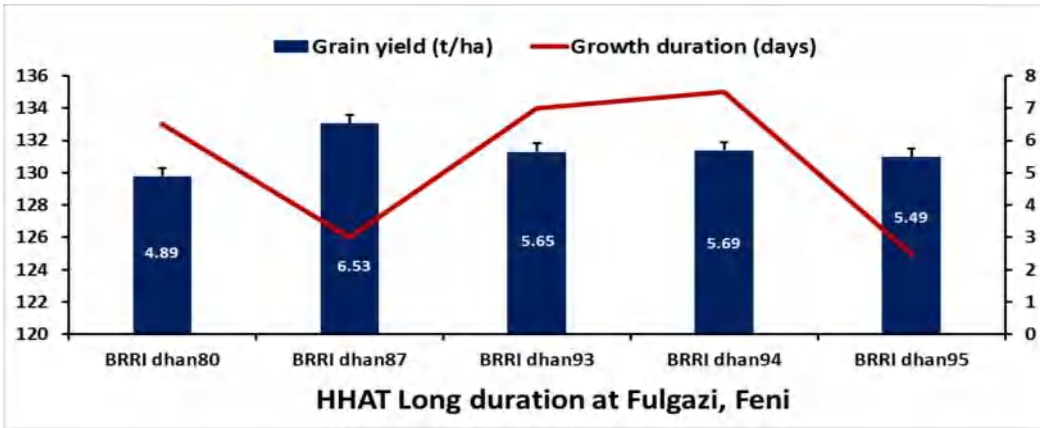

Fig. 6. HHAT of modern rice varieties in Boro 2021

SPDP during T. Aman 2020 under GOB

A total of 35 SPDPs were conducted in 35 bigha land under 11 Upazila of five districts (Feni, Noakhali, Chattogram, Laxmipur and Khagrachari) during Aman 2020 in collaboration with DAE. BRRI dhan71, BRRI dhan76, BRRI dhan78 and BRRI dhan87 were used in the SPDPs. Area of each SPDP was 1 bigha and total area of SPDP was 35 bigha. . BRRI provided input support like quality seeds, fertilizer and signboard while crop managements were done by the farmers under the supervision of DAE and BRRI. BRRI dhan87 gave the highest mean grain yield (6.36 t ha^{-1}) followed by BRRI dhan71 (5.54 tha^{-1}) and the lowest grain yield was found in BRRI dhan78 (4.33 tha^{-1}). Mean growth duration BRRI dhan71, BRRI dhan76, BRRI dhan78 and BRRI dhan87 was 112, 160, 136 and 127 days, respectively. Total production of all the varieties was 25664 kg from which 5546 kg was retained as seeds (21.6% of total production) by the farmers for next season cultivation. About 2118 farmers gained awareness and knowledge about the varieties and 418 farmers (19.7% of total farmers) were motivated to cultivate the varieties.

SPDP during T. Aman 2020 under SPIRA

A total of 3 SPDPs were conducted in eleven Upazila of five districts (Feni, Noakhali, Chattogram, Laxmipur and Khagrachari) during Aman 2020. BRRI dhan71, BRRI dhan78 and BRRI dhan87 were used in the SPDPs. Area of each SPDP was 6 bigha and total area of SPDP was 18 bigha. The program was executed in collaboration of Department of Agricultural Extension (DAE). BRRI provided input support like quality seeds, fertilizer and signboard while crop managements were done by the farmers under the supervision of DAE and BRRI. BRRI dhan87 gave the highest mean grain yield (6.47 tha^{-1}) followed by BRRI dhan71 (5.53 tha^{-1}) and the lowest grain yield was found in BRRI dhan78 (4.64 tha^{-1}). Mean growth duration BRRI dhan71, BRRI dhan78 and BRRI dhan87 was 112, 140 and 127 days, respectively. Total production of all the varieties was 14093 kg from which 3110 kg was retained as seeds (22.1% of total production) by the farmers for next season cultivation. About 632 farmers gained awareness and knowledge about the varieties and 120 farmers (19.0% of total farmers) were motivated to cultivate the varieties.

SPDP during Boro 2020-21 under GOB

A total of 90 SPDPs were conducted in 90 bigha land under 11 Upazila of 4 districts (Feni, Chattogram, Noakhali and Khagrachari) during Boro 2021. Area of each SPDP was 1 bigha. BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan79, BRRI dhan88, BRRI dhan89 and BRRI dhan92 were used in the SPDPs. BRRI dhan92 gave the highest average grain yield (7.80 tha^{-1}) followed by BRRI dhan89 (7.76 tha^{-1}), BRRI dhan58 (6.94 tha^{-1}), BRRI dhan74 (6.82 tha^{-1}), BRRI dhan88 (6.51 tha^{-1}) and BRRI dhan79 (6.15 tha^{-1}). The lowest grain was produced by BRRI dhan67 (5.82 tha^{-1}). Total production of all the varieties was 81240 kg from which 12985 kg was retained as seeds (16.0% of total production) by the farmers for next season cultivation. About 5755 farmers gained awareness and knowledge about the varieties and 1105 farmers (20.1% of total farmers) were motivated to cultivate the varieties.

SPDP during Boro 2020-21 under SPIRA

A total of 3 SPDPs were conducted in 3 (Sonagazi, Fulgazi and Dagonbhuiyan) Upazila of Feni district under SPIRA project. Area of each SPDP was 6 bigha. BRRI dhan67, BRRI dhan74, BRRI dhan89 and BRRI dhan92 were used in the SPDPs. BRRI dhan92 gave the highest average grain yield (8.31 tha^{-1}) followed by BRRI dhan89 (8.11 tha^{-1}) and BRRI dhan74 (7.16 tha^{-1}). The lowest grain was produced by BRRI dhan67 (6.18 tha^{-1}). Total production of all the varieties was 18486 kg from which 3120 kg was retained as seeds (16.9% of total production) by the farmers for next season cultivation. About 705 farmers gained awareness and knowledge about the varieties and 142 farmers (20.1% of total farmers) were motivated to cultivate the varieties.

Farmers Training:

Farmers' trainings were arranged in Noakhali, Feni, Chattogram, Coxes bazar and Khagrachari districts with the collaboration of DAE as an important tool to train up farmers on updated modern rice cultivation technologies and to encourage them to

adopt modern rice varieties with associated technologies. A total number of 35farmers trainings on “Modern Rice production technology” were conducted in five different districts during the reporting period. In farmers training 784 male and 226 female farmers along with 79 male and 11 female DAE field stuffs participated in which they were trained up with rice production technology in different ecosystem especially on tidal submergence, salinity and favorable environment. A total of 1100 farmers and DAE staffs were trained during the reporting period.

Field Day

Field days were arranged for awareness building and create interest among the farmers and concerned extension agents about the modern rice production technologies. These aided in wide publicity and familiarity of the institute, our technologies and BRRI's contribution towards national economy. About 150-200 persons (farmers, researchers, extension service providers, local leaders, public representatives and administrative people etc.) were invited in a field day. A total of 14 field days were arranged during Aus, T. Aman & Boro season. Out of 14 field days 9 were funded by GOB and 6 by SPIRA. Nearly 2250 progressive farmers, local leaders, DAE field stuff, public representatives & NGO workers participated in those occasions.

ENRICHMENT OF SEED STOCK

Truthfully labeled Seed (TLS) Production

Truthfully labeled Seed (TLS) production activities were undertaken at BRRI research field during Aus, 2020, Aman 2020 and Boro 2020-21. This seed production category was an easy way without any supervision of SCA but quality was maintained providing our own facilities and declared truthfully. Seeds were produced as per physical and technical capacity, opportunity and local need of BRRI, Sonagazi. As a result, farmers purchased the seeds of BRRI released varieties. Seeds were also purchased by different organizations. Total production of TLS during Aus, Aman and Boro were 1500 kg, 11500 kg and 5300 kg respectively.

Breeder Seed Production

Nucleus seeds were supplied from Genetic Resources and Seed (GRS) Division for breeder seed production during Aman and Boro seasons. BRRI dhan34, BRRI dhan75 and BRRI dhan82 were cultivated during Aman season where as BRRI dhan28, BRRI dhan29 and BRRI dhan92 during Boro season. A total of Breeder seed during Aman and Boro were 3.57 tons and 10.5 tons respectively. All produced seeds were sent to GRS division of BRRI, Gazipur.

BRRI RS, Kushtia

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SUMMARY

During Aus 2020, BR9006-40-2-3-1 line gave higher yield (5.9 t/ha) than the check varieties BRRI dhan48 & BRRI dhan82 in ALART. Among the tested genotypes showed statistically significant yield difference than two standard checks BRRI dhan48 & BRRI dhan82 in RYT.

Thirteen RYT and three ALART were conducted during the T. Aman 2020. In ALART for the development of insect resistant rice, four advanced breeding lines yielded higher than both of the checks BRRI dhan93 and T27A (4.57 t/ha and 1.04 t/ha, respectively). The tested lines IR98386-B-B-B-B-33 yielded significantly higher than check variety BRRI dhan87 (5.59t/ha) (Table 3) with similar growth duration observed in RLR-3 (RYT). All of the tested genotypes were outyielded over local and standard checks in RYT of both premium quality rice.

One screening, three ALART, ten RYT and one MLT were conducted during the Boro 2020-21. Among the tested lines, six lines gave higher yield than the check variety BRRI dhan92 (7.47 t/ha) with shorter growth duration and highest yield found from the line IR16L1293 (8.08 t/ha) in screening of aerobic rice. All of the tested genotypes were outyielded over susceptible check BRRI dhan58 and resistant check IRBB60 in RYT for disease resistant rice. All of the tested genotypes were outyielded over standard check BRRI dhan81. Among them highest yield was found from the line TP30610 (8.69 t/ha) in RYT for favorable boro rice. In RYT for ZER, BR8419-8-2-1-4-1-3-8-5 line outyielded (7.54 t/ha) than all the checks varieties BRRI dhan74, BRRI dhan84 and BRRI dhan89. The tested genotypes appeared as very promising materials in RYT for Barishal. BRC335-1-3-2-2-1 genotype performed exceptional yield (8.08 t/ha) compared to all genotypes and check varieties in RYT for Cumilla-2. Most of the lines outyielded than check BRRI dhan28 (6.53 t/ha) in MLT for Blast.

T. Aman 2020, the highest yield (6.81 t/ha) was recorded from the plot which was treated with Urea@STB-20% less and MoP@STB+30% additional and in Boro 2020-21, highest yield (8.69 t/ha) was recorded from the dose combination of Urea @STB+20% additional and MoP @STB+30% additional in Boro-Fallow-T. Aman cropping pattern.

In stability analysis trial T. Aman 2020, among 47 varieties the highest yielder was BRRI dhan87 and among 46 tested varieties highest yield was found from BRRI Hybrid dhan2 in Boro 2020-21. At the 1st transplanting time of 30th April, 2020 (T1) and the 2nd transplanting time of 10th May, 2020 (T2) BR26 was found the highest yielder. On the other hand, 3rd transplanting time of 20th May, 2020 (T3) and the last transplanting time of 1st June, 2020 (T4) BRRI dhan48 was found the highest yielder under time of planting experiment. In the reporting year, a total of 23 batches of farmers' training were organized in which 700 farmers participated. At the same time, modern rice varieties and relevant technologies were disseminated through field demonstration and seven field days in which more than 700 farmers participated.

VARIETY DEVELOPMENT

AUS 2020

ALART for favourable environment (FE), T. Aus, 2020

To find out the yield potential and adaptability of the advanced lines at farmers' field in different agro-ecological zones two advanced lines along with two standard checks BRRI dhan48 and BRRI dhan82 were evaluated under this trial conducted in BRRI RS farm, Kushtia. Twenty-four-day-old seedlings were transplanted in 4 m x 5 m unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications.

Both the tested genotype's growth duration was more or less similar to check varieties BRRI dhan48 and BRRI dhan82. Though the highest yield was recorded from BR9006-40-2-3-1 (5.9 t/ha), but it was not statistically significant than that of the checks (Table 1). Plant growth of the genotypes BR9006-40-2-3-1 was attractive with long bold grain. It can be considered for further trial or used as a crossing material.

PI: M E Uddin, **CI**: M R B H Pranto, A Ansari, M M R Dewan

Table 1. Performance of some Advanced genotypes (FE) in ALART, T. Aus 2020.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	**1000** grain wt. (g)	Grain/ panicle	Yield (t/ha)
V1=BR9005-53-1-1	110	83	379	20.03	83	5.20
V2=BR9006-40-2-3-1	111	94	335	23.36	97	5.90
V3= BRRI dhan48 (ck)	114	93	385	23.71	80	5.88
V4= BRRI dhan82 (ck)	110	100	337	22.57	85	5.03
$LSD_{0.05}$	NS	4.56	NS	NS	NS	NS
CV(%)	1.52	2.47	9.11	8.34	9.66	7.35

DS: 17 Apr 2020 DT: 10 May 2020

Regional yield trial, Aus 2020

To find out the yield specific and general adaptability of the advanced breeding lines as compared with standard checks under on-station condition three genotypes and two standard checks BRRI dhan48 and BRRI dhan82 were tested under this experiment conducted in BRRI RS farm, Kushtia. Twenty-one-day-old seedlings were transplanted in 5.4 m x 10 rows unit plots with 20 X 15 cm^2 row spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per BRRI recommendation.

Among the tested genotypes showed statistically significant yield difference than two standard checks with similar growth duration (Table 2).

PI: A Ansari, **CI**: M E Uddin, M R B H Pranto and M M R Dewan

T. Aman 2020

ALART for insect resistant rice (IRR-BPH), T. Aman 2020

To find out the yield potential and adaptability of the advanced rice genotypes at farmers' field in different agro-ecological zones four advanced lines along with one standard check BRRI dhan93 and one resistant check T27A were evaluated under this trial conducted in Joynabad, Kumarkhali, Kushtia. Twenty-two-day-old seedlings were transplanted in 4 m x 5m unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. The selected field location was favorable for BPH. No insecticide was used in the experimental plot.

All the tested genotypes performed excellent considering growth duration (range: 122-127 days) (Table 3). The four advanced breeding lines yielded higher than both the checks BRRI dhan93 and T27A (4.57 t/ha and 1.04 t/ha, respectively). During experiment BR9880-40-1-3-34 and BR9881-24-2-2-25 were found with strong culm where BR9880-27-4-1-18 was partially logged. The first two genotypes (V1 and V2) showed excellent recover ability when it was attacked by stem borer at vegetative stage. No BPH attack found during the experiment. BR9881-24-2-2-25 (5.55 t/ha) can be considered for next step up.

