BRRI ANNUAL REPORT
2019-2020

BANGLADESH RICE RESEARCH INSTITUTE

BRRI ANNUAL REPORT 2019-2020 BANGLADESH RICE RESEARCH INSTITUTE

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Contents

Preface

The present volume of BRRI Annual Report is a summary of research works carried out by 19 research divisions and nine regional stations of the institute during July 2019 to June 2020. This document consists of the significant portions of the research covering eight programme areas.

The programme areas, such as 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 different location specific, climate smart, stress tolerant rice varieties and some nutritionally enriched premium quality ones.

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

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 between research level and farmer's fields. 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.

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Weather information

Weather is the state of the atmosphere, describing for example the degree to which it is hot or cold, wet or dry, calm or stormy, clear or cloudy. We present here the available weather parameters *viz* maximum and minimum temperature (^{0}C), rainfall (mm), evaporation (mm), humidity (mostly 9 am and 2pm), sunshine hours (hours/day) and solar radiation (Cal/cm^{2}/day) during the experimental year (July 2019 – June 2020) as recorded from BRRI headquarter and seven regional stations Rangpur, Barishal, Habiganj, Bhanga, Rajshahi, Sonagazi and Cumilla by Plant Physiology Division.

Temperature. Monthly average maximum temperature was quite high during April and August in most of the stations. It was the highest in August at Cumilla (35.9)^{0}C followed by Habiganj (34.7^{0}C), Gazipur (33.78^{0}C) and Rangpur (32.6^{0}C). On the other hand, highest monthly average maximum temperature was recorded in April at Rajshahi (34.73^{0}C) followed by Bhanga (34.17^{0}C) and Barishal (32.98^{0}C), while it was in September at Sonagazi (32.4^{0}C). Mean minimum temperature was the lowest in January for all the stations. The lowest temperature (11.2^{0}C) was recorded during January in Rangpur (Fig. 1).

Rainfall and Pan Evaporation. During the reporting period, the highest rainfall was occurred in July followed by June, May, September, August, April and October. Other months had little rainfall except in February when there was no rainfall. Total rainfall was the highest at Habiganj (2172 mm) during the reported year. It was the lowest in Rajshahi (1200 mm). Irrespective of station, the highest pan evaporation was recorded in April but it was the lowest in January (Fig. 2).

Solar radiation and solar hours. The highest solar hour/day was recorded in March due to clear sky in all stations. On the contrary, it was the lowest in July due to cloudy sky in most of the stations. The solar radiation is directly proportional to the solar hour. So, the highest solar radiation was recorded in the month march for all the station except Rangpur where it was in August. The lowest solar radiation was found in January in all the stations (Fig. 3).

Relative Humidity. Relative humidity was higher in June to September and then it decreased. It was found the lowest during February to March. Relative humidity was higher at morning but decreased gradually till noon. (Fig. 4).

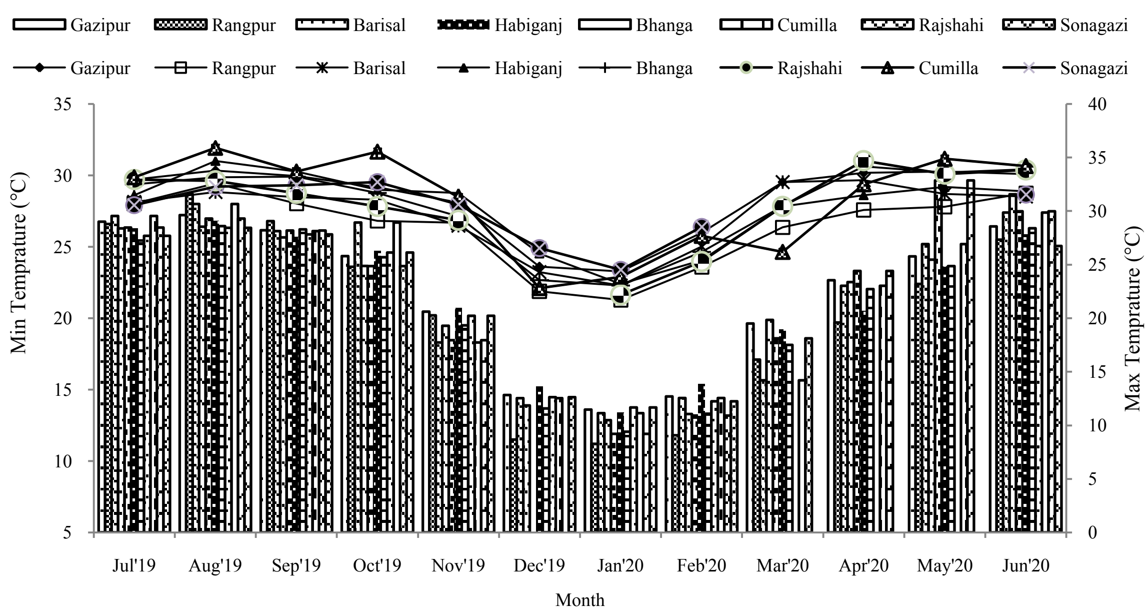


Fig. 1. Maximum and minimum temperature of eight different stations of BRRI during the period of July 2019 to June 2020. Bar and line graph show minimum and maximum temperature respectively.