PI: M E Uddin, **CI**: M R B H Pranto, A Ansari, M M R Dewan

Table 2. Performance of some Aus advance lines in RYT, Aus 2020.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	**1000** grain wt. (g)	Grain/ panicle	Yield (t/ha)
BR9829-80-2-2-1	113	98	431	22.02	100	4.5
BR9830-53-3-5-2	115	96	427	23.85	83	5.0
BR9830-74-4-3-1	114	96	405	22.41	87	4.5
BRRI dhan48 (ck)	114	95	400	24.09	85	4.2
BRRI dhan82 (ck)	110	103	405	23.84	69	3.9
CV (%)	63.8	29.9	29.0	24.4	7.8	10.5
LSD (0.05)	2.05	3.76	16.45	1.10	12.61	0.49

DS: 26 Apr 2020 DT: 16 May 2020

Table 3. Performance of some advanced genotypes (IRR) in ALART, T. Aman 2020.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	**1000** grain wt. (g)	Grain/ panicle	Yield (t/ha)
V1=BR9880-40-1-3-34	125	103	279	18.75	128	5.36
V2=BR9881-24-2-2-25	127	103	287	19.47	143	5.55
V3= BR9880-27-4-1-18	122	113	251	24.12	112	5.30
V4= BR9880-2-2-2-1	123	116	275	23.28	107	5.21
V5= BRRI dhan93 (ck)	131	126	269	20.47	151	4.57
V6=T27A (R. ck)	144	153	308	18.43	59	1.04
$LSD_{0.05}$	NS	3.26	45.38	3.53	70.56	1.36
CV(%)	5.96	0.96	5.75	6.00	21.29	10.63

DS: 7 Jul 2020 DT: 28 Jul 2020

ALART, rainfed lowland rice (RLR), T. Aman 2020.

To find out the yield potential and adaptability of the advanced rice genotypes at farmers' field in different agro-ecological zones two advanced lines along with two standard check BRRI dhan49 and BRRI dhan87 were evaluated under this trial conducted in Anjangachi, Mirpur, Kushtia. Twenty-four-day-old seedlings were transplanted in 4 m x 5m unit plots with 25 cm x 15 cm spacing. The trial was designed in RCB with three replications.

None of the tested lines performed better than the checks BRRI dhan49 and BRRI dhan87 (5.73 t/ha and 6.3 t/ha, respectively) (Table 4).

PI: M E Uddin, **CI**: M R B H Pranto, A Ansari, M M R Dewan

ALART, zinc enriched rice (ZER), T. Aman 2020.

To find out the yield potential and adaptability of the advanced rice genotypes at farmers' field in different agro-ecological zones one advanced line along with two standard checks BRRI dhan72 and BRRI dhan87 were evaluated under this trial conducted in Anjangachi, Mirpur, Kushtia. Twenty-four-day-old seedlings were transplanted in 4 m x 5m unit plots with 25 cm x 15 cm spacing. The trial was designed in RCB with three replications.

The advanced genotypes yielded (6.09 t/ha) very similar to BRRI dhan87 (6.06 t/ha) (Table 5). But the highest yielder found BRRI dhan72 (6.4 t/ha). The grain type of tested line was long bold with attractive plant growth. The line may be used for further trial.

PI: M E Uddin, **CI**: M R B H Pranto, A Ansari, M M R Dewan

Table 4. Performance of some advanced genotypes (RLR) in ALART, T. Aman 2020.

Designation	Growth duration (day)	Plant height (cm)	Panicle/ m^2	**1000** grain wt. (g)	Grain/ panicle	Yield (t/ha)
V1=BR9571-13-1-9-1-1	137	122	310	16.7	121	4.47
V2=BR9574-9-5-3-1-1	135	104	290	19.9	158	5.33
V3= BRRI dhan49 (ck)	131	100	318	18.9	157	5.73
V4= BRRI dhan87 (ck)	129	118	246	22.5	143	6.30
$LSD_{0.05}$	NS	6.18	NS	1.26	20.46	0.28
CV(%)	2.48	2.80	13.82	3.20	7.08	2.60

DS: 20 Jul 2020 DT: 12 Aug 2020

Table 5. Performance of some Advanced genotypes (ZER) in ALART, T. Aman 2020.

Designation	Growth duration (day)	Plant height (cm)	Panicle/ m^2	**1000** grain wt. (g)	Grain/ panicle	Yield (t/ha)
V1=BR10001-94-2-B	127	107.3	203	30.37	166	6.09
V2=BRRI dhan72 (ck)	130	110.6	233	28.25	154	6.40
V3= BRRI dhan87 (ck)	128	116.3	255	24.3	118	6.06
$LSD_{0.05}$	NS	5.44	28.80	1.28	34.69	NS
CV(%)	1.03	2.16	5.51	2.04	10.47	3.63

DS: 20 Jul 2020 DT: 12 Aug 2020

Regional yield trial (RYT-1, 2), special yield trial (RLR-1, 2) T. Aman 2020.

To find out specific and general adaptability of some released varieties compared under under on-station and on-farm conditions eight varieties were evaluated under this experiment conducted in Baradi farm (BWDB), Kushtia. Twenty-three-day-old seedlings were transplanted in 5.4 m x 12 rows unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per BRRI recommendation.

The entry SP02, SP06 and SP05 performed better (5.78, 5.69 and 5.60t/ha) in on farm (Baradi farm, Kushtia) (Table 6 a) and SP02, SP06 and SP05 performed better (5.78, 5.69 and 5.60t/ha) in on Station (BRRI farm, Kushtia) (Table 6 b) respectively than all the tested varieties. However, no disease infection was found in any of the lines but yield was loss occurred due to rat damage

PI: A Ansari, **CI**: M E Uddin, M R B H Pranto and M M R Dewan

RYT-3, RLR-3 T. Aman 2020.

To find out specific and general adaptability of the advance breeding lines as compared with standard checks under on-station condition seven genotypes and two standard checks BRRI dhan49 and BRRI dhan87 were evaluated under this experiment conducted in BRRI RS, farm, Kushtia. Twenty-one-day-old seedlings were transplanted in 5.4 m x 12 rows unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per BRRI recommendation.

Table 6 a. Performance of special yield trial (RLR-1) at Baradi farm, Kushtia, T. Aman 2020.

Entry no.	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain weight (g)	Yield (t/ha)
SP01	108	361	97	82	21.90	4.63
SP02	112	301	92	137	20.75	5.78
SP03	112	312	92	100	23.82	5.20
SP04	110	341	110	91	18.39	4.82
SP05	112	260	121	128	21.43	5.60
SP06	112	304	100	102	21.72	5.69
SP07	113	293	107	98	27.63	4.93
SP08	112	282	112	94	26.08	5.49
CV (%)	1.39	10.47	9.92	18.14	13.16	8.28
LSD (0.05)	1.42	29.30	9.38	17.21	2.73	0.40

DS: 2 Jul 2020 DT: 25 Jul 2020

*One replication of SP01 had 20% yield loss due to rat damage

Table 6 b. Performance of special yield trial (RLR-2) at on station, Kushtia. T. Aman 2020.

Entry no.	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain weight (g)	Yield (t/ha)
SP01	106	403	104	134	21.55	4.58
SP02	110	271	98	131	21.86	4.88
SP03	110	257	98	92	21.80	5.47
SP04	107	301	113	135	20.27	5.24
SP05	109	224	129	121	24.17	4.78
SP06	108	264	111	113	24.81	3.91
SP07	109	268	107	136	22.13	5.51
SP08	109	257	119	112	25.19	5.86
CV (%)	1.32	19.09	9.55	12.77	7.78	12.74
LSD (0.05)	1.31	48.88	9.56	14.16	1.61	0.60

DS: 02 Jul 2020 DT: 22 Jul 2020

*One replication of SP03, SP04 and two replications of SP06 had 50-80% yield loss due to rat damage

The tested lines IR98386-B-B-B-B-33 yielded significantly higher than the check variety BRRI dhan87 (5.59t/ha) (Table 7) with similar growth duration. But considering another check BRRI dhan49, IR98386-B-B-B-B-33, IR98381-B-B-B-B-71, IR100122-B-B-B-B-2 and IR98377-B-B-B-B-24 yielded significantly higher (5.59, 5.42 5.33 and 5.27t/ha, respectively).

PI: A Ansari, **CI**: M R B H Pranto, M E Uddin and M M R Dewan

RYT-4, RLR-4 T. Aman 2020

To find out specific and general adaptability of the advanced breeding lines as compared with standard checks under on-station condition seven genotypes and two standard checks BRRI dhan49 and BRRI dhan87 were evaluated under this experiment conducted in BRRI RS farm, Kushtia. Twenty-two-day-old seedlings were transplanted in 5.4 m x 12 rows unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per BRRI recommendation.

All the tested lines yielded lower than the check variety BRRI dhan87 and BRRI dhan49 except BR9840-52-1-2-1 (5.96 t/ha) with shorter growth duration, some of the tested lines yielded higher but not significantly higher than both the checks (Table 8).

PI: A Ansari, **CI**: M R B H Pranto, M E Uddin and M M R Dewan

Table 7. Performance of some RLR lines (RLR-1), T. Aman 2020.

Designation	Plant height (cm)	Growth duration (day)	Panicle/m^2	Grain/ panicle	1000 grain weight (g)	Yield (t/ha)
BR9857-7-6-5-1	106	130	262	153	24.03	4.56
IR100122-B-B-B-B-2	120	129	308	113	24.57	5.33
IR103352-B-B-205	111	128	286	92	25.60	4.39
IR98377-B-B-B-B-24	105	129	326	126	23.17	5.27
IR98381-B-B-B-B-71	109	128	319	97	26.72	5.42
IR98386-B-B-B-B-33	107	131	363	77	26.81	5.59
IR98396-B-B-B-B-40	114	126	312	108	25.69	5.20
BRRI dhan49(ck)	102	137	321	121	21.91	4.78
BRRI dhan87(ck)	116	133	246	138	24.43	5.19
CV (%)	5.27	2.47	11.58	20.75	6.53	8.08
LSD (0.05)	4.98	2.77	30.36	20.31	1.39	0.35

DS: 5 Jul 2020 DT: 25 Jul 2020

Table 8. Performance of some RLR lines (RLR-2), T.Aman 2020.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain weight (g)	Grain/ panicle	Yield (t/ha)
BR9840-52-1-2-1	114	227	118	142	22.83	5.96
BR9840-52-1-4-2	121	277	109	125	22.33	5.02
BR9857-4-2-3-5	121	268	102	138	19.64	4.39
BR8492-9-5-3-2-HR1	127	266	102	152	19.27	4.91
BR8492-9-5-3-2	128	246	107	125	22.35	4.66
Kanihati-4	117	286	106	111	25.01	5.15
Kanihati-9	113	238	106	134	20.80	3.66
BRRI dhan49(ck)	132	293	103	125	20.13	4.81
BRRI dhan87(ck)	121	264	122	144	22.89	5.14
CV (%)	5.27	8.39	6.49	9.38	8.61	12.84
LSD (0.05)	5.51	18.97	6.04	10.72	1.61	0.54

DS: 5 Jul 2020 DT: 26 Jul 2020

RYT-5, zinc enriched rice (ZER-1), T. Aman 2020

To find out of specific and general adaptability of the advanced breeding lines as compared with standard checks under on-station condition two genotypes and three standard checks BRRI dhan49, BRRI dhan72 and BRRI dhan87 were evaluated under this experiment conducted in Baradi farm (BWDB), Kushtia. Twenty-day-old seedlings were transplanted in 5.4 m x 12 rows unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per the BRRI recommendation.

Among the tested two lines, IR101757-146-1 yielded slightly higher (5.85 t/ha) than zinc enriched check variety BRRI dhan72 (5.63 t/ha). However, none of the advanced lines yielded significantly higher than checks (Table 9).

PI: A Ansari, **CI**: M E Uddin, M R B H Pranto and M M R Dewan

RYT-6, zinc enriched rice (ZER-2), T. Aman 2020.

To find out of specific and general adaptability of the advanced breeding lines as compared with standard checks under on-station condition five genotypes and three standard checks BRRI dhan49, BRRI dhan72 and BRRI dhan87 were evaluated under this experiment conducted in Baradi farm (BWDB), Kushtia. Twenty-one-day-old seedlings were transplanted in 5.4 m x 12 rows unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per the BRRI recommendation.

None of the tested lines yielded higher than the check varieties and BRRI dhan87 was the highest yielding variety (Table 10).

PI: A Ansari, **CI**: M E Uddin, M R B H Pranto and M M R Dewan

Table 9. Performance of some zinc enriched rice (ZER-1) lines, T. Aman 2020.

Designation	Growth duration (day)	Panicle/ m2	Plant height (cm)	Grain/ panicle	1000 grain weight (g)	Yield (t/ha)
IR101757-46-1	128	306	121	85	27.08	5.54
IR101757-146-1	108	317	85	93	25.92	5.85
BRRI dhan49 (CK)	131	286	108	151	19.83	5.99
BRRI dhan72 (CK)	128	264	113	133	28.85	5.63
BRRI dhan87(CK)	125	286	130	137	21.87	5.76
CV (%)	7.35	6.99	15.34	24.30	15.16	3.07
LSD (0.05)	10.53	23.51	19.68	33.59	4.32	0.20

DS: 4 Jul 2020 DT: 23 Jul 2020

Table 10. Performance of some Zinc enriched rice (ZER-2) lines, T. Aman 2020.

Designation	Growth duration (day)	Panicle/m2	Plant height (cm)	Grain/ panicle	1000 grain weight (g)	Yield (t/ha)
BR9674-1-1-5-2-P4	113	266	119	185	21.33	4.79
BR9674-1-1-5-4-P4	106	246	112	154	23.17	3.34
BR9674-3-2-4-2-P3	111	260	112	152	22.67	4.92
BR9674-3-3-1-1-P3	112	253	116	185	21.07	4.68
BR7528-2R-HR16-2-24-1-HR1	112	299	126	140	22.21	4.16
BRRI dhan49(ck)	129	266	111	128	19.67	4.70
BRRI dhan72(ck)	128	260	115	121	29.50	5.16
BRRI dhan87(ck)	125	288	122	135	24.17	5.18
CV (%)	7.34	6.66	4.53	16.3	12.95	13.15
LSD (0.05)	7.84	16.23	4.82	22.3	2.71	0.55

DS: 4 Jul 2020 DT: 24 Jul 2020

*One replication of BR9674-1-1-5-4-P4 and BR7528-2R-HR16-2-24-1-HR1 with 50% and 10% yield loss due to rat damage.

RYT-7, premium quality rice (PQR-1) T. Aman 2020.

To find out specific and general adaptability of the advanced breeding lines as compared with standard checks under on-station condition three genotypes, one local and one standard check BINA dhan-13 were evaluated under this experiment conducted in BRRI RS farm, Kushtia. Twenty-day-old seedlings were transplanted in 5.4 m x 10 rows unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per the BRRI recommendation.

All of the tested genotypes were outyielded local and standard checks (Table 11). Also, the mentioned lines completed a performance with shorter growth duration (10 days earlier) than checks.

PI: A Ansari, **CI**: M R B H Pranto, M E Uddin and M M R Dewan

RYT-8, premium quality rice (PQR-2) T. Aman 2020.

To find out specific and general adaptability of the advanced breeding lines as compared with standard checks under on-station condition three genotypes, one local and one standard check BINA dhan13 were evaluated under this experiment conducted in BRRI RS farm, Kushtia. Twenty-one-day-old seedlings were transplanted in 5.4 m x 10 rows unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per the BRRI recommendation.

All of the tested genotypes were outyielded over standard check with similar growth duration (Table 12).

PI: A Ansari, **CI**: M R B H Pranto, M E Uddin and M M R Dewan

RYT-9 for disease resistance rice (BB), **T. Aman 2020.**

To find out of the breeding lines for yield potential and adaptability test under different agro-climatic conditions of Bangladesh six genotypes, two standard checks (BRRI dhan49 and BRRI dhan87) and one resistant check (IRBB60) were evaluated under this trial conducted in BRRI RS farm, Kushtia. Twenty-three-day-old seedlings were transplanted in 5.4 m×12 rows unit plots with 20 cm × 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per the BRRI recommendation.

Table 11. Performance of some premium quality rice (PQR-1) lines, T. Aman 2020.

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
BR8493-3-5-1-P1	132	231	108	168	15.00	3.91
BR9590-45-1-3-2-P2	140	262	132	236	16.52	3.89
BR8515-28-1-1-3-HR3(Cum)	140	264	162	164	13.07	3.86
Kalizira (L. ck.)	141	332	164	134	9.81	2.34
BINA dhan-13(Std ck.)	147	246	158	111	14.75	2.97
CV (%)	3.66	14.51	16.81	28.90	18.50	20.90
LSD (0.05)	5.92	44.71	28.10	54.26	2.95	0.82

DS: 7 Jul 2020 DT: 26 Jul 2020

Table 12. Performance of some premium quality rice (PQR-2) lines, T. Aman 2020.

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
BR9054-6-1-2-3	126	282	108	159	18.17	4.72
BR9844-7-4-1-2-4-2	133	312	108	151	16.72	5.29
BR9581-16-3-5-3	137	266	105	122	16.94	5.22
D. Kataribhog (L. ck)	126	277	26	151	13.45	3.38
BRRI dhan37(Std ck)	Not adequate seedlings due to failure of seed germination					
CV (%)	4.07	6.96	46.74	11.14	12.35	19.06
LSD (0.05)	6.85	25.53	52.36	20.94	2.60	1.14

DS: 7 Jul 2020 DT: 27 Jul 2020

The standard check variety BRRI dhan87 performed better (4.90 t/ha) than the all tested lines (Table 13), all of the tested genotypes had lower yield than standard checks. But all of the tested genotypes outyielded over resistant check with similar growth duration. However, no disease infection found in any of the lines.

PI: A Ansari, **CI**: M E Uddin, M R B H Pranto and M M R Dewan

IRR-1, T. Aman 2020.

To find out promising breeding lines for their specific and general adaptability compared with standard checks in different agro-ecological conditions thirteen genotypes and three standard checks BRRI dhan33, BRRI dhan49 and BRRI dhan93 were evaluated under this experiment conducted in BRRI RS Farm, Kushtia. Twenty-two-day-old seedlings were transplanted in 5.0 m x 10 rows unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per BRRI recommendation. No insecticides were applied in the experimental plot.

None of the tested genotypes performed exceptional considering yield parameter (Table 14). Actually, the result revealed a significant yield difference between the line BR9888-15-3-7-2 (5.25 t/ha) and the check BRRI dhan49 (4.88 t/ha). The growth durations of tested genotypes were more or less same. During the experimental period no attack of BPH and GM was noticed. Slight infestation of stem borer and leaf roller was recorded but it was not significant.

PI: M E Uddin, **CI**: M R B H Pranto, A Ansari, M M R Dewan

RYT, insect resistant rice (IRR-2), T. Aman 2020.

To find out promising breeding lines for their specific and general adaptability compared with standard checks in different agro-ecological conditions 12 genotypes and three standard checks BRRI dhan33, BRRI dhan49 and BRRI dhan93 were evaluated under this experiment conducted in BRRI RS farm, Kushtia. Twenty-two-day-old seedlings were transplanted in 5.0 m x 10 rows unit plots with 20 cm x 15 cm spacing. The trial was designed in RCB with three replications. Fertilizer was applied as per BRRI recommendation. No insecticides were applied in the experimental plot.

None of the tested genotypes appeared as promising in context of yield. The highest yield was recorded from the check variety BRRI dhan93 (5.61 t/ha) (Table 15). The growth durations of most of the tested genotype was more or less same. During the experimental period no attack of BPH and GM was noticed. Slight infestation of stem borer and leaf roller was recorded which was recovered later.

PI: M E Uddin, **CI**: M R B H Pranto, A Ansari, M M R Dewan

TECHNOLOGY TRANSFER

In the reporting year, 23 batches of farmers' training were organized in which 700 farmers participated. Modern rice varieties and relevant

Table 13. Performance of some BB resistant lines in RYT-9, T. Aman 2020.

Designation	Growth duration (day)	Panicle/m^2	Plant height (cm)	Grain/ panicle	1000 grain wt. (g)	Yield (t/ha)
BR10397-3-2-1-1	119	277	116	113	24.70	4.49
BR10397-3-2-1-3	120	277	108	108	20.10	4.20
BR10401-5-1-3-4	120	284	118	117	18.77	4.17
BR10401-5-3-3-2	120	304	114	84	25.41	4.32
BR10392-B-B-12-P2	118	271	108	92	24.05	4.36
BR103923-4-1-1-1	116	310	105	125	28.69	4.37
BRRI dhan49 (Std. ck)	130	268	111	146	19.03	4.62
BRRI dhan87 (Std. ck)	119	315	105	140	23.65	4.90
IRBB60 (R. ck)	119	274	116	111	22.73	4.02
CV (%)	3.23	6.25	4.49	17.53	14.14	5.98
LSD (0.05)	3.33	15.39	4.30	17.36	2.80	0.23

DS: 8 Jul 2020 DT: 29 Jul 2020

Table 14. Performance of insect resistant rice (IRR-1) lines in RYT, T.Aman 2020.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Grains/ panicle	Yield (t/ha)
BR10035-6-2-1	114	98.93	264	18.63	136	4.81
BR10038-2-12-1	124	109.67	291	20.83	120	4.87
BR10039-11-3-2	125	109.87	316	19.90	133	4.81
BR10039-13-3-4	123	104.67	280	20.50	165	4.58
BR10039-15-7-1	122	117.33	236	21.03	125	3.75
BR10039-19-1-2	123	111.80	244	22.50	144	4.88
BR10039-21-7-2	123	113.07	227	24.50	143	4.64
BR10039-5-5-5	122	114.47	245	23.83	115	3.97
BR9888-15-3-7-2	136	130.73	298	24.90	132	5.25
BR9888-23-5-9-2	123	112.73	295	24.07	100	5.00
BR9888-26-9-14-2	123	116.47	258	20.80	147	5.04
BR9888-26-9-14-3	123	115.53	280	21.37	134	5.23
BR9888-4-3-17-2	123	114.93	280	23.20	101	5.05
BRRI dhan33 (Ck)	126	99.87	251	24.73	105	5.01
BRRI dhan49 (Ck)	139	102.60	291	20.00	123	4.88
BRRI dhan93 (Ck)	136	123.00	278	19.53	136	5.64
$HSD_{0.05}$	2.0	7.1	73.6	3.5	35.6	0.8
CV(%)	0.5	2.1	8.9	5.2	9.1	5.5

DS: 5 Jul 2020 DT: 27 Jul 2020

Table 15. Performance of insect resistant rice (IRR-2) lines in RYT, T. Aman 2020.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Grains/ panicle	Yield (t/ha)
BR10039-19-1-3	125	111.73	280	18.21	143	4.00
BR10039-19-4-4	128	115.33	282	23.52	148	4.88
BR10039-19-4-5	126	105.80	293	24.27	113	4.75
BR10039-19-4-7	125	109.03	309	22.90	167	4.17
BR10039-21-4-3	128	112.50	281	24.92	140	4.44
BR9143-25-7-2-2	138	129.47	298	25.33	109	3.94
BR9880-24-2-1-14	125	100.00	295	20.20	132	4.79
BR9881-33-4-2-39	124	104.20	296	19.37	152	4.49
BR9881-33-4-2-39	124	99.87	302	20.21	134	4.71
BR9882-6-2-2-4	124	102.93	280	20.08	126	4.82
BR9888-26-9-14-3	124	113.87	295	21.09	154	5.06
BR9889-11-6-16-3	121	130.53	258	25.37	123	3.81
BRRI dhan33 (ck)	127	102.40	255	24.58	111	4.37
BRRI dhan49 (ck)	135	103.73	287	19.67	146	4.65
BRRI dhan93 (ck)	131	118.53	256	19.76	143	5.61
$HSD_{0.05}$	3.23	6.64	NS	4.74	32.63	0.65
CV(%)	0.85	1.98	8.05	7.12	7.92	4.73

DS: 5 Jul 2020 DT: 27 Jul 2020

technologies were disseminated through field demonstration and seven field days in which more than 700 farmers participated. A total of 150 demonstrations of the BRRI developed HYVs were conducted under GoB, SPIRA and TRB projects in the farmers' field in Kushtia, Chuadanga, Meherpur, Magura and Jhenaidah districts. The varieties include BRRI dhan71, BRRI dhan75, and BRRI dhan87 in T. Aman and BRRI dhan58, BRRI dhan63, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan89 and BRRI hybrid dhan5 in Boro. Also BRRI developed technologies were demonstrated in Development Fair and Agriculture Technology Fair held in Kushtia.

PI: M M R Dewan, **CI**: M R B H Pranto, M E Uddin and A Ansari

BRRI RS, Sirajganj

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SUMMARY

Two RYTs (Barishal#1 and (Barishal#2) for favourable Boro 2020-21 were conducted. In RYT (Barishal#1), all the entries produced similar yield performance with the BRRI dhan92 than BRRI dhan58. However, BRBa 2-1-3 and BRBa 3-2-4 produced 0.61 t/ha yield advantage over the control. In RYT (Barishal#2), IR15A3466, IR04A429 and IR12A329 showed similar yield performance with the standard check BRRI dhan92 but statistically differed with the check variety, BRRI dhan58. In Boro 2020-21 season, RYT#1-Cum; four entries (BRC389-4-2-4-2, BRC427-9-1-3, BRC401-1-1-1-1B and BRC426-4-2-1) out of six showed statistically similar yield performance with BRRI dhan81 than the other two checks. However, the entry, BRC389-4-2-4-2 performed the better yield of 9.83 t/ha over the control. In RYT#2-Cum trial, four entries (BRC394-1-1-1-2, BRC335-1-3-2-2-1, BRC398-4-1-1-1B and BRC428-3-1-2) out of seven showed statistically similar yield performance with the check varieties BRRI dhan50, BRRI dhan58 and BRRI dhan89. However, the genotype BRC394-1-1-1-2 and BRC335-1-3-2-2-1 showed the highest yield performance.

In special yield trial, RLR, T. Aman 2020, SP05 produced the highest yield at Chandia, Dhunat, Bogura followed by Joypurhat sadar and BRRI RS, Sirajganj. Similarly, the 2nd highest yield was obtained from the entry SP02 at BRRI RS, Sirajganj and Joypurhat sadar, and that was for SP03 at Chandia, Dhunot, Bogura. However, rat damage was also recorded higher (%) on SP04 followed by SP01 and SP06 entries during harvest at Joypurhat sadar.

Two peaks of GLH were observed, the first was on September and thesecond one was on October and November. WBPH and YSB populations reached peak on November, and on September to November 2020, respectively. Among natural enemies, STB population was the highest in September and decreased gradually in October and November. GMB population depended on the pest population, and found peak in November with BPH.

Use of an entomopathogenic fungus to control RPH showed that fungal conidia or mycelia have capacity to infect live BPH, WBPH and SBPH at field and glasshouse condition.

Out of 415 rice germplasm / entries, fifteen HR (including BRRI dhan33), 5 R, 4 MR and seven MS donor parents were identified against gallmidge. Plant Breeding Division made 18 crosses with eight breeding lines for gallmidge resistance, and developed 1,229 F1 seeds.

Rice field with BPH nil infest earlier by WBPH and it became peak on 14 October 2020 followed by BPH. The BPH number reached peak on 21 October 2020. However, hoppers (BPH and WBPH) population suddenly decreased on 11 November 2020 due to the maturity of the crop (BPH nil). However, IR101791-10-1-4-3-2-4 provided better yield of 5.51 t ha^{-1} over the standard check IR24 (5.09 t ha^{-1}) with similar growth duration.

Fields for the component treatments/ technologies were selected scattered way to find out the suitable pest management options in RPH prone area at Dobila, Hamkuria and westpara (WP) in Tarash under Sirajganj. Transplanting rice seedlings at 20 x 20 x 40 cm spacing produced a positive contribution to control the pests. BPH and WBPH population in the research management (RM) plot (recommended) and the farmer practiced (FP) plot slightly differed. Additional MoP with recommended fertilizer dose slightly reduced the rice planthoppers (BPH and WBPH) number per hill in research management (RM) plot than the farmer practiced (FP) plot. Alternate wet and drying (AWD) and continuous water level (5-7 cm) in rice field did not have any effect on the RPH population. Single nozzle sprayer was used to spray insecticide on RPH at flowering stage. Before spray, pest population was almost similar in three locations. But after spray, it was nock downed upto 3 DAS at Dobila and westpara, and that was 10 DAS at Hamkuria. However, pest population started to increase seven to 10 DAS at Dobila, 20 DAS at Hamkuria and 10 DAS at westpara, Tarash. It means that location wise pest incidence differ due to microclimatic condition of the crop field though same dose was applied. In addition, the effect of

pesticide on RPH eggs (having inside plant) was unknown. Almost similar results were also observed for double nozzle sprayer.

Fall armyworm moth was monitored using pheromone trap. No adult moth was recorded in BRRI RS, Sirajganj as well as in rice field ecosystem. But 2-3 moths/trap/day was caught in maize growing areas in Tarash, Sirajganj and Sherpur, Bogura districts.

Owl watching towers (OWT) are effective from dusk to dawn. The collected and observed pellets of owl from OWT confirmed the rat predation. Owl regurgitate pellets were analyzed carefully and found that most of the pellets consist of rat bones, skins, exo-skeleton of insects. Among the five different types of owl nest boxes, barn owl preferred triangular shape nest boxes for their nesting and breeding. The rat capturing devices that developed by BRRI component were used in rice field bunds, close to the bund or on burrow systems and found that rat capturing devices were very effective at field condition.

Application of soil test based recommended fertilizer dose (Urea-TSP-MOP-GYP @ 217-75-80-62 kg ha^{-1}) produced significantly higher yield (8.02 tha^{-1}) of BRRI dhan92 than the control treatment, but it was statistically similar with the yield of other treatments (Poultry manure @ 3 t ha^{-1}, vermicompost @ 1 t ha^{-1} and cowdung @ 4 t ha^{-1}) vermi-compost added (@2.5 t ha^{-1}) on the top soil (0-10 cm) was found to be a suitable soil amendment practice for improving rice yield both in T. Aman and Boro season to improve soil physical properties, soil water retention capacity from the root zone depth of the char land soil.

Reduction of 30% fertilizer from the recommended dose in the biochar treated plots produced grain yields similar to full dose of recommended fertilizer. So, application of biochar @ 4 t ha^{-1} with recommended fertilizer resulted in the highest yield in Boro 2020-21 season.