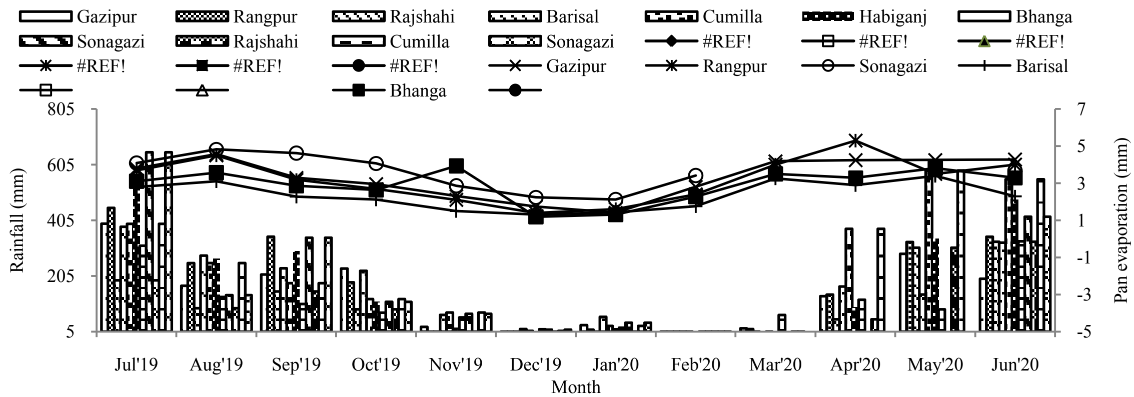


Fig. 2. Rainfall at eight stations and pan evaporation at five stations of BRRI during the period of July 2019 to June 2020. Bar and line graph show rainfall and pan evaporation respectively.

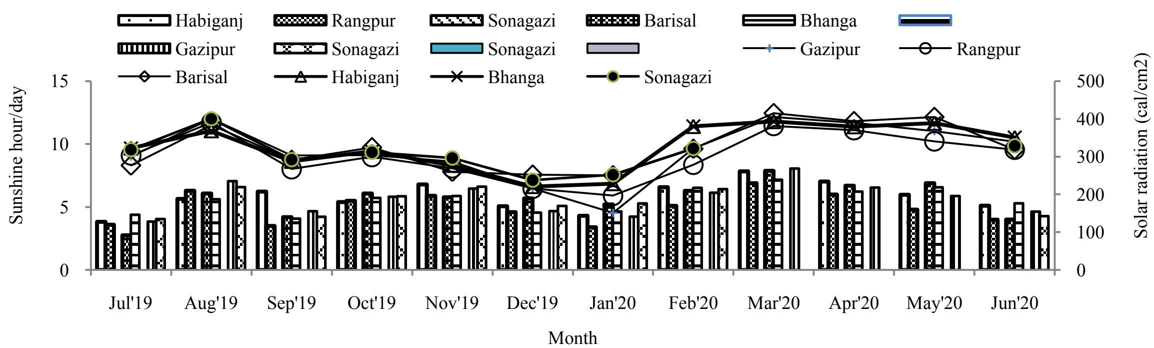


Fig. 3. Sunshine hour and solar radiation of six different stations of BRRI during the period of July 2019 to June 2020. Bar and line graph show sunshine hour and solar radiation respectively.

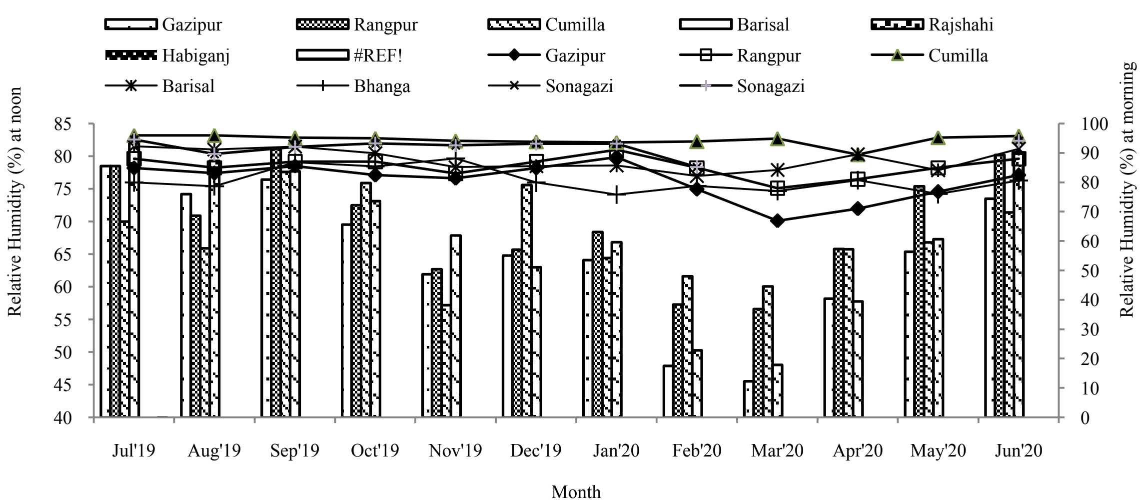


Fig. 4. Relative humidity at morning of six stations and at noon of five stations of BRRI during the period of July 2018 to June 2019. Bar and line graph show relative humidity at noon and morning respectively.

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
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
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
WMM	=	Workshop Machinery and Maintenance
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
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

SUMMARY

For the development of rice varieties under different ecosystems 313 crosses were made and 304 crosses were confirmed during 2019-20. In pedigree nursery, 2,104 individual plants were selected from F_3 to F_5 generations based on phenotypic performance of each cross and 139 fixed lines were bulked. A total of 3,54,553 individual plants were advanced from $F_{2\text{-}6}$ generation following single seed decent (SSD) method under rapid generation advance (RGA) condition. From line-stage testing (LST), 6,870 genotypes were selected based on yield and other agronomic performances. A total of 1,144 genotypes from observational yield trial (OYT) and 547 advanced breeding lines were selected from different yield trials such as PYT, SYT, RYT, AYT and PVT. One transgenic GR2E line namely IR112060 GR2-E:2-7-63-2-96 was selected and evaluated at eight locations viz. Gazipur, Cumilla, Habiganj, Rajshahi, Barishal, Satkhira, Rangpur and Sonagazi with the non-transgenic counterpart BRRI dhan29 as standard check and under process of government approval. A total of 80 germplasm from different biotic and abiotic screening nurseries were selected to use as parent in the breeding programme.