In T. Aman 2020, third transplanting on 17 August produced the highest yield (5.01 t/ha) of BRRI dhan71 followed by 2nd, first and 4th transplanting. However, third transplanting on 15 January 2021 produced the highest yield (7.87 t/ha) of BRRI dhan81 followed by 2nd, 4th and first transplanting. So, transplanting of BRRI dhan81 on January produced the lowest GD, the highest plant height, the highest number of panicle/hill and good yield during Boro 2021 season.

Optimum planting of BR26, BRRI dhan48 and BRRI dhan82 produced significantly higher yield than the late planting. However, seeding on 1st June did not produce any yield due to high temperature at flowering stage. Five different doses of urea fertilizer, forty kg N ha^{-1} produced higher yield with BRRI dhan82 (2.49 t $ha^{-1)}$ followed by BR26 (2.34 t ha^{-1}) and BRRI dhan48 (2.10 t ha^{-1}) compared to the other dose of N-fertilizer. Rainfed condition produced higher yield of BRRI dhan48 (2.62 tha^{-1}) and BR 26 (2.30 t ha^{-1}) compared to theother treatments (irrigation applied when water level went at 15 cm and at 30 cm depth below ground surface) due to frequent rainfall at that period.

In Chandia, Dhunat, BRRI dhan94 performed better with the yield of 7.91 t/ha followed by Shorna-5 (7.90 t/ha) and BRRI dhan80 (7.32 t/ha) during T. Aman 2020. However, in Chondi bhogue, Tarash; BRRI dhan94 performed better yield of 6.97 t/ha followed by BRRI dhan93 (6.74 t/ha). Here, BRRI dhan94 performed better yield than the local check Sharna-5 both in Dhunot, Bogura and Tarash, Sirajganj.

BRRI dhan52 produced 5.78 t/ha yield at Nandina Madhu followed by BRRI dhan79 (5.70 t ha) and again, 5.02 t/ha yield at Rasulpur followed by BRRI dhan51 (4.82 t/ha). So, BRRI dhan52 performed better yield than the local check Parjac with similar GD in both the locations (Nandina Madhu and Rasulpur) of Kamarkhanda under Sirajganj district.

VARIETY DEVELOPMENT

RYT (Barishal#1) for favourable Boro 2020-21

Two RYTs (Barishal#1 and (Barishal#2) for favourable Boro 2020-21 were conducted. Six genotypes for Barishal#1 and seven genotypes for Barishal#2 were grown separately along with the check varieties BRRI dhan58 and BRRI dhan92 during Boro 2020-21 season to evaluate the advanced breeding lines for their adaptability.

RYT (Barishal#1). All the entries produced similar yield performance with the BRRI dhan92 than BRRI dhan58. BRBa 2-1-3 and BRBa 3-2-4 produced the highest yield of 7.76 t/ha. However, BRBa 2-1-3 had the highest plant height (cm), grains/panicle (no.) and sterility (%) among the tested genotypes (Table 1).

RYT (Barishal#2). Seven genotypes from favourable Boro rice were tested with two standard check BRRI dhan58 and BRRI dhan92. Among them, IR15A3466, IR04A429 and IR12A329 showed similar yield performance with the standard check BRRI dhan92 but these genotypes statistically differed with the check variety, BRRI dhan58. However, the genotype, IR15A2820 produced the lowest yield (5.99 t/ha) with the highest per cent of sterility (29.92%) among the test entries. However, the plant height (cm) and number of panicle/hill were almost similar with the standard check, BRRI dhan58 (Table 2).

RYT#1-Cum, Boro 2020-21

Six genotypes along with three standard check varieties such as BRRI dhan81, BRRI dhan84 and BRRI dhan88 were evaluated for specific and general adaptability of advanced breeding lines. Among the six test entries, four entries (BRC389-4-2-4-2, BRC427-9-1-3, BRC401-1-1-1-1B and BRC426-4-2-1) showed statisticaly similar yield performance with BRRI dhan81 than the other two checks. However, the entry, BRC389-4-2-4-2 performed better yield of 9.83 t/ha than the others (Table 3). Standard checks were harvested seven days earlier than the test entries.

Table 1. Effect of different genotype on plant height (cm), panicle/hill, grains/panicle, Sterility and yield of rice during Boro 2020-21.

Genotype	Plant height (cm)	Panicle/hill (No.)	Grains/Panicle (No.)	Sterility (%)	Yield (t/ha)
BRBa 1-4-9	102.46±1.54	8.67±0.71	120.33±6.64	20.66±1.82	6.77±0.05
BRBa 2-1-3	105.87±1.13	8.80±0.12	180.00±4.58	24.23±0.97	7.76±0.29
BRBa 2-5-3	91.71±0.80	9.33±0.18	145.33±7.84	16.82±1.62	7.38±0.11
BRBa 3-1-7	88.11±0.28	8.47±0.24	158.33±3.53	15.91±1.68	7.16±0.18
BRBa 3-2-4	94.20±0.46	8.73±0.29	145.33±5.78	20.24±2.16	7.76±0.28
BRBa 3-3-1	93.89±0.38	8.80±0.20	147.67±5.93	18.23±3.13	7.15±0.27
BRRI dhan58 (ck)	94.35±1.24	9.67±0.18	161.00±4.51	16.65±0.95	6.66±0.07
BRRI dhan92 (ck)	106.19±1.57	9.67±0.24	139.67±7.13	16.68±1.53	7.49±0.33
$Lsd_{0.05}$	3.01	0.94	15.22	5.57	0.70
CV (%)	1.77	5.94	5.81	17.04	5.46

Table 2. Effect of different genotypes on plant height, panicle/hill, grains/panicle, sterility and yield (t/ha) of rice during Boro 2020-21.

Genotype	Plant height (cm)	Panicle/hill (no.)	Grains/Panicle (no.)	Sterility (%)	Yield (t/ha)
IR04A429	95.59±1.50	11.27±1.12	155.00±4.04	10.23±0.93	6.99±0.18
IR12A329	96.55±1.27	10.27±0.71	127.33±10.27	14.99±1.08	6.96±0.32
IR13A515	96.91±0.74	9.60±0.50	150.33±8.35	15.73±1.67	6.60±0.23
IR15A2820	91.71±2.16	11.27±0.71	157.33±22.05	29.52±5.84	5.99±0.11
IR15A2854	93.26±1.74	9.20±0.50	143.67±8.01	14.85±3.20	6.88±0.07
IR15A3466	96.73±1.52	11.20±0.12	131.33±17.89	16.16±2.09	7.30±0.02
IR16A2022	95.49±1.35	9.93±0.52	163.67±10.17	25.16±4.85	6.66±0.37
BRRI dhan58 (ck)	98.46±2.54	10.87±0.82	172.33±17.15	24.40±3.23	6.71±0.04
BRRI dhan92 (ck)	103.07±1.39	9.67±0.07	163.67±14.10	22.37±2.68	6.77±0.14
$Lsd_{0.05}$	5.05	1.95	41.68	9.95	0.55
CV (%)	3.03	10.86	15.88	29.84	4.69

Table 3. Effect of different genotype on growth duration, plant height and yield of rice during Boro 2020-21 at BRRI RS, Sirajganj.

Genotype	GD (day)	Plant height (cm)	Yield (t/ha)
BRC426-4-2-1	153	112.81±2.72	8.73±0.24
BRC366-2-2-4-2-1	153	107.20±1.15	7.18±0.58
BRC427-9-1-3	153	104.40±1.82	9.15±0.89
BRC389-4-2-4-2	153	113.83±1.10	9.83±0.63
BRC401-1-1-1-1B	153	105.43±1.56	8.92±0.46
BRC366-2-2-4-2-3	153	104.91±4.11	8.15±0.55
BRRI dhan81 (ck.)	147	100.26±4.34	9.26±0.62
BRRI dhan84 (ck.)	147	109.95±1.71	8.14±0.11
BRRI dhan88 (ck.)	147	95.43±4.75	7.39±0.18
$Lsd_{0.05}$	-	9.29	1.64
CV (%)	-	5.06	11.09

RYT#2-Cum, Boro 2020-21. Seven genotypes along with the check varieties BRRI dhan50, BRRI dhan58 and BRRI dhan89 were grown during Boro 2020-21 to evaluate specific and general adaptability of the advanced breeding lines. Four (BRC394-1-1-1-2, BRC335-1-3-2-2-1, BRC398-4-1-1-1B and BRC428-3-1-2) out of seven entries showed statistically similar yield performance with the standard checks varieties; BRRI dhan50, BRRI dhan58 and BRRI dhan89 (Table 4). However, the genotype BRC394-1-1-1-2 showed the highest yield performance followed by BRC335-1-3-2-2-1 and BRRI dhan58 with similar GD (152 days).

Special yield trial, RLR, T. Aman 2020-21.
Three experiments were conducted for specific and general adaptability during T. Aman 2020 season. Eight genotypes were compared under on-station (at BRRI RS, Sirajganj) and on-farm (at Chandia, Dhunat, Bogura and Joypurhat sadar) conditions. Among the test entries, SP05 produced the highest yield at Chandia, Dhunat, Bogura followed by Joypurhat sadar and BRRI RS, Sirajganj. Similarly, the 2nd highest yield was obtained from the entry SP02 at BRRI RS, Sirajganj and Joypurhat sadar, and that was for SP03 at Chandia, Dhunot, Bogura. On average, the highest growth duration (GD) was recorded at Dhunot, Bogura followed by BRRI RS, Sirajganj and Joypurhat sadar (Table 5) due to the fertility of the land.

Tested entries were also affected by diseases (sheath blight and leaf blight) and pest (rat damage). The highest incidence of pest and diseases was observed at Joypurhat sadar followed by BRRI RS, Sirajganj. Entries SP01, SP03, SP04 and SP06-08 were severely infected by sheath and leaf blight diseases. In addition, rat damage was also recorded higher (%) on SP04 followed by SP01 and SP06 entries during harvest at Joypurhat sadar and slightly lower at BRRI RS, Sirajganj (Table 6). No infestation of rat and infection of diseases was observed at Chandia, Dhunot, Bogura except the entry SP08 with sheath blight disease.

Table 4. Performance of different rice genotypes on growth duration, plant height (cm) and yield during Boro 2020-21 at BRRI RS, Sirajganj.

Genotype	GD (day)	Plant height (cm)	Yield (t/ha)
BRC398-4-1-1-1B	152	103.83±1.48	6.98±0.43
BRC428-2-2-1	161	86.44±0.62	6.39±0.23
BRC428-3-1-1	159	80.65±0.97	6.57±0.63
BRC428-3-1-2	161	92.91±0.44	6.65±0.52
BRC394-1-1-1-2	152	116.37±1.52	7.93±0.30
BRC394-1-1-1-5A	161	92.84±0.28	6.47±0.67
BRC335-1-3-2-2-1	152	105.36±1.00	7.13±0.56
BRRI dhan50 (ck.)	155	78.54±0.81	6.94±0.27
BRRI dhan58 (ck.)	152	93.91±1.26	7.69±0.62
BRRI dhan89 (ck.)	159	105.64±0.23	7.98±0.41
$Lsd_{0.05}$	-	3.00	1.38
CV (%)	-	1.83	11.37

Table 5. Performance of different entries under special yield trial, RLR during T. Aman 2020.

Entry	BRRI RS, Sirajganj			Chandia, Dhunat, Bogura			Bonkhur, sadar, Joypurhat		
	GD (day)	Panicle/ hill (no.)	Yield* (tha^{-1})	GD (day)	Panicle/hill (no.)	Yield (t ha^{-1})	GD (day)	Panicle/hill (no.)	Yield*(t ha^{-1})
SP01	115	10.40	2.88	116	9.50	3.89	111	6.65	1.08
SP02	126	9.33	4.14	128	8.63	4.13	119	8.77	3.19
SP03	124	9.87	3.91	126	10.32	4.36	119	10.31	2.68
SP04	115	9.87	2.96	116	9.16	3.92	111	7.71	0.81
SP05	124	10.60	4.22	126	9.86	4.61	119	10.17	4.56
SP06	115	8.47	2.51	116	9.07	3.80	111	7.57	1.44
SP07	115	9.47	2.63	116	8.25	3.71	111	8.47	1.12
SP08	115	9.60	3.37	116	8.80	3.97	111	8.81	1.62

*Disease infestation and rat damage

Table 6. Abundance of pest and diseases in special yield trial, RLR during T. Aman 2020.

Entry	BRRI RS, Sirajganj			Chandia, Dhunat, Bogura			Bonkhur, sadar, Joypurhat		
	SB (%)	LB (%)	RD (%)	SB (%)	LB (%)	RD (%)	SB (%)	LB (%)	RD (%)
SP01	43.33	13.33	21.67	0	0	0	55.00	50.00	85.00
SP02	23.33	8.33	0	0	0	0	8.33	6.67	13.33
SP03	28.33	15.00	0	0	0	0	48.33	38.33	18.33
SP04	26.67	6.67	0	0	0	0	25.00	25.00	90.00
SP05	30.00	6.67	0	0	0	0	0.00	0.00	0.00
SP06	18.33	5.00	0	0	0	0	28.33	25.00	81.67
SP07	26.67	8.33	15.00	0	0	0	46.67	41.67	66.67
SP08	28.33	6.67	0	8.33	0	0	55.00	56.67	43.33

Here, SB= Sheath blight, LB= Leaf blight and RD= Rat damage, RLR=Rice leaf roller

Pest Management

Light trap collection of rice insect pests and natural enemies

Rice insect pests and their natural enemies were monitored from July 2020 to March 2021 using Pennsylvanian light trap from dusk to dawn at BRRI RS, Sirajganj. The abundance of GLH, YSB and WBPH was high during the period (Fig. 2). Two peaks of GLH were observed the first was on September and the second was on October and November. WBPH started to be observed on September and the population reached peak on November. YSB was recorded in light trap from July and got peak in September to November 2020 (Fig. 1).

Natural enemies like GMB, damsel fly, LBB, STB and CB were also observed in light trap catches (Fig. 2). STB and LBB was observed throughout the reporting period. However, STB population was the highest in September and decreased gradually in October and November. GMB population density depended with the pest, and found peak in November.

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Use of an entomopathogenic fungus to control BPH. A quick growing entomopathogenic fungus, *Metarhizium anisopliae*, was cultured on **artificial culture media** (plain boiled rice) at glasshouse temperature (30^0C) (Figs. 3 and 4). Boiled rice was used for its multiplication.

Fungal conidia or mycelia have capacity to infect live BPH, WBPH and SBPH at field and glasshouse condition. However, its effect on environment need to be studied.

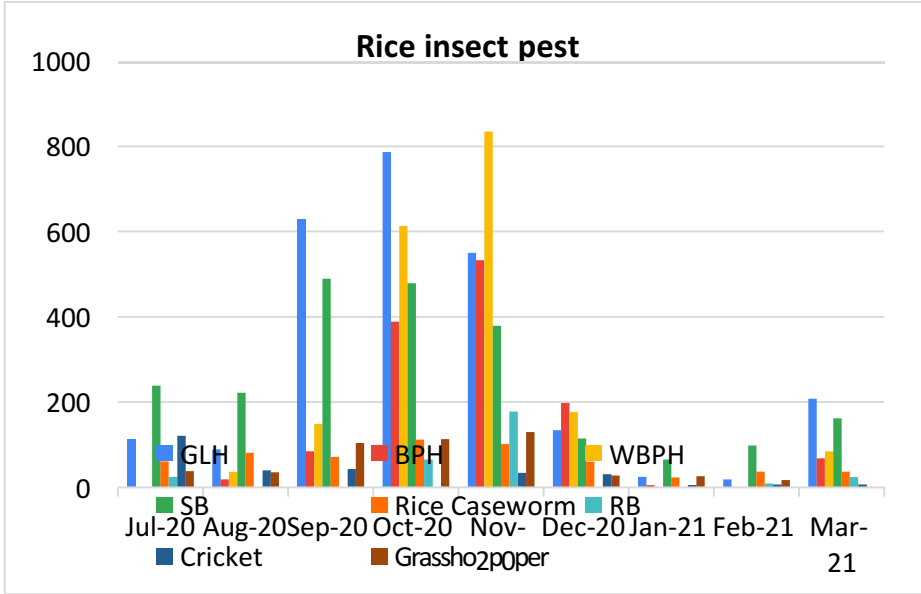

Fig 1. Total population of insect pests at BRRI RS, Sirajganj

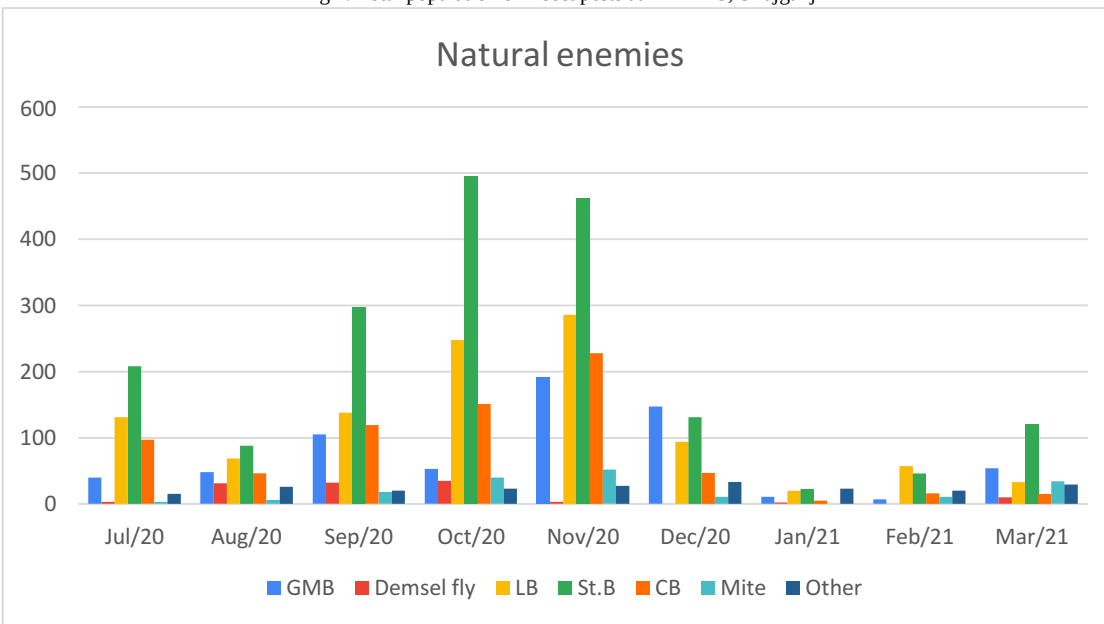

Fig. 2. Survey of natural enemies of rice pest in Bogura region during T. Aman 2020.

Fig. 3. Fungal development on PDA, boiled rice, hyphae with conidia.

Fig. 4. Conidia sprayed on BPH infested pot and dead BPH on Water.

Screening of rice germplasm, advanced line and F_2 materials against rice gallmidge (KGF project). Rice germplasm (released varieties, advanced lines, land races etc) collected from national and international sources were grown on Yoshida culture solution to identify resistant source (s) in rice for developing high yielding gallmidge tolerant resistant line (s) through breeding programme. For this, sprouted seeds of test entries were sown separately in 11cm long line in a row keeping 6.5 cm distance from line to line. Each line was represented a test entry. Nine test entries including one susceptible (BRRI dhan49) and one resistant (BRRI dhan33) check were assigned. Complete randomized design was followed with three replications. About one hundred mated gallmidge females were released in confined net at 13-15-day-old seedlings and allowed them to lay eggs on the test materials. During infestation, temperature (27-32ºC) and relative humidity (85-90%) were maintained. Data on infested (Onion shoots or silver shoots) and un-infested tillers on the test entries were recorded. Percent data were analyzed according to SES, (IRRI, 2007).

A total of 415 rice germplasm/ varieties/ lines were screened. Ten different groups of germplasm (e.g., BR-Cross materials/lines, E-TP germplasm, GRS accessions, IR materials, ALART, OYT, PYT1, PYT2, RYT, and RYT1 materials) were screened against rice GM (Table 7). Out of 21 E-TP germplasm, TP30693 was found moderately susceptible (MS) against GM. Among the 82 BR-Cross materials; two lines (BR8521-30-3-1 and BRH11-4-3-2-7 (CN-7) were recorded as highly resistant (HR) to resistant (R) respectively, another two entries (BR8335-10-6-3-10 and Habudhan) were moderately resistant (MR) and only three (BR9392-3-5-8-2, BR9892-6-2-2B and BR9892-4-5-7-2) were MS to GM (Table 7). Among the 164 IR materials, seven entries showed HR, one showed R, one MS and the rest of the entries were susceptible (S) to highly susceptible (HS) against GM. Four ALART materials showed HS reaction to GM. In addition, PYT1, PYT2 and RYT materials were also tested against GM. Out of 15 entries of PYT1, three were R and one was MS. Besides, out of 17 entries of PYT2, two showed HR and one entry was recorded as R (Table 7). Among the five RYT1 materials, only one showed MR and one recorded as MS. However, four RYT-biotech materials were recorded as HS to GM. Among the 41 GRS accessions and 56 OYT breeding materials, all entries showed S to HS reaction against GM. In GM screening programme, BRRI dhan49 was used as susceptible check (S.ck> 60% OS), and BRRI dhan33 as resistant check (R.ck, 0% OS), which is the only resistant source used as resistant check in GM screening programme (Table 7).

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In addition, the un-infested tillers were selected as breeding materials for further study. The un-infested tillers / resistant genotype (s) were rescued/ removed from the infested tray and were grown in the field under normal condition to complete its or their life cycle. These genotype (s) were used in breeding programme for hybridization between two parents, and rapid generation advance (RGA) studies to develop high yielding GM resistant line (s) / varieties.

Hybridization and rapid generation advance (RGA). Plant Breeding division made 18 crosses with eight breeding lines for gallmidge resistance, and developed 1,229 F1 seeds (Table 8). The materials of these crosses have been grown to confirm as true F1s and generations were advanced through rapid generation advance method (Fig. 5).

Table 7. Summary screening result of different germplasms, GRS accessions, OYT, PYT, RYT and ALART, different IR germplasms against rice gall midge during the reporting period (March to September 2020).

Group	Total entry	Rice germplasm / variety	Germplasm code	Tiller number	% Onion shoot	Reaction
E-TP	21	TP 30693	E-36	21	19.11	MS
BR crosses	82	BR9892-6-2-2B	16	21	12.23	MS
		BR9892-4-5-7-2	17	17	15.47	MS
		BR9392-3-5-8-2	18	16	11.57	MS
		BRH11-4-3-2-7(CN-7)	19	14	4.76	R
		BR8335-10-6-3-10	22	21	5.74	MR
		BR8521-30-3-1	45	14	0.01	HR
		Habudhan	54	24	6.72	MR
PYT1	15	BR10037-11-4-3	PYT1-2	17	11.89	MS
		BR10039-5-5-5	PYT1-8	21	3.17	R
		BR10039-9-6-4	PYT1-9	22	4.35	R
		BR10039-14-3-2	PYT1-10	29	4.17	R
PYT2	17	BR10039-19-4-5	PYT2-1	23	0.01	HR
		BR10039-19-4-7	PYT2-2	30	6.20	MR
		BR10040-11-3-5	PYT2-5	13	0.81	HR
IR	164	IR126952-41-201-270-1-1	IR-40	19	0.01	HR
		IR126953-624-22-18-8-1-B	IR-98	33	0.01	HR
		IR126952-41-148-38-9-44-B	IR-107	23	0.01	HR
		IR126952-41-148-38-9-60-B	IR-111	34	18.38	MS
		IR126952-41-211-128-5-1-B	IR-124	23	0.01	HR
		IR126952-443-12-47-4-8-B	IR-127	40	0.01	HR
		IR126952-41-125-24-4-2-B	IR-128	29	2.22	R
		IR126952-41-201-16-5-9-B	IR-132	28	0.01	HR
		IR126952-41-148-38-1-52-B	IR-145	25	0.01	HR
ALART	4	BR(Bio)9786-BC2--				HS
RYT	13	BR9571-28-2-1-2-1	RYT-1	22	4.17	MR
		BR9573-28-1-1-1-1	RYT-1	20	14.70	MS
OYT	56	Different BR Crosses	-		-	HS
GRS acc	41	Acc. 479 to 531 (selected one)				HS
R	1	BRRI dhan33(R.ck)	-	42	0.01	HR
		BRRI dhan33(R.ck)	-	40	0.01	HR
		BRRI dhan33	-	38	0.01	HR
S	1	BRRI dhan49 (S.ck)	-	70	91.00	S
		BRRI dhan49 (S.ck)	-	58	88.80	S
		BRRI dhan49	-	59	89.74	S

*Onion shoot (OS) percentage data were transformed by Arc Sine, HR- Highly resistant (0% Onion shoot, OS), R-resistant (<5% OS), MR- Moderately resistant (6-10% OS), MS- Moderately susceptible (11-20 % OS, S-Susceptible (21-50% OS), HS- Highly susceptible (> 50% OS) (According to SES, (IRRI 2007).

Table 8. The following crosses made using newly identified donors for gallmidge resistance and have been grown to confirm during T. Aman 2020 at BRRI, Gazipur.

Cross combination	No. of F1 seeds	SN	Cross combination	No. of F1 seeds
BRRI dhan75/ ARC 5987	65	10	BR9142-32-2-2-3/ARC 5984	60
BRRI dhan75/ ARC 11704	110	11	BR9143-55-3-2-1/ARC 5987	120
BR8693-17-6-2-2/ ARC 11704	80	12	BR9141-25-2-2-3/ARC 5987	80
BR9881-24-2-2-25/ARC 11704	45	13	BRRI dhan79/ARC 5987	46
BR9881-24-2-2-25/ARC 5984	60	14	BRRI dhan75/ARC 5987	50
BR9880-36-4-2-33/ARC 5987	80	15	BRRI dhan72/ARC 5984	48
BR9880-36-4-2-33/ARC 11704	35	16	BRRI dhan87/ARC 5984	100
BR9880-24-2-1-14/ARC 5987	55	17	BRRI dhan87/ARC 5987	65
BR9880-24-2-1-14/ARC 5984	85	18	BR9881-24-2-2-25/ARC 5987	45
			Total:	1229 seeds

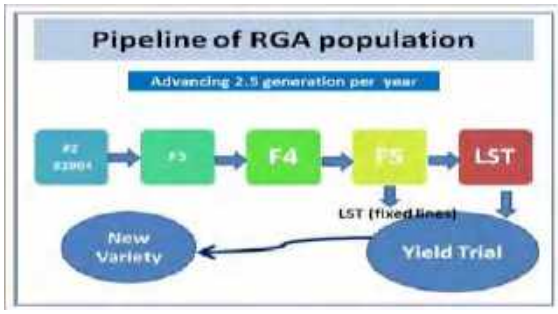

Fig. 5. Method for advancing generation through FRGA/RGA.

The following crosses were confirmed and obtained F2 populations. These 10 crosses registered into BRRI cross list. These 26200 F2 progenies will be grown in field RGA to advance generation quickly (Table 9).

Table 9. List of confirmed crosses for initiating field RGA.

Cross Combination	No. of F2 progenies
BR9669-21-2-1-19 / ARC 5984	2,000
BR9891-17-2-2-68 / ARC 11704	2,700
BR9891-17-2-2-68 / ARC 5984	3,000
BR9891-33-2-2-69 /ARC 5984	2,500
BR9891-20-2-2-24/ARC 11704	3,200
BR9669-24-2-2-2-26/ARC 11704	2,600
BR8339-6-2-5-2/ARC 5984	2,700
BR9669-24-2-2-26/ARC 5984	2,500
BR9669-21-2-1-19/ARC 10834	3,000
BR8339-7-4-3-7/ ARC 11704	2,000
Total	26,200

Evaluation of BPH NILs under selected hotspots of Bangladesh

Fifteen genotypes including one resistant check T27A and two susceptible checks IR24 and BR3 (local susceptible) were evaluated at BRRI RS, Sirajganj during T. Aman 2020. No insecticide was applied. Insect infestation data were collected from 5 hills. Data on plant height (cm), hill (no.) $5m^{-2}$, grain yield (t ha^{-1}), BPH $hill^{-1}$ (no.), WBPH $hill^{-1}$ (no.), SBPH $hill^{-1}$ (no.), Spider $hill^{-1}$ (no.) and GMB $hill^{-1}$ (no.) was recorded. Insect was counted every seven days interval from maximum tillering stage to maturity. At maturity, the crop was harvested from $5m^2$ areas of each plot and the grain yield was adjusted to 14% moisture content.

All the entries were allowed to natural infestation of BPH. Infestation started when most of the entries at PI stage. Figs. 6-13 show the weekly fluctuation of rice planthoppers and their natural enemies on BPH Nils. The rice field with BPH Nils infest earlier by WBPH and it became peak on 14 October 2020 followed by BPH. The BPH number got peak on 21 October 2020 (Figs. 10 - 12). However, hoppers (BPH and WBPH) population suddenly decreased on 11 November 2020 due to the maturity of the crop (BPH Nils) (Fig. 13). The number of Spider and GMB was low than the number of BPH and WBPH per hill on BPH Nils (Figs. 6-13). However, IR101791-10-1-4-3-2-4 performed better yield of 5.51 t ha^{-1} over the standard check IR24 (5.09 t ha^{-1}) with similar growth duration (Table 10).

PI: S S Haque, **CI:** M M Hossain, N Bari and S M M S Tonmoy

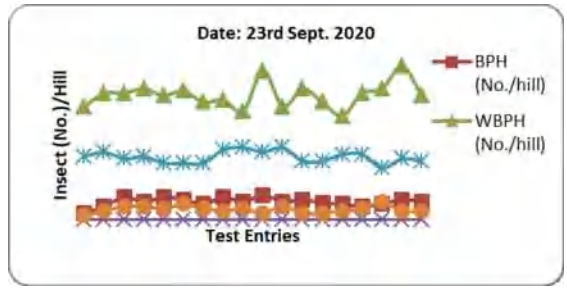

Fig. 6. Weekly incidence of rice planthoppers and natural enemies.