National seed board (NSB) of Bangladesh has released three promising genotypes viz BR-SF (Rang)-PL1-B, BR-RS (Raj)-PL4-B and BR8210-10-3-1-2 as BRRI dhan93, BRRI dhan94 and BRRI dhan95 respectively for cultivation in rain fed lowland rice (RLR) ecosystem. BRRI dhan93 produced 0.71 t ha^{-1} higher yield and BRRI dhan94 produced 0.81 t ha^{-1} higher yield than BRRI dhan49 (5.06 t ha^{-1}) in T. Aman 2018-19. Both the varieties showed growth duration four days longer than BRRI dhan49. Again, BRRI dhan95 showed 0.59 t ha^{-1} higher yield than the check variety BRRI dhan49. The growth duration of the variety was around five days earlier than the check variety BRRI dhan49.

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. Five crosses were made using seven parents, 14 crosses were confirmed as true F_1s. By growing F_3 population, 15,170 plants were maintained from 25 crosses through field RGA (Rapid Generation Advance) technique. Similarly, 8,640 plants of F_5 progenies comprised of 18 crosses grown from F_5 population were maintained through field RGA. A total of 313 individual plant progenies were selected from F_5 generation and 44 fixed lines were isolated from F_6 generation. Sixty-seven entries were selected considering growth duration, yield, uniformity of morpho-agronomic traits and superiority in one or more traits over the standard checks from 210 advanced materials in OYT-1. Similarly, only two entries out of 12 tested entries were selected in OYT-2. Ten genotypes such as BR10409-15-2-8, BR10411-42-2-24, BR10411-56-1-25, BR10411-59-5-33, BR10413-2B-15, BR10417-15-2-11, BR10418-32-1-58, BR10418-54-4-96, BR10418-8-3-10 and BR10446-2B-15 among 34 tested entries were selected on the basis of yield and growth duration (earliness) in PYT. 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. Forty crosses were made using 16 parents. Nine entries namely Mongthongno, Ranqui, Kanbui, Gunda, Sanki, Bish Number, Jamai Binni (Habiganj), Chinese rice line and advanced breeding line like IR101756-115-1-P1 were selected considering growth duration, yield and uniformity of morpho-agronomic traits (Table 1).

Table 1. Performance of entries in observational yield trial (OYT), development of Jhum rice (B. Aus), 2019-20.

Genotype	Plant height (cm)	Growth duration	Yield (t ha^{-1})	ACC%	Amylose Group
Mongthongno	126	100	2.14	20.7	I
Ranqui	103	100	1.10	22.1	I
Kanbui	116	102	3.02	28.7	H
Gunda	113	102	2.05	26.5	H
Sanki	112	104	2.21	21.0	I
Bish number	112	107	2.02	26.2	H
Chinese rice	107	105	2.94	28.9	H
YAAS-V5	102	99	1.44	18.1	L
IR101756-115-1-P1	105	112	1.54	11.1	L
BR26 (Ck)	97	105	2.49	22.6	I
BRRI dhan55 (ck)	111	104	2.25	19.4	L
BRRI dhan62 (ck)	103	101	2.05	23.4	I
BRRI dhan69 (ck)	108	102	3.24	18.0	L
Heritability	0.93	0.99	0.93		
LSD (0.05)	6.0	0.7	0.6		

ACC: Apparent amylose content

Amylose group: L-Low (10-19%), I- Intermediate (20-25%) and H-High (>25%) of grain amylose content.

Investigators: M A Hossain and M R Quddus

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 tolerance and good grain quality. Twenty-nine crosses were made using 40 parents and 3,938 F_1 seeds were obtained; 14 crosses were confirmed as true hybrid; 10,000 progenies from 16 crosses were advanced from F_2 generations through green-house RGA; 22,182 progenies from 52 crosses were advanced from F_{3-6} generations through modified field RGA. Ten genotypes were selected from 27 entries in observational yield trial (OYT) and two advanced lines out of ten from PYT#1 for favourable ecosystem and three advanced lines out of six from PYT#2 for non-saline tidal ecosystem in Barishal region were selected on the basis of homogeneity with respect to plant height, phenotypic acceptability at vegetative and maturity stages and physicochemical properties. Two genotypes out of seven from RYT#1 were selected compared to popular cultivar BRRI dhan48 and BRRI dhan82. For non-saline tidal ecosystem, two genotypes out of three from RYT#2 were selected based on growth duration, PAcp, grain quality and grain yield compared to popular cultivar BRRI dhan27 and BRRI dhan48. From ALART, B. Aus variety BRRI dhan83 was recommended to cultivate in the T. Aus areas of Bangladesh. The proposed line BR9011-67-4-1 was evaluated under proposed variety trial (PVT) by Seed Certification Agency (SCA) to release as a variety for T Aus season (Table 2). The advanced line had long slender grain and produced 0.8 t/ha higher yield than the check variety BR26 with the benefit of high amylose (27.9%).

Table 2. Performance of the line BR9011-67-4-1 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 (%)	Amylose (%)
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 Debsharmaand S Das

Improvement of rice for shallow flooded and deep water environment. The major objectives of 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, kneeing ability and hypoxia tolerance. In total, 35 crosses were made and 35 F_1s crosses were selected and confirmed through QC SNP panel analysis. A total of 6,460 F_2 progenies, 300 F_6 progenies were advanced through FRGA. Eleven modern shallow flood tolerant advanced lines having medium elongation under semi-deep flooded conditions were selected from yield trial. In SYT, five advanced materials were selected for semi deep water conditions. In RYT, nine local deep water rice varieties and six advanced lines were evaluated in four locations and finally six materials (BR9390-6-2-2B, BR9390-6-2-1B, BR9376-6-2-2B, Khoia-motor, BR10260-5-15-21-6B and Lalmohon) having faster elongation were selected for deep water conditions and three materials (BR10230-7-19-B, BR10238-5-1-9-3B and BR10247-14-18-7-3-3B) having moderate elongation were selected for stagnant flooded conditions. Fifteen local deep water rice varieties having faster elongation under very deep flooded conditions were selected. Seed of the local cultivars were increased for genetic purity.