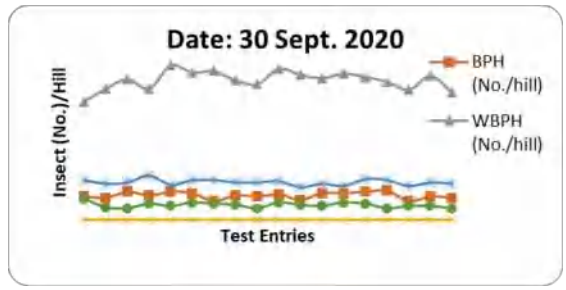

Fig. 7. Weekly incidence of rice planthoppers and natural enemies.

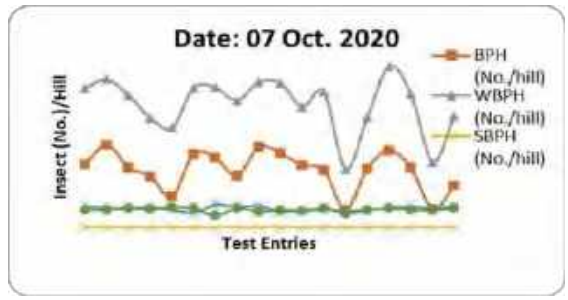

Fig. 8. Weekly incidence of rice planthoppers and natural enemies.

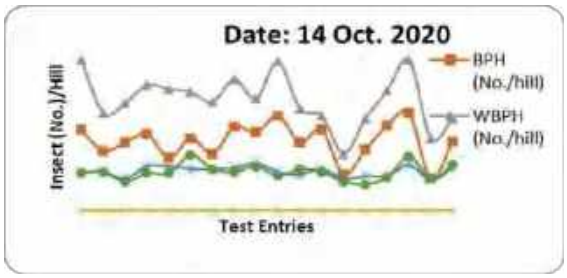

Fig. 9. Weekly incidence of rice planthoppers and natural enemies.

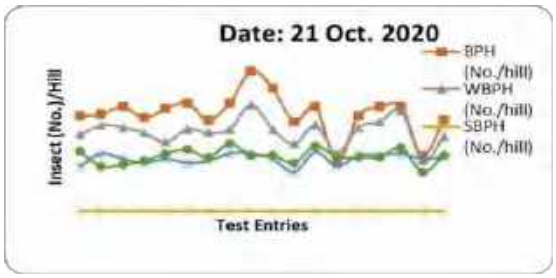

Fig. 10. Weekly incidence of rice planthoppers and natural enemies.

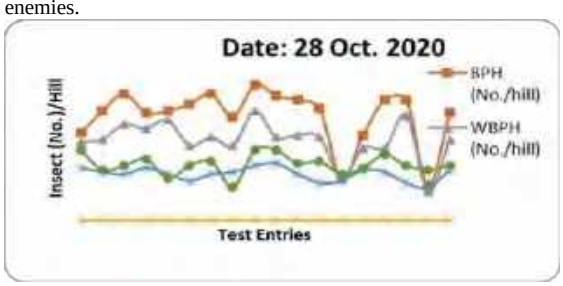

Fig. 11. Weekly incidence of rice planthoppers and natural enemies.

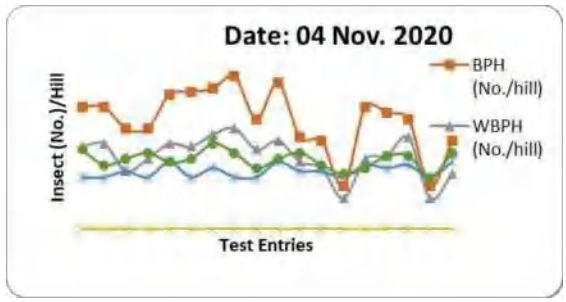

Fig. 12. Weekly incidence of rice planthoppers and natural enemies.

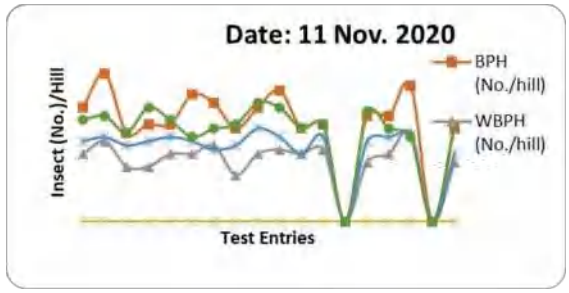

Fig. 13. Weekly incidence of rice planthoppers and natural enemies.

Fig. 6-13. Weekly incidence of rice planthoppers on BPH Nils at BRRI RS, Sirajganj from 23 Sep to 11 Nov 2020.

Table 10. Performance of BPH NILs during T. Aman 2020 at BRRI RS, Sirajganj.

Entry	Growth duration (day)	Hill no. /5m2	Plant height (cm)	Grain Yield (t/ha)
IR101792-9-1-4-1-1-8	111	119	92.33	3.71
IR101794-4-1-11-3-1-6	111	118	91.33	3.04
IR132373-3-1-1-1-5	111	118	95.80	3.98
IR101840-1-1-11-2	109	120	91.20	3.79
IR101797-9-3-1-1-1-20	112	119	94.80	4.26
IR101796-1-2-3-20	112	119	91.80	3.78
IR101796-1-4-5-2-1-3	115	119	95.47	3.33
IR101795-1-5-1-1	111	118	94.53	4.68
IR101791-1-2-8	115	119	96.20	5.32
IR101791-10-1-4-3-2-4	120	120	103.87	5.51
IR132754-2-1	111	119	92.80	3.56
IR107736-21-1-5-1	112	119	93.93	4.12
IR107736-22-1-1-1	100	116	85.67	1.37
IR107736-7-1-2-1	111	118	93.60	3.99
IR107736-5-2-1-1	115	118	99.67	3.50
IR24	115	119	94.93	5.09
BR3 (susceptible ck.)	100	117	85.07	1.10
T27A	115	120	91.13	4.12

Validation of the conventional component technologies for RPH management

Fields for the component treatments/ technologies were selected scattered way to find out the suitable pest management options from the RPH prone area in Dobila, Hamkuria and West para (WP) in Tarash under Sirajganj district. Farmers having larger rice fields were selected in such a way that the selected fields remain scattered throughout the whole rice growing area. Each of the field was divided in two equal halves. One portion of each field remained under the respective farmers' supervision without any intervention. The other portion was managed under a single component technology. The technologies (treatments) were as follows: i) spacing, ii) line transplanting with gaps after certain hills, iii) water management, iv) fertilizer management, v) insecticide application, vi) use of single nozzled sprayer, vii) use of double nozzled sprayer and viii) control (no measure) (Table 11). In addition, two light traps were operated in two locations of the selected site but a little away from the experimental area to control the RPH winged adult.

The variety grown in the field (farmer's choice) remained the same for both the halves. Each component technology was assigned in three farmers' fields. These experiments were conducted in RCB design. Data on RPH were collected from 20 randomly selected hills along the diagonal of each field at 7-10 days interval.

The rice pests, found during the study period, were BPH, WBPH, YSB, LF, RB etc and among natural enemies, spider, GMB, LBB etc to component technologies. In this study a single component was applied such as the use of plant spacing, and moderate resistant variety, fertilizer, water management, application of insecticide using single nozzle and double nozzle sprayer (spraying method, volume, and active ingredients) to BPH and WBPH. Here, BRRI dhan29 was used as the mega variety that has moderate resistance to BPH and WBPH.

PI: M M Hossain and **CI:** S M M S Tonmoy

The Components of IPM

Plant spacing: Rice seedlings were transplanted at 20 x 20 x 40 cm spacing that considered a positive contribution to the control of pests. The BPH and WBPH population in the research management (RM) plot (recommended) and the farmer practiced (FP) plot were slightly different (Fig 14). Furrow or empty space (40 cm) was used to manage the intercultural operation and activity of pests in rice field. The microclimate variations that occurred in the rice ecosystem were thought to be less supportive biologically and ecologically, so that the population or attack rate was decreased. (Fig.14)

Table 11. Rice pests control technology components.

Treatment	Recommendation	Farmer
Spacing	20 x 20 x 40 cm	20 x 15 x 30 cm
Water management	AWD (Alternate Wetting and drying)	Flooded
Fertilizer management	10-15 days after transplanting (DAT), 25-30 days, and (5-7 days before of panicle initiation (PI) stage: urea fertilizer 217 kg/ ha in three split. Additional dose of MoP @ 38 kg/ha with 3rd split of Urea.	Urea: 50 – 150 kg/ha Additional dose of MoP: No
Insecticide spray volume	Spray volume 500 l/ha	200 – 250 l/ha
Use of nozzled sprayer	Single nozzled sprayer at the bottom of the plant (for BPH control), over the rice plant (for rice stemborers and rice bugs)	Single nozzled sprayer/ Hand sprayer: Over the rice plant
Insecticide type	Mipsin 75WP for RPH, Virtako for rice stemborers	Abamectin, Chlorpirifos, Cartap, Pymetrozin
Rice variety	BRRI dhan29	BRRI dhan29
Control	No application	Farmers Practice
Light trap	A little away from the experimental field to control the BPH, WBPH winged adult, stem borer, leaf folder and rice bug.	

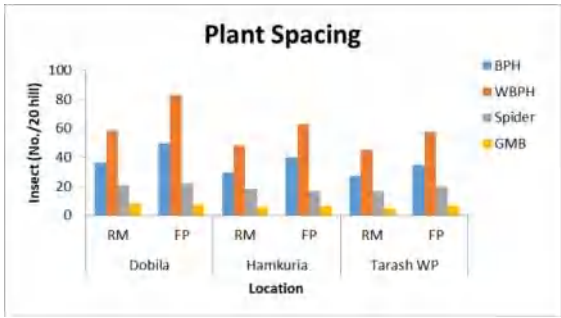

Fig. 14. Effect of plant spacing (20 cm X 20 cm) on the RPH population during Boro 2021 season at Dobila, Hamkuria and Westpara, Tarash.

Additional MoP with recommended fertilizer dose. Additional MoP with recommended fertilizer dose slightly reduced the rice planthoppers (BPH and WBPH) number per hill in research management (RM) plot than farmer practiced (FP) plot (Fig 15).

Alternate wetting and drying (AWD). Alternate wetting and drying (AWD) and continuous water level (5-7 cm) in rice field did not have any effect on the RPH population (Fig. 16). However, pest population was the highest in Dobila followed by Hamkuria and Westpara, Tarash.

Single and double nozzle sprayer. Application of insecticide using single nozzle sprayer on the RPH population was observed at flowering stage. Before spray, pest population was almost similar in three locations. But after spray, it was nock downed upto three DAS at Dobila and Westpara, and that was 10 DAS at Hamkuria (Fig. 17). However, pest population started to increase seven to 10 DAS at Dobila, 20 DAS at Hamkuria and 10 DAS at Westpara, Tarash. It means that location wise pest incidence differ due to microclimatic condition of the crop field though same dose was applied in all the locations (Fig. 17). In addition, the effect of pesticide on RPH eggs (having inside plant) was unknown. Almost similar results were also observed for double nozzle sprayer (Fig. 18).

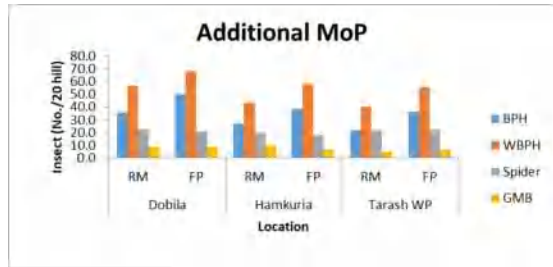

Fig. 15. Effect of additional MoP on the RPH population during Boro 2021 season at Dobila, Hamkuria and Westpara (Recommended fertilizer dose: Urea_TSP_MoP_Gyp @ 270_112_150_112 kg ha^{-1}) in Tarash

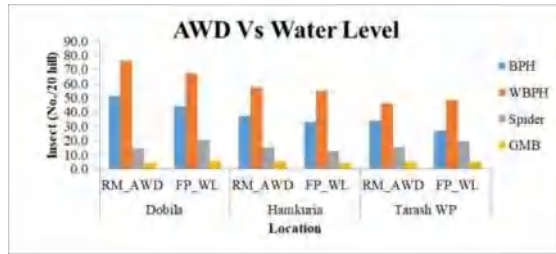

Fig. 16. Effect of alternate wetting and drying and continuous water level (5-7 cm) in rice field on the RPH population during Boro 2021 season at Dobila, Hamkuria and Westpara, Tarash.

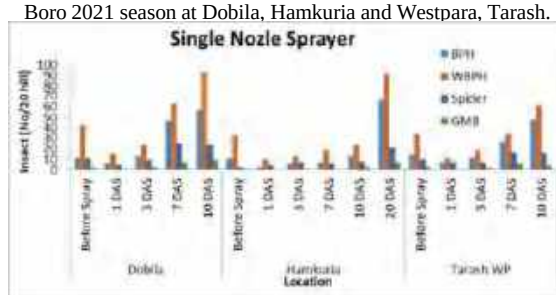

Fig. 17. Effect of single nozzle spray on the RPH population at flowering stage during Boro/2021 season at Dobila, Hamkuria and Tarash WP, Tarash, Sirajganj.

Double Nozle Sprayer:

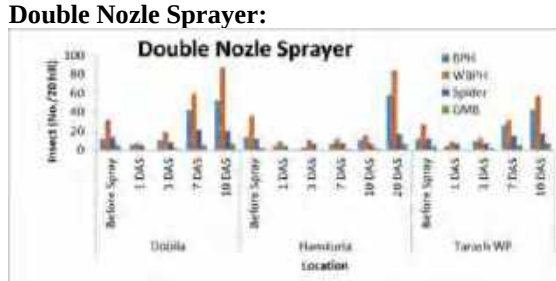

Fig. 18. Effect of double nozzle spray on the RPH population at flowering stage during Boro 2021 season at Dobila, Hamkuria and Westpara in Tarash, Sirajganj.

Monitoring of Fall armyworm moth using pheromone trap

To record the present status of Fall armyworm, S. frugiperda in rice based irrigated low land ecosystem, a monitoring programme was conducted in BRRI RS, Sirajganj and in rice farmers field of Tarash, Sirajganj and Sherpur, Bogura. For this, sex pheromone traps with lures were collected from Ispahani Agro Ltd. Bangladesh. Monitoring were done in collaboration with Department of Agricultural Extension in Tarash, Sirajganj and in Sherpur, Bogura. The Traps were visited weekly and number of moth (s) trapped were recorded. No adult moth was recorded in BRRI RS, Sirajganj as well as in rice field ecosystem. But 2-3 moths/trap/day was caught in maize growing areas in Tarash, Sirajganj and Sherpur, Bogura districts.

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SUMMARY

In Special Yield Trial, RLR, during T Aman 2020 six high yielding varieties and two hybrid rice were evaluated at BRRI RS, Gopalganj. Two RYTs for favourable Boro rice (FBR) in Boro 2020-21 were conducted. In RYT#1 (FBR) Boro, two advanced lines BRBa 1-4-9 and BRBa 3-1-7 produced a higher yield (9.86-10.27 t ha^{-1}) than the standard check BRRI dhan58 (7.96 t ha^{-1}) and BRRI dhan92 (9.69 t ha^{-1}) with similar or four days shorter growth duration. In RYT#2 (FBR) Boro, two advanced lines IR12A329 and IR04A429 produced a higher yield (8.74-9.74 t ha^{-1}) than the standard check BRRI dhan58 (6.65 t ha^{-1}) and BRRI dhan92 (8.36 t ha^{-1}). In a regional yield maximization trial (RYMT), one advanced line BRH13-2-4-6-4B produced a slightly higher yield (9.61 t ha^{-1}) than the check variety BRRI dhan63 (9.19 t ha^{-1}). One evaluation trial of hybrid rice in Boro 2020-21 was conducted. In Boro 2020-21, a total of 616 kg hybrid seeds from BRRI hybrid dhan5 were obtained.

The quality of supplied water sample from BRRI RS, farm Gopalganj is not suitable for drinking. Based on the irrigation quality indicators, the water can be used for irrigation. In Aus 2020, BRRI hybrid dhan7 produced a higher grain yield (>7 ton/ha) with 17-day-old seedling. Economic N rate for BRRI hybrid dhan7 produced maximum grain yield with application of N @ 90-95 kg/ ha splitting with basal 1/3, after 4-5 tiller (15 DAT), 1/3 and 1/3 before PI (25-30 DAT) (S1) or ½ at basal and ½ before PI (S3) at BRRI RS, farm Gopalganj. The treatment (T_5), polythene covering for all time with round shape opening at both ends of the seedbed highly performed in terms of seedling dry weight and height.

During the reporting year, nine varietal replacements through head to head (HTH) demonstrations each of one bigha (33 decimal) of land, three in Aman season 2020 and six in Boro season 2020-21 were conducted under the TRB-BRRI project. Besides, five block demonstrations each of two acres (200 decimal) of land, three in Aman season and two in Boro season were conducted under the SPIRA project. A total of 107 (53 in T. Aman and 54 in Boro) field demonstrations were conducted (about one bigha each) of newly developed BRRI varieties in Gopalganj, Bagherhat and Norail districts. On the other hand, ten farmers' training and ten field days in different locations of BRRI RS, Gopalganj recommended areas were organized. BRRI RS, Gopalganj also participated in one krishi mela, agricultural fair and development fair.

In the reporting year, 1.3 tons of breeder seeds of different BRRI varieties were produced and sent to the GRS Division, BRRI HQ, Gazipur. However, 6.65 tons of TLS of BRRI rice varieties were produced and frees distributed for quick dissemination of BRRI developed released varieties.

VARIETAL DEVELOPMENT

Special yield trial, RLR, T. Aman 2020.

In T. Aman 2020, two varieties BRRI Hybrid dhan6 and BRRI dhan71 produced higher grain yield (6.08-6.18 t ha^{-1} and 116-119 days) than all the other varieties (4.85-5.95 t ha^{-1} and 107-118 days) (Table 1).

RYT# 1 for favourable Boro rice (Barishal), Boro 2020-21

Six advanced lines along with BRRI dhan58 and BRRI dhan89 as checks were grown at BRRI RS Gopalganj during Boro 2020-21. Two advanced lines BRBa 1-4-9 and BRBa 3-1-7 produced a higher yield (9.86-10.89 t ha^{-1}) than the standard check BRRI dhan58 (7.96 t ha^{-1}) and BRRI dhan92 (9.69 t ha^{-1}) with similar or four days shorter growth duration (Table 2).

RYT# 2 for favourable Boro rice (Barishal), Boro 2020-21

Seven advanced lines along with two checks BRRI dhan58 and BRRI dhan89 were grown at BRRI RS Gopalganj during Boro 2020-21. Two advanced lines IR12A329 and IR04A429 produced a higher yield (8.74-9.74 t ha^{-1}) than that of the standard check BRRI dhan58 (6.65 t ha^{-1}) and BRRI dhan92 (8.36 t ha^{-1}) with similar or four days shorter growth duration (Table 3).

RYMT (Regional yield maximization trial), Boro 2020-21

In a regional yield maximization trial, one advanced line BRH13-2-4-6-4B produced a slightly higher yield (9.61 t ha^{-1}) than the check variety BRRI dhan63 (9.19 t ha^{-1}) with similar growth duration (Table 4).

Evaluation trial of US-88 hybrid along with company and BRRI developed promising hybrids

In Boro 2020-21, two promising hybrids were evaluated along with two BRRI developed hybrids and three company hybrids as check variety. Among the tested hybrids, the highest yield was observed in promising hybrid-1 (8.6 t ha^{-1}) followed by US-88 (8.54 t ha^{-1}) and BRRI hybrid dhan5 (8.49 t ha^{-1}) with similar growth duration (Table 5).

F_1 Seed production of BRRI hybrid dhan5

A total of 616 kg hybrid seeds were produced from BRRI hybrid dhan5 (BRRI 17A/BRRI31R) at BRRI RS, Gopalganj during Boro 2020-21 (Table 6).

Table 1. Performance of some high yielding and hybrid rice varieties, Aman 2020.

Designation	Plant height (cm)	Growth duration(day)	Yield (t ha^{-1})
SP101 (BINA dhan16)	100.83	107	5.29
SP102 (BINA dhan17)	103.25	115	5.72
SP103 (BINA dhan22)	101.25	118	5.95
SP104 (BRRI dhan57)	106.50	113	4.85
SP105 (BRRI dhan71)	123.50	116	6.08
SP106 (BRRI dhan75)	105.92	115	5.55
SP107 (BRRI Hybrid dhan4)	112.00	118	5.43
SP108 (BRRI Hybrid dhan6)	113.25	119	6.18
CV (%)	1.6	2.0	5.99
Lsd (0.05)	3.08	4.86	0.59

Table 2. Yield and ancillary characters of RYT-1 genotypes, Barishal, Boro 2020-21.

Designation	Plant height (cm)	Growth duration(day)	Yield (t ha^{-1})
BRBa 1-4-9	118.58	152	9.86
BRBa 2-1-3	116.25	153	8.83
BRBa 2-5-3	102.5	152	9.44
BRBa 3-1-7	107.83	152	10.27
BRBa 3-2-4	100.25	152	7.75
BRBa 3-3-1	101.75	151	9.31
BRRI dhan58 (ck)	101.17	151	7.96
BRRI dhan 92 (ck)	115.25	156	9.69
CV (%)	6.4	0.933	14.44
Lsd (0.05)	12.0998	2.49	NS

Table 3. Yield and ancillary characters of RYT-2 genotypes, Barishal, Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
IR04A429	107.58	153	9.74
IR12A329	104.08	153	8.74
IR13A515	105.83	153	6.85
IR15A2820	98.25	145	5.47
IR15A2854	96.00	145	6.24
IR15A3466	97.42	143	7.07
IR16A2022	99.00	144	6.52
BRRI dhan58 (ck)	90.58	151	6.65
BRRI dhan92 (ck)	108.58	157	8.36
CV (%)	3.44	0.71	16.65
Lsd (0.05)	6.01	1.83	2.1

Table 4. Performance of some advanced breeding lines, RYMT, Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t/ha)
V1=BRH11-9-11-4-5B-HR3	93.27	153	8.84
V2=BRH13-2-4-6-4B	91.71	152	9.61
V3=BRRI dhan63	92.50	150	9.19
CV (%)	1.23	0.81	5.60

Table 5. Performance of some hybrids, evaluation trial, Boro 2020-21.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRRI hybrid dhan3	109.25	148	7.25
BRRI hybrid dhan5	108.42	147	8.49
US-88	114.42	150	8.54
Tej Gold	108.17	147	7.93
SL-8H	102.00	147	7.12
Promising hybrid-1	111.33	152	8.60
Promising hybrid-2	111.58	149	7.54
CV (%)	6.53	0.81	14.95
Hsd (0.05)	NS	3.42	NS

Table 6. F_1 Seed production of BRRI hybrid dhan5.

Hybrid	Plant height (cm)		50% flowering		Plot area (m^2)	Yield kg/plot	Seed yield (t ha^{-1})
	A line	B line	A line	B line			
BRRI 17A/BRRI31R	86	95.5	100	122	3000	616.00	2.05

DS: R1=16 Nov 2020 R2=23 Nov 2020 A= 12 Dec 2020
DT: R=25 Dec 2020 A=15 Jan 2021

CROP-SOIL-WATER MANAGEMENT

Water quality assessment of supplied water sample from BRRI RS, Gopalganj

The quality of supplied water sample from BRRI RS, Gpalganj farm, is not suitable for drinking. Based on the irrigation quality indicators, the water can be used for irrigation (Tables 7 and 8).

Determination of optimum seedling age for maximize grain yield of BRRI hybrid dhan7

In Aus season, seedling age of short-duration T. Aus rice varieties is recommended about 15-20 days. BRRI hybrid dhan7 is a newly released T. Aus hybrid variety. We have to know the exact seedling age of the variety to observe its growth, and yield potential. The treatments of the experiment were seedling age of 10 days, 15 days, 20 days, 25 days, 30 days and 35 days. The experiment was conducted following RCBD design with three replications at BRRI RS, farm, Gopalganj. Rice was transplanted on 7 May 2020 during T. Aus season with 20×20cm spacing. For transplanting, seeding was done for 10,15, 20, 25,30 and 35 days before. A regression model was calculated to determine the actual seedling age to obtain the maximum yield. The regression model was $y = -7.2524x^2 + 252.51x + 4906.1$, $R^2 = 0.9881^{**}$. After calculation of regression model with grain yield and seedling age (Fig.1) the optimum seedling age appeared for BRRI hybrid dhan7 is 17 days. Higher grain yield of lower

Table 7. Chemical properties of supplied water sample from BRRI RS, Gopalganj.

Chemical concentration	Unit	Value		Recommended value	
		90 feet depth	110 feet depth	Drinking water (WHO standard)	Irrigation water (FAO standard)
EC	dSm^{-1}	1.8	1.6	0.3	3.0
Iron	mgL^{-1}	4.7	2.2	1.0	5.0
Sodium	mgL^{-1}	238.0	268.0	60.0	900.0
Potassium	mgL^{-1}	8.6	7.8	20.0	-
Calcium	mgL^{-1}	90	101.0	200.0	400.0
Magnesium	mgL^{-1}	50	39.0	30.0	60.0

Table 8. Water quality indicator of supplied sample from BRRI RS, Gopalganj.

Quality indicator	Value		Recommended value	
	90 feet depth	110 feet depth	Recommended Limit (FAO)	Status
EC (dSm^{-1})	1.8	1.6	-	Moderate
SAR	5.0	5.7	10	Normal
MAR	47.8	38.9	50	Normal
KR	1.2	1.4	1.2	Normal
TH	430.3	412.5	500.0	Normal

SAR= Sodium Adsorption Ratio, MAR=Magnesium Adsorption Ratio, KR= Kellys Ratio, TH= Total Hardness.

seedling age is supported by higher tiller m^{-2}, panicle m^{-2} and 1000 grain weight (Table 9). Table 9 shows that the higher the seedling age the higher the growth duration of BRRI hybrid dhan7. After calculation of regression model with grain yield and age of seedling the optimum seedling age found for BRRI hybrid dhan7 is 17 days through 108 days growth durations.

Nitrogen management and scheduling for BRRI hybrid Dhan7

The experiment was conducted to find out the amount of N needed for maximum grain yield and to determine the economic fertilizer rate of BRRI hybrid dhan7 and to find out the best N scheduling for BRRI hybrid dhan7. The experiment was conducted considering two factors. Factor A is nitrogen dose (kg ha^{-1}) @ 0, 30, 60,90,120 and 150 kg ha^{-1}. Factor B is nitrogen application schedule; 1.Basal 1/3, 1/3 after 4-5 tiller (15 DAT) and 1/3 before PI (25-30 DAT) (S_1) 2 .½ at 10-12 DAT and ½ before PI (S_2) 3.½ at basal and ½ before PI (S_3). The experiment following factorial RCB design with three replications at BRRI RS, farm, Gopalganj during the T. Aus season of 2020.

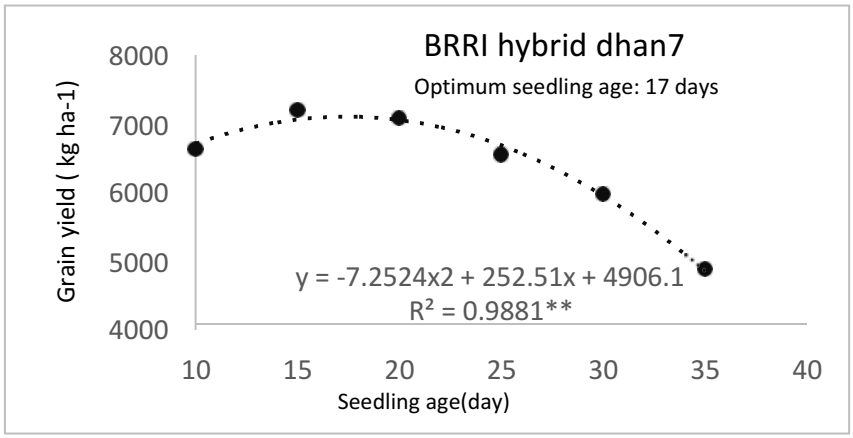

Fig. 1. Determination of seedling age depending on grain yield of BRRI hybrid dhan7 at BRRI RS, farm Gopalganj.

Table 9. Effect of seedling age on grain yield of BRRI hybrid dhan7 at BRRI RS, farm Gopalganj.

Seedling age (day)	Grain yield (t ha^{-1})	Tiller m^{-2}	Panicle m^{-2}	Grain $panicle^{-1}$	Growth duration (day)
10	6.63	411	334	88	105
15	7.20	391	347	89	107
20	7.07	360	343	90	109
25	6.55	321	306	89	111
30	5.98	283	266	86	115
35	4.88	230	214	85	119
$LSD_{(0.05)}$	0.64	67.09	39.26	ns	1.95
CV(%)	5.5	11.10	7.2	3.9	1.0

Fifteen-day-old seedlings were transplanted on 7 May 2020 with 20×20 cm spacing. The variation of grain yield of BRRI hybrid dhan7 in different schedules determined different nitrogen rates through regression equation (Fig. 2). Differentiating the quadratic equation of yield response with respect to applied N doses the economic N rate appeared as 95, 97 and 90 kg ha^{-1} for S_1, S_2 and S_3 respectively. Considering economic N rate, application of N @ 90-95 kg ha^{-1} splitting with basal 1/3, after 4-5 tiller (15 DAT) 1/3 and 1/3 before PI (25-30 DAT) (S_1) or .½ at basal and ½ before PI (S_3) are better options for getting the maximum grain yield of BRRI hybrid dhan7. However, to come up with a concrete recommendation, this research has to be repeated under similar condition.