Investigators: A S M Masuduzzaman, Sharmistha Ghosal, K M Iftekharuddaula and T L Aditya

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, 2,046 F_1 seeds were obtained from 15 single crosses and 11 cross were confirmed as true hybrids. A total of 43,365 individual progenies of 124 crosses combinations from $F_{2\text{-}6}$ generation were advanced through RGA method. In observational yield trials (OYT), 31 genotypes were selected out of 100 genotypes. For preliminary yield trials (PYT), 13 genotypes were selected out of 31 tested genotypes. In secondary yield trials (SYT), 11 genotypes were selected out of 41 tested genotypes. In RYT, two genotypes were selected out of seven genotypes. The mean heritability obtained from yield was 84%, indicating high level of precision of these experiments. The proposed lines BR-SF (Rang)-PL1-B, BR-RS (Raj)-PL4-B and BR8210-10-3-1-2 produced 5.77, 5.87 and 5.65 t/ha grain yield respectively, which were significantly higher than the yield of check variety BRRI dhan49 (5.06 t ha^{-1}) (Table 3).

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^{-1}), earliness (135-145 days) and acceptable grain quality for favourable irrigated ecosystem in Bangladesh. In the reporting year, 17 crosses were made and 23 crosses were confirmed as true F_1. A total of 13,331 individual panicles were collected from 17,322 individual plants of 43 cross combinations of F_2-F_7 generations. Out of 11,046 lines, 1,673 uniform lines were identified from LST based on uniformity in heading, plant height and grain type. Also disease incidence was recorded after artificial inoculation. Fifty breeding lines having 6.7-8.6 t ha^{-1} yield with 148-165 days growth duration were selected. Fifteen genotypes out of 60 from AYT were

Table 3. Performance of the variety BRRI dhan93, BRRI dhan94 and BRRI dhan95 under proposed variety trial (PVT), RLR, T. Aman 2018-19.

Designation	Plant height (cm)*	Growth duration (day)*	Grain yield (t ha^{-1})*	Grain Characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Elongation ratio	Protein (%)	Amy lose (%)
BRRI dhan93 (BR-SF(Raj)-PL1-B	117	134	5.77	65	2.5	MB	1.2	7.5	26.1
BRRI dhan94 BR-RS(Rang)-PL4-B	118	134	5.87	63	2.5	MB	1.3	7.9	25.7
BRRI dhan95 (BR8210-10-3-1-2)	120	125	5.65	66	2.5	MB	1.4	8.0	28.0
BRRI dhan49 (ck)	103	130	5.06	65	2.5	MB	1.3	8.5	24.7

*Mean of 10 locations

Investigators: M A Kader, A K M Shalahuddin, Al Amin and Tapan Kumar.

selected for further evaluation. As part of nucleus seed maintenance of Boro rice varieties, a total of 42 varieties were grown in varietal display lot and panicles as well as bulked seeds were collected. In addition, 235 parental lines fingerprinted with 1k-RiCA SNP were maintained as nucleus stock.

Investigators: Wazifa Afrin, Md Emam Ahmed, Fahmida Akhter, Md Rafiqul Islam, Md Shalauddin Ahmed, M R A Sarker, K M Iftekharuddaula 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^{-1} yield and 135-145 days growth duration for haor areas) and high yielding medium duration (6.5-7.5 t ha^{-1} yield with 145-150 days growth duration for northern regions) rice varieties tolerant to cold stress at seedling and reproductive stage. Ten crosses were made. Eight crosses were confirmed as true F_1 through F_1 verification using QC genotyping with purity SNP panel. In total 9,540 individual plants were harvested from 83 crosses of F_2-F_6 generation by RGA system. Out of 5,370 lines, 1,780 uniform lines were selected from LST based on uniformity in heading, plant height and grain type. Also disease incidence was recorded after artificial inoculation. Fifty-two genotypes were selected from 668 breeding lines tested under cold stress conditions in OYT. From AYT, 12 genotypes were selected and had yield advantage over check varieties. In multi-location trials in haor areas and regional yield trials, two genotypes were selected based on growth duration, yield and other morpho-agronomic traits. In addition, 389 breeding lines with 1k-RiCA SNP fingerprinting data were maintained as nucleus stock.

Investigators : Wazifa Afrin, Md Emam Ahmed, Md Anisar Rahman, Fahmida Akhter, Md Rokebul Hassan, M R A Sarker, Md Rafiqul Islam, K M Iftekharuddaula and P S Biswas.

Development of salt tolerant rice. 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 southern coastal zone of Bangladesh. In T. Aman season, 20 crosses were made using 16 parents. A total of 26 F_1s were confirmed and selected during T. Aman season. The field (RGA) was done at BRRI farm, Gazipur and Satkhira. In T. Aman season, 46,524 segregating progenies derived from 68 crosses were advanced in F_2-F_6 generations using FRGA technique. Yield trials were conducted in Gazipur, Koyra, Khulna and Assasuni, Debhata, Kaliganj and BRRI RS, farm Satkhira in T. Aman season with salinity level (EC) varied from 1.2 dS/m - 25 dS/m (Fig.1). Out of 3,850 breeding lines, 778 lines were selected on the basis of strong culm, acceptable grain type and uniformity at heading stage in field condition. A total of 666 LST lines were evaluated for grain quality traits. Amylose content of the most of the genotypes (394) was found high that ranged from 26.-30.0 % (Fig. 2)

Forty-eight genotypes out of 98 genotypes were selected from OYT. Four PYTs (PYT-1 to PYT-4) were conducted using 80 breeding lines. Forty-seven genotypes were selected from these trials depending on yield, salinity tolerance and phenotypic acceptability. Five genotypes, out of 14, were selected from SYT and 10 genotypes were selected from RYT for further evaluation.

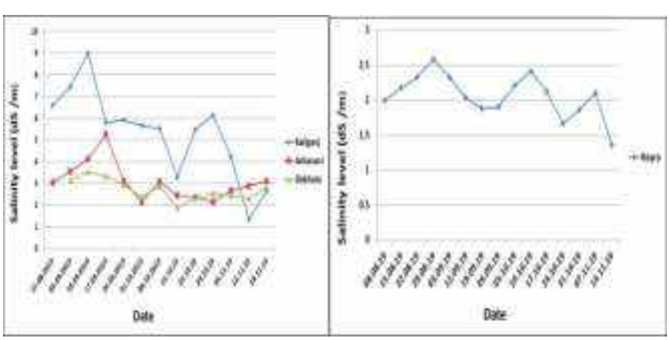


Fig. 1. Salinity level at experimental fields in coastal saline areas in T. Aman 2019-20.