Effect of polythene covering on seedling raising in Boro Season 2020-21

The results obtained from the seedbed exhibited that all-time polythene cover with round shape opening (T_5) produced the highest seedling dry matter (2.51g) followed by polythene covering from 11.0 am to sunset (T_3) (2.34g). Likewise, the highest seedling height was noticed by the application of T_5 treatment (27.57 cm). However, under field conditions, an insignificant effect of different seedling raising techniques was recorded on yield and yield components of BRRI dhan81 except for grains/panicle. Similar to the seedbed results, the highest grains/panicle (101) was found from the plot which received T_5 treatment.

TECHNOLOGY TRANSFER

Variety replacement through head to head trial during T. Aman 2020 and Boro 2020-21 under TRB-BRRI project

Two group of BRRI modern rice varieties were tested at nine locations of Gopalganj, Bagherhat and Norail districts during T. Aman and Boro seasons. BRRI dhan32 group comprising of BRRI dhan80, BRRI dhan87, BRRI dhan93, BRRI dhan94 and BRRI dhan95 in two different locations and BRRI dhan57 group comprising of BRRI

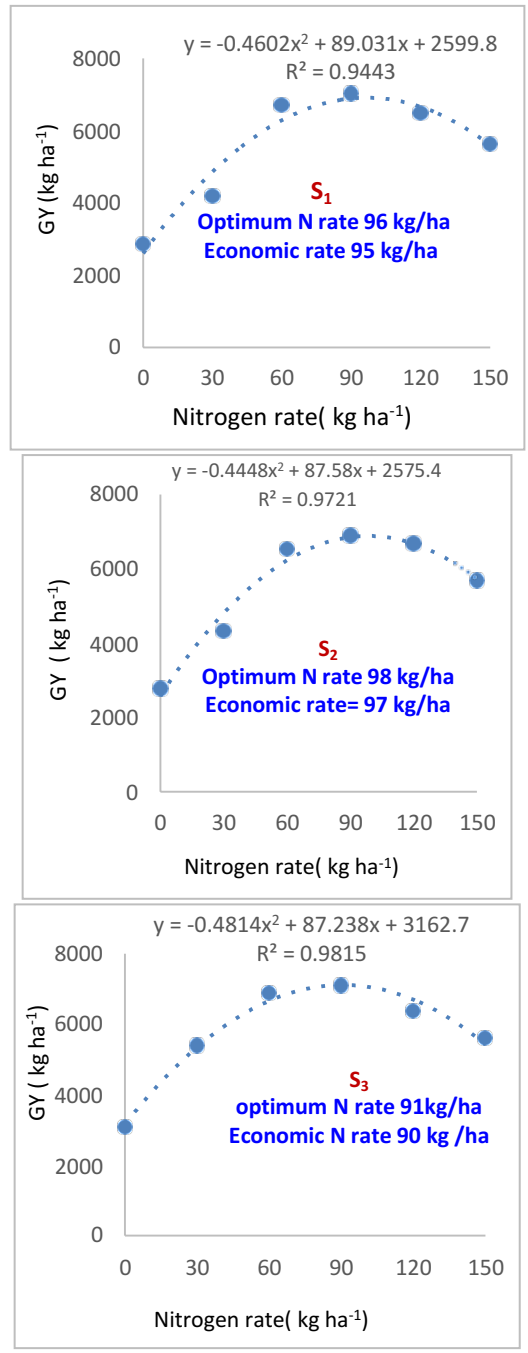

Fig. 2. Determination of N rate and N scheduling of BRRI hybrid dhan7 at BRRI RS farm, Gopalganj.

Table 10. Effect of polythene covering techniques on seedling growth, yield and yield components in Boro season 2020-2021.

Treat	Seedbed		Main field			
	Seedling dry matter (g)	Seedling height (cm)	Panicle/m2	Grain/panicle	TGW (g)	Grain yield (t/ha)
T_1	1.45f	22.04c	271	101a	23.05	6.30
T_2	1.97e	25.75b	261	87bc	22.91	6.19
T_3	2.36a	26.46b	281	83d	23.99	6.44
T_4	2.05d	25.20b	294	81cd	21.89	6.41
T_5	2.53a	28.51a	289	102a	22.88	6.36
T_6	2.22c	25.45b	261	86b	21.89	6.31
CV (%)	2.11	4.21	7.14	2.01	5.43	6.36
Lsd	0.08	1.96	NS	3.30	NS	NS

TGW = 1000 grain weight

dhan71, BRRI dhan75, BINA dhan16, BINA dhan17 and BINA dhan22 were tested in one location (Tables 11 and 12). Data showed BRRI dhan32 group varieties were tested at two different locations in Gopalganj district. Among then BRRI dhan87 (6.70 t ha^{-1}) provided the highest yield followed by BRRI dhan95 (6.40 th^{-1}), BRRI dhan93 (6.20 t ha^{-1}), BRRI dhan94 (6.0 th^{-1}) and BRRI dhan80 (5.80 t ha^{-1}) and BRRI dhan57 group varieties were tested at one location in Gopalganj district. Among then BRRI dhan71 (5.20 t ha^{-1}) produced the highest yield followed by BRRI dhan75 (5.15 t ha^{-1}), BINA dhan22 (5.10 t ha^{-1}), BINA dhan17 (5.00 t ha^{-1}), BINA dhan16 (4.40 t ha^{-1}) BRRI dhan57 (4.10 t ha^{-1}). Tables 13 and 14 showed that in all locations BRRI dhan 67 (6.90 t ha^{-1}) and BRRI dhan89 (8.47 t ha^{-1}) produced the highest yield. Demonstration farmers as well as neighbour farmers were very interested to cultivate BRRI dhan87 in T. Aman and BRRI dhan67, BRRI dhan89 and BRRI dhan92 in Boro season.

Table 11. Performance of promising new rice varieties through HTH trial during T. Aman 2020 season (medium short duration).

Location	BRRI dhan32		BRRI dhan80		BRRI dhan87		BRRI dhan93		BRRI dhan94		BRRI dhan95	
	GD days	Yd t/ha	GD days	Yd t/ha	GD days	Yd t/ha	GD days	Yd t/ha	GD days	Yd t/ha	GD days	Yd t/ha
Sadar Gop.ganj	140	5.00	130	5.80	127	6.70	135	6.20	140	6.00	138	6..40
Sarar Gop.ganj	140	3.90	131	4.90	130	6.10	133	5.80	135	5.10	138	500
Farmer Preference (1-6)	6		2		5		4		1		3	

Farmer preference (1-6): 1-6 means from high to low

Table 12. Performance of promising new rice varieties through HTH trial during T. Aman 2020 season (short duration).

Location	BRRI dhan57		BRRI dhan71		BRRI dhan75		BINA dhan16		BINA dhan17		BINA dhan22	
	GD days	Yd t/ha	GD days	Yd t/ha	GD days	Yd t/ha	GD days	Yd t/ha	GD days	Yd t/ha	GD days	Yd t/ha
Sadar Gop.ganj	107	4.10	110	5.20	115	5.15	105	4.40	114	5.00	119	5.10
Farmer Preference (1-6)	2		1		3		4		5		6	

Farmer preference (1-6): 1-6 means from high to low

Table 13. Performance of promising short duration rice varieties through HTH trial during Boro 2020-21(BRRI dhan28 group, short duration).

Location	BRRI dhan28		BRRI dhan67		BRRI dhan81		BRRI dhan84		BRRI dhan88	
	GD (day)	Yd (t/ha)	GD (day)	Yd (t/ha)	GD (day)	Yd (t/ha)	GD (day)	Yd (t/ha)	GD (day)	Yd (t/ha)
Mollahat, Bagherhat	137	5.60	142	6.20	140	5.50	141	6.24	144	6.10
Mollahat, Bagherhat	138	5.90	144	6.90	139	5.50	140	6.10	145	6.50
Fakirhat, Bagherhat	141	6.10	146	6.50	140	6.15	141	6.88	142	6.80
Farmer preference (1-5)	4		1		5		2		3	

Farmer preference (1-5): from high to low

Table 14. Performance of promising short duration rice varieties through HTH trial during Boro 2020-21(BRRI dhan29 group, long duration).

Location	BRRI dhan29		BRRI dhan58		BRRI dhan89		BRRI dhan92	
	GD (day)	Yd (t/ha)	GD (day)	Yd (t/ha)	GD (day)	Yd (t/ha)	GD (day)	Yd (t/ha)
Sadar Gopalganj	165	8.05	158	7.72	156	7.87	155	7.87
Sadar Gopalganj	165	8.10	160	7.58	156	7.91	155	8.17
Kashiani Gopalganj	166	8.10	160	7.81	156	7.85	154	8.47
Farmer Preference (1-5)	4		3		1		2	

Farmer preference (1-5): 1-5 means from high to low.

Block demonstration, dissemination and quality seed production of rice varieties during Aman 2020 and Boro 2020-21 (SPIRA project)

In T. Aman 2020, the average yield of BRRI dhan87, BRRI dhan90 and BRRI dhan95 were found 6.71, 3.87 and 5.18 t/ha respectively. In all the blocks, the highest yield was showed in BRRI dhan87 (6.98 t ha^{-1}).

In Boro 2020-21, the average yield of BRRI dhan58, BRRI dhan89 and BRRI dhan92 were found 7.54, 8.03, 8.00, 8.31 t ha^{-1} respectively (Table 15). In all the blocks, the highest yield was obtained from BRRI dhan92 (8.45 t ha^{-1})**.** Demo farmers as well as neighbouring farmers were also interested to cultivate BRRI dhan87 in T. Aman and BRRI dhan89 and BRRI dhan92 in Boro season.

Field Demonstration

A total of 107 (53 in T. Aman and 54 in Boro) field demonstrations (about one bigha each) of newly released BRRI varieties were conducted in Gopalganj, Bagherhat and Norail districts. Among of them, 21 in the Gopalganj district, 18 in the Bagherhat district and 14 trials in the Norail district were conducted. The average yield of BRRI hybrid dhan4 and BRRI hybrid dhan6 were observed 6.15 and 6.45 t ha^{-1}respectively (Table 16). On the other hand, in Boro 2020-21 season, the average yield of BRRI hybrid dhan3 and BRRI hybrid dhan5 were found 7.92 and 8.37 t ha^{-1} respectively (Table 17). Farmer's acceptance of BRRI hybrid dhan6 in T Aman season and BRRI hybrid dhan5 in Boro season were found very high in those respective areas for its grain size, panicle length and high yield.

Table 15. Block demonstration of BRRI varieties during Aman 2020 and Boro 2020-21.

Location	Variety	GD (day)	Yield (t/ha)	Comment
T. Aman 2020				
1. Sadar, Gopalganj	BRRI dhan87	129	6.39	
	BRRI dhan90	121	3.87	Rat damage
	BRRI dhan95	127	5.20	
2.Sadar , Bagerhat	BRRI dhan87	127	6.78	
	BRRI dhan90	126	3.95	Rat damage
	BRRI dhan95	128	5.35	
3. Sadar, Norail	BRRI dhan87	129	6.98	
	BRRI dhan90	122	3.80	
	BRRI dhan95	125	5.00	Lodging
Boro 2020-21				
1. Sadar, Gopalganj	BRRI dhan58	154	7.63	Lodging
	BRRI dhan29	159	7.90	
	BRRI dhan89	156	7.89	
	BRRI dhan92	160	8.18	
	BRRI dhan58	152	7.45	Lodging
2.Sadar , Bagerhat	BRRI dhan29	157	8.16	
	BRRI dhan89	156	8.11	
	BRRI dhan92	158	8.45	

Table 16. Demonstration of recently BRRI released rice varieties during T. Aman 2020.

District	Variety	Avg. GY (t/ha)	Avg. GD (day)	No. of Demo.
Gopalganj	BRRI dhan87	6.12	129	05
	BRRI dhan93	5.25	135	02
	BRRI dhan94	5.24	134	02
	BRRI dhan95	5.52	127	02
	BRRI Hy.dhan4	6.15	118	05
	BRRI Hy.dhan6	6.45	116	05
Bagherhat	BRRI dhan61	4.85	132	02
	BRRI dhan73	4.75	115	02
	BRRI dhan87	6.32	128	02
	BRRI dhan95	5.30	125	02
	BRRI Hy.dhan4	5.89	120	05
	BRRI Hy.dhan6	6.45	118	05
Norail	BRRI dhan75	4.25	115	02
	BRRI dhan80	4.35	125	01
	BRRI dhan87	5.81	128	01
	BRRI Hy.dhan4	5.56	117	05
	BRRI Hy.dhan6	6.27	118	05
Total				53

Table 17. Demonstration of recently BRRI released rice varieties during Boro 2020-21.

District	Variety	Avg. GY (t/ha)	Avg. GD (day)	No. of Demo.
Gopalganj	BRRI dhan74	7.21	144	02
	BRRI dhan81	5.25	145	02
	BRRI dhan84	5.52	143	02
	BRRI dhan86	6.50	147	02
	BRRI dhan88	6.88	143	02
	BRRI dhan89	7.15	155	02
	BRRI dhan92	7.53	156	02
	BRRI Hy.dhan3	7.78	144	02
	BRRI Hy.dhan5	7.98	145	10
Bagherhat	BRRI dhan81	6.75	143	02
	BRRI dhan84	6.32	140	02
	BRRI dhan89	7.92	155	02
	BRRI dhan92	7.88	156	02
	BRRI Hy.dhan3	8.15	146	02
	BRRI Hy.dhan5	8.65	147	05
Norail	BRRI dhan84	6.25	144	02
	BRRI dhan88	7.54	144	02
	BRRI dhan92	7.88	155	02
	BRRI dhan96	7.15	144	01
	BRRI Hy.dhan3	7.85	144	01
	BRRI Hy.dhan5	8.49	145	05
Total				54

Table 18. Farmers' Training on modern rice cultivation and blast disease management in different regions during 2020-21.

Upazila	Date	No. of trainees				Total Trainees
		SAAOs		Farmer		
		M	F	M	F	
GOB fund, BRRI RS, Gopalganj						
Gopalganj	05.11.2020	-	-	46	14	60
Bagerhat	12.11.2020	-	-	50	10	60
Norail		-	-	23	07	30
Total				119	31	150
SPIRA project, BRRI						
Gopalganj	17.11.2020	-	-	58	22	80
Bagerhat	23.11.2020		-	61	19	80
Norail	10.03.2021		-	31	09	40
			-	150	50	200
Grand Total				269	81	350

Farmers field day and krishi mela

Ten field days were organized in the block demonstration in the Gopalganj, Bagerhat and Norail districts during T. Aman 2020 and Boro 2020-21 seasons funded by GoB, SPIRA and BMGF project. About 1,335 farmers as well as extension personnels' attended the field days. Most of the farmers interested to cultivate new rice varieties in their areas specially BRRI dhan67, BRRI dhan87, BRRI dhan88, BRRI dhan89, BRRI dhan92 and BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6. BRRI RS, Gopalganj also participated in one krishi mela, agriculture fair, and development fair.

Seed Production

In the reporting year, 1.3 tons breeder seeds of different BRRI varieties were produced and sent to the GRS Division, BRRI HQ, Gazipur. However, 6.65 tons of TLS of BRRI rice varieties were produced and freely distributed for quick dissemination of BRRI varieties.

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BRRI dhan97


BRRI dhan98


BRRI dhan99