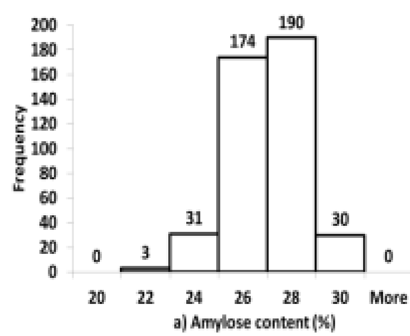


Fig. 2. Frequency distribution of the LST lines for amylose content in T. Aman 2019-20.

In Boro Season, 20 crosses were made using 19 parents. In total 25 F_1s were confirmed as true hybrid through F_1 verification by quality check (QC) genotyping with purity SNP panel. Totally 44,458 segregating progenies from 65 crosses (F_3-F_5) were harvested from FRGA nursery. In LST trial, 292 lines out of 2,703 lines were selected on the basis of plant type, grain quality and uniformity in flowering under field condition. These LST lines derived from eight elite vs elite crosses. A total of 406 genotypes selected out of 1,283 from OYT based on growth duration, yield, and homogeneity in different morpho-agronomic traits. Out of 106 genotypes, 25 genotypes were selected from five PYTs. Six genotypes were selected from AYT. Four genotypes from RYT-1 and four genotypes from RYT-2 were selected. Yield trials were conducted in Gazipur, Khulna and Satkhira during Boro season where salinity level (EC) varied from 3.3 dS/m to 27.3 dS/m (Fig. 3) in the field.

The proposed genotype IR83484-3-B-7-1-1-1 was evaluated under PVT by NSB team in eight locations of coastal areas of Bangladesh in Boro 2018-19. The advanced lines produced 0.7 t ha^{-1} higher yield than the salinity tolerant check BRRI dhan67 (Table 4).

Development of premium quality rice (PQR), T. Aman 2019-20. Efforts were made to develop aromatic and non-aromatic fine quality rice with national and international standards (Kalizira/ Chinigura/Kataribhog/Radhunipagol type), anti-oxidant enriched (black and red) rice and photosensitive rice for domestic use and export. In T. Aman 2019-20, totally 37 crosses (24 crosses for PQR, six for anti-oxidant enriched rice and seven for photosensitive rice) were made and 27 crosses were confirmed as true hybrid (12 for PQR, 10 for anti-oxidant enriched rice and five for photosensitive rice). A total of 306 progenies of 14 crosses were selected from F_3 generation. From pedigree nurseries, 48 progenies of eight crosses were selected from F_{4-5} generation. Sixty-six fixed progenies were selected as bulk from F_6 generation. In total, 29 genotypes were selected out of 42 from observational trial (OT) based on growth duration, yield, homogeneity and morpho-agronomic traits. From PYT#1, 2 and 3, totally 23 genotypes were selected out of 40 genotypes. In SYT#1, 2 & 3 total 27 genotypes were selected out of 42 genotypes. The advanced genotypes had 0.7-1.5 t ha^{-1} yield advantage over check varieties Kalizira, Chinigura, Kataribhog, BRRI dhan34 and BRRI dhan37. From RYT three genotypes were selected for conducting ALART in next T. Aman 2020-21. For the development of anti-oxidant rice, 459 progenies of 32 crosses were selected from F_{2-3} generation. In total 5,850 progenies of three crosses were harvested from F_3 generation in RGA method. For photosensitive rice development 126 progenies of nine crosses were selected from F_2 and 14 progenies of three crosses were selected from F_4 generation. Totally, 19 genotypes were selected out of 35 from observational trial (OT) based on growth duration, yield, homogeneity and morpho-agronomic traits. From PYT, 12 genotypes were selected out of 22 genotypes and eight genotypes were selected out of 20 genotypes from SYT based on growth duration, yield, homogeneity and morpho-agronomic traits. The advanced lines BR9178-7-2-4-4, BR8528-2-2-3-HR2, BR8882-30-2-5-2 performed better than the check varieties and will be advanced to ALART (Table 5).

Investigators: M Akhlasur Rahman, Hasina Khatun, Md Ruhul Quddus, Md Asif Rahman, R Farzana Disha, Avijit Biswas, R Yasmeen and M Ibrahim

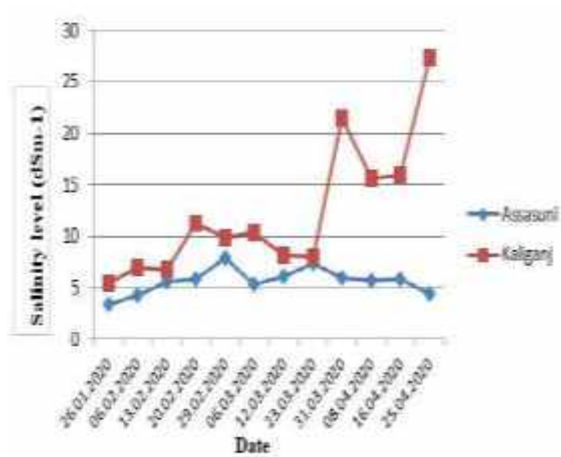


Fig. 1. Salinity level at experimental fields in coastal saline areas in Boro 2019-20.

Table 4. Performance of the line IR83484-3-B-7-1-1-1 under proposed variety trial, salinity, Boro 2018-19.

Designation	Plant height (cm) *	Growth duration (day) *	Grain yield (t ha^{-1}) *	Grain characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
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)

Table 5. Performance of genotypes in regional yield trial (RYT), PQR, T. Aman 2019-20.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})					Mean	Remarks
			Gaz	Rajsh	Kus	Rang	Hbj		
BR9178-7-2-4-4*	131	143	2.49	2.81	3.72	2.98	3.80	3.16	Kataribhog type, Aroma**
BR8528-2-2-3-HR2*	118	131	3.61	2.11	4.69	3.53	2.98	3.38	Kataribhog type, Aroma*
BR8882-30-2-5-2*	133	139	4.51	3.44	4.27	4.34	3.20	3.95	Kataribhog type, coloured grain
Kataribhog (ck)	149	138	2.94	1.59	2.90	3.21	3.42	2.61	Aroma**
Dinajpur Kataribhog (Local ck)	154	140	2.57	0.57	2.73	2.27	2.36	2.10	Aroma*
BRRI dhan37 (Std. ck)	134	141	3.22	2.03	3.14	3.55	3.51	3.09	Aroma**
Heritability (%)	67	85	89	64	92	78	68	72	

Investigators: K M Iftekharuddaula, M E Haq and T L Aditya

Development of premium quality rice (PQR), Boro. The project was aimed to develop aromatic and non-aromatic fine quality rice with international (Basmati/Banglamati/SoruBalam type) standards in Boro season for domestic use and export. Totally 1,495 F_1 seeds were obtained from 23 crosses. In Boro 2019-20, fourteen F_1 crosses were confirmed out of 16 crosses as true hybrid. A total of 7,099 progenies of 11 crosses from F_{2-3} generation were harvested through RGA method. In total, 16,409 progenies of 21 crosses from F_{4-5} generation were advanced through RGA method. In observational yield trials, 40 genotypes were selected out of 76 genotypes tested. For preliminary yield trials, 12 were selected out of 23 tested genotypes. In secondary yield trials, five genotypes were selected out of seven tested genotypes. In RYT, two genotypes were selected out of four for conducting ALART in next Boro 2020-21. One ALART was conducted at 10 different locations of Bangladesh consisting of two advanced genotypes by Adaptive Research Division. PVT was conducted consisting of one proposed line (BRC266-5-1-1-1) with low GI value at 10 different locations of Bangladesh.

Investigators: M A Kader, M E Haq, A K M Shalahuddin, Kaniz Fatema and T L Aditya

Development of zinc enriched rice (ZER). The project was aimed to develop high yielding rice varieties with improved nutritional quality in terms of high zinc (Zn≥24 mg/kg) in polished grain as well as development of stress tolerant with zinc enriched rice varieties like submergence + zinc, drought + zinc, salinity + zinc and cold + zinc with improved grain yield. The experiments were conducted in both T. Aman and Boro seasons. In T. Aman, 23 single crosses were made from which 6,325 F_1 seeds were obtained. A total of 28 crosses were selected and confirmed as true F_1s. A total of 49,561 progenies from 70 crosses were advanced from F_{2-4} generation through RGA method. In pedigree method, 1,437 progenies were selected from F_5-$_6$ generation. Fourteen fixed lines were harvested as bulk from F_6 generation. From OYT, 101 genotypes were selected based on yield and growth duration considering significant difference in growth duration from the check variety. Totally, 13 genotypes from PYT#1 and PYT#2, six genotypes from SYT#1 and SYT#2 were selected. One genotype out of six was selected from RYT. One special trial was conducted at three different locations of BRRI and one genotype (BR8442-12-1-3-1-B5) was recommended for PVT evaluation (Table 6). TLS of BRRI dhan62 and BRI dhan72 were produced at the amount of 100 kg and 350 kg respectively. In Boro season, 50 single crosses were made from which 8,011 F_1 seeds were obtained. A total of 43 crosses were confirmed as true F_1s. From F_2 population 1,002 progenies, 647 progenies from F_4 population were harvested through RGA method. In pedigree method 912 progenies from F_{4-5} generation were selected. In addition, 118 fixed lines were isolated as bulk from F_6 generation. From OYT, 47 uniform genotypes were selected based on yield and growth duration considering significant difference in growth duration from the check variety. Totally six genotypes from PYT, three genotypes from SYT and two genotypes from RYT were selected. ALART was conducted consisting of one advanced line by Adaptive Research Division at 10 different locations of Bangladesh. PVT was conducted consisting of one proposed line (BR8631-12-3-5-P2) at 10 different locations of Bangladesh by Seed Certification Agency. TLS of BRRI dhan74 and BRRI dhban84 were produced at the amount of 450 kg and 700 kg respectively.

Investigators: M A Kader, M E Haq, A K M Shalahuddin and Kaniz Fatema

Development of disease resistant rice. Efforts were made for developing varieties resistant to bacterial blight (BB), rice tungro virus (RTV) and blast diseases. Seven crosses for BB and eight for blast in T. Aman and 15 crosses for BB and 16 for blast were made in Boro season. Seventeen crosses for BB and ten crosses for blast were confirmed as true F_1. A total of 18,400 progenies for BB and 12,800 progenies for blast were advanced from F_{2-6} generation through FRGA. Out of 5,308 lines, 1,815 uniform lines were identified from LST based on uniformity in heading, plant height and grain type. Also, disease incidence was recorded after artificial inoculation. Twenty-five genotypes for BB were selected from observational yield trial (OYT) in T. Aman season while 62 entries out of 281 for BB during Boro season showed better yield potential and agronomic performance over the check varieties and tolerance to BB. From PYT, six advanced lines were promoted based on growth duration, grain yield and BB score compared to the check varieties in T. Aman season and three genotypes for BB were selected in Boro season. From AYT, two genotypes in Boro season were selected considering to yield, growth duration, BB resistance and better grain quality characters. The promising BB resistant line BR8938-19-4-3-1-1 was evaluated under ALART, Boro 2018-19.

Investigators: M Khatun, S K Debsharma, S Das, M A I Khan and A Ara

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 T. Aman, 27 crosses were made using 16 parents and 15 crosses were confirmed as true hybrid. In total 48,950 segregating progenies from 68 crosses of F_2-F_5 generations were advanced using field rapid generation advanced (FRGA) technique. Out of

Table 6. Performance of genotypes in special yield trial, development of zinc enriched rice (ZER), T. Aman 2019-20.

Designation	GD (day)	PH (cm)	Grain Yield (t ha^{-1})			
			Gaz	Cum	Bar	Average
BR8442-12-1-3-1-B5**	135	143	5.76	5.67	6.01	5.81
BRRI dhan49 (ck)	134	108	5.59	5.02	5.53	5.38
BRRI dhan72 (ck)	129	123	5.71	5.01	5.67	5.47
BRRI dhan87 (ck)	126	128	5.55	5.76	5.81	5.71
BR8492-9-5-3-2 (RLR)	127	117	5.37	5.69	5.63	5.56
BR7528-2R-HR16-2-24-1 (ZER)	112	112	5.17	5.89	5.49	5.51
BRRI dhan39 (ck)	122	112	5.07	5.05	5.05	5.06
LSD (0.05)	3.51	9.00			0.41	
H (%)	0.97	0.94			0.74	

** selected for PVT evaluation in T. Aman 2020-21

2,871 LST lines, 460 genotypes were selected based on strong plant type, grain type and uniformity in heading under field condition that derived from seven different crosses. Fifty genotypes were selected from 124 breeding lines in OYT. Forty-four lines were selected from two PYT's. Twenty-nine genotypes were selected from two SYTs. 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 selected from RYT to carry out ALART that showed moderately resistance reaction to BPH (SES score 5.0). One advanced line (BR8693-8-4-2-1) was evaluated at 10 locations in different AEZs in Bangladesh as proposed variety trial (PVT). Table 1 shows, the performance of the proposed line. NSB may recommend this line for releasing as new insect resistant (Gall midge) variety. In Boro season, 23 crosses were made and all crosses were confirmed as true hybrid through F_1 verification using quality check (QC) genotyping with purity SNP panel. A total of 31,475 individual plants were harvested from 67 crosses in F_3-F_5 generations by FRGA technique. In LST, 256 lines having strong plant type, grain quality and uniformity in heading under field condition were selected from 2,042 breeding lines that are the descendants of eight crosses. Sixty-five out of 198 genotypes were selected from OYT. Out of 11 and six genotypes, three and two were selected from PYT and SYT respectively. From RYT, five genotypes such as BR9669-21-2-1-1-19, BR9669-23-3-2-23, BR9669-15-3-2-31, BR9891-19-2-2-8 and BR9891-19-2-2-28 were selected and had yield advantage (0.2-0.5 t ha^{-1}) over check varieties BRRI dhan58 and T27A (R. check). Seed certification agency (SCA) evaluated the proposed line BR8693-8-4-2-1 under PVT in T. Aman 2019-20 (Table 7).

Development of submergence and water stagnation tolerant rice varieties. The project is aimed to high yielding rice varieties tolerant to submergence (flash flooding) and medium stagnant water (MSW) stresses. Totally 2,305 F_1 seeds were obtained from 26 single crosses. Sixteen single and three multiple F_1s crosses were selected and confirmed through QC SNP panel analysis. Panicles of 4,256 from 9 F_2 crosses, 3,488 from 14 F_4, 6,432 from F_5 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 a total of 2,877 lines were genotyped with trait markers using custom SNP panel among which 285 lines were selected based on uniformity and traits markers like Sub1, Wx-A group, Wx-A_NB, xa13, Xa21 etc. In yield trial, out of 165 tested genotypes 49 were selected based on phenotypic acceptance, growth duration, survivability and higher yield performance. From OYT#1 four genotypes out of 14, from OYT#3, eight genotypes out of 28, from OYT#4, 17 genotypes out of 60, from PYT#2, four genotypes out of 15, from PYT#3, three genotypes out of 10, from SYT, five genotypes out of nine, from AYT, one genotype out of eight, were selected. In OYT#1, a photosensitive submergence tolerant genotype produced the highest yield of 5.6 t ha^{-1}. In OYT#3, the genotype BR11185-5R-467-5 produced higher yield (5.8 t ha^{-1}). The genotype BR11196-5R-38 obtained highest yield (6.4 t ha^{-1}) followed by BR11196-5R-133 (6.3 t ha^{-1}) having a growth duration of 132 days in OYT#4. In PYT#2 the highest yield was 5.7 t ha^{-1} given by the genotype IR14F550 followed by IR14F468 (6.6 t ha^{-1}) with 135 days growth duration. In PYT#3 the genotype BR9158-19-9-6-50-2-HR1 produced the highest pooled yield of 5.7 t ha^{-1} with a yield of 4.1 t ha^{-1} under stress condition. From AYT, one genotype with long slender grain viz IR16F1096 was selected that produced 5.1 t ha^{-1} with 135 days growth duration. From PVS, two genotypes viz IR13F441 and BR9158-3-2-2-14-3 were selected based on their performance both under submergence and rainfed condition.

Investigator: M Akhlasur Rahman, Md. Ruhul Amin Sarker, Hasina Khatun and M. Ruhul Quddus

Both of the entries showed higher survival with a pooled grain yield of 6.0 t ha^{-1} and 5.7 t ha^{-1}, respectively, under rainfed condition. Their yield under severe flooding were 3.6 t ha^{-1} and 3.3 t/ha. BR9158-3-2-2-14-3 also got the highest preference score in PVS function under rainfed condition. The pooled heritability obtained from grain yield of PVS trial conducted under flooding condition was 66 % indicating acceptable level of precision in this experiment.

Investigators: K M Iftekharuddaula, Sharmistha Ghosal and T L Aditya

Table 7. Performance of the proposed line (BR8693-8-4-2-1) in PVT, IRR, T. Aman 2019-20.

Designation	Plant height (cm)*	Growth duration (day)*	Grain Yield (t ha^{-1})*	Grain Characteristics					
				Milling Outturn (%)	HRY (%)	Appear ance	Chalki ness	Amy lose	IR
BR8693-8-4-2-1	116	133	5.10	72.7	66.0	Good	Tr	25	3.7
BRRI dhan49 (Ck)	103	131	4.82	69.9	61.3	Good	Wc9/Tr	25	4.5

*Mean of 10 locations (Gazipur, Mymensingh, Cumilla, Feni, Rajshahi, Dinajpur, Rangpur, Bogura, Jashore, Habiganj); IR: Imbibition Ratio

Development of drought tolerant rice (DTR). The project is aimed to develop high yielding rice varieties tolerant to drought stresses in the rainfed lowland rice ecosystem in T. Aman season. In T. Aman 2019-20, totally 1,647 F_1 seeds were obtained from 13 crosses. Ten F_1s were confirmed as true hybrid. A total of 28,055 individual panicles from 110 crosses of F_{2-6} were harvested through RGA method. From OYT, 17 uniform genotypes were selected based on yield and growth duration considering significant difference in growth duration from the check variety. In PYT, 13 genotypes were evaluated and in RYT nine genotypes were evaluated at seven different locations of BRRI, but none of the genotypes from these experiments were selected for further trials. In Boro 2019-20 reporting year, 10 F_1 crosses were confirmed as true hybrids. Panicles of 7,746 progenies from F_3 of 10 crosses, 2,580 progenies from F_4 generation of nine crosses, 11,612 progenies from F_5 generation of 45 crosses and 4,161 progenies from F_6 generation of 16 crosses were harvested at the time of maturity as well as preserved as well as processed with proper labels through RGA method.

Investigators: M A Kader, M E Haq, A K M Shalahuddin, Tapan Kumar and Kaniz 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 seven crosses were confirmed as true hybrids. From LST population of 1,400 lines of three crosses, 79 fixed lines were selected based on uniformity in flowering, plant type, grain type and higher predicted yield. From yield trial conducted under AWD condition 22 genotypes were selected from 88 genotypes grown. Eleven genotypes from OYT#1, three from OYT#2, four from OYT#3 and four from PYT were selected. However none of the genotypes produced higher yield than the check varieties BRRI dhan89 and BRRI dhan29. Only based on the similar yield performance and phenotypic acceptance the genotypes were selected for further evaluation.

Investigator: Sharmistha Ghosal, K M Iftekharuddaula and T L Aditya

Improvement of green super rice (GSR). The project aims at developing of less input but high yield potential genotypes with tolerance to different stresses. Four advanced lines from OYT in T. Aman season and 12 advanced lines out of 36 tested entries were selected from PYT based on earliness, grain quality and high yield potential in Boro season. Two genotypes were selected from SYT in T Aman season. Five entries out of 37 from SYT#1, eight out of 28 from SYT#2 and five out of 16 from SYT#3 were selected based on PAcp, growth duration, yield and grain quality. From AYT, three entries were selected from T. Aman and one genotype was isolated from Boro season. The proposed genotype 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. Both of the advanced lines produced 0.9-1.2 t/ha higher yield than the salinity tolerant check BRRI dhan67 (Table 8).

Investigators: M A Ali, M Khatun, M A Rahman, F Akter, M A Islam, M Ibrahim, R F Disha and S K Debsharma

Development of transgenic provitamin A, high Iron and zinc 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. In T. Aman 2019-20 season, six crosses were made for provitamin A enriched rice from which 3,631 F_1 seeds were produced. Totally 141 progenies were selected comprising three backcrosses from BC_3F_3

generations and 15 homozygous progenies were harvested as bulk from three crosses through marker-assisted selection method.

Investigators: M A Kader, M E Haq, A K M Shalahuddin, Tapan Kumar and Kaniz Fatema.

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 80 germplasm from five INGER nursery sets of T. Aman 2019 were selected to use in different breeding programmes for direct use in the breeding pipeline.

National Coordinator: K M Iftekharuddaula

Key Cooperator: Sharmistha Ghosal

Table 8. Performance of the salinity tolerant proposed lines under proposed variety trial (PVT), GSR, Boro 2018-19.

Designation	Plant height (cm) *	Growth duration (day) *	Grain yield (t ha^{-1})	Grain characteristics					
				Head rice yield (%)	L/B ratio	Size and shape	Elongation ratio	Protein (%)	Amylose (%)
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
HHZ12-SAL2-Y3-Y2 (GSR IR1-12-S2-Y3-Y2)	95	155	5.1	62.7	2.9	LB	1.5	8.4	24.9
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

SUMMARY

In the reporting year 2019-20, a short duration high yielding and protein enriched (10.80%) rice variety for Boro season has been developed. National Seed Board of Bangladesh approved the proposed line BR(Bio)9787-BC2-63-2-2 as BRRI dhan96. The variety produced 0.8 ton/ha higher yield than BRRI dhan28 with similar growth duration of BRRI dhan28. The average yield of BRRI dhan96 is 7 ton/ha. Twenty-one experiments were conducted under eight projects during the reporting period. A total of 68 homozygous lines were evaluated in different yield trials including OT, PYT, SYT and ALART. Among them 19 promising lines were selected based on phenotypic appearance, growth duration and yield performance for further evaluation. During Aus and T. Aman 2019, a total of 85, 148 and 105 EMS treated somaclonal plants (M_1SC_4) were selected from BRRI dhan48, BR11 and, Tilbajal respectively. On the other hand during Boro 2019-20, a total of 52, 16, 111 and 25 somaclonal plants (M_1SC_4) were selected from BRRI dhan28, BRRI dhan29, BRRI dhan86 and BRRI dhan92 respectively. A total of 165 somaclone lines (SC_4) developed from BRRI dhan48 were evaluated during Aus 2019 season. From them 65 plants were selected for further evaluation. A total of 161 (SC_4) and 82 (SC_3) antioxidant enriched plants were selected during T. Aman 2019. On the other hand, 66 (SC_3) and 81 (SC_2) antioxidant enriched plants were selected during Boro 2019-20. In total, 35 pedigree lines developed from wide hybridization were grown during T. Aman 2019 and among them 72 plants were selected. Eleven back crosses were done with previously embryo rescued plants to reduce hybrid sterility and 424 BC1F1 seeds were harvested. Genotyping was done using 20 polymorphic primers with 184 F_2 individuals developed from a cross between BR11 × Sadamota (Acc. no. 1876). From the mapping population 18 pedigree lines were grown in T. Aman 2019 and from them 11 plants were selected for further evaluation. A total of 71 selected F_2 progenies developed from a cross between BRRI dhan87 and Kalizira were screened against functional marker of fragrance gene *BADH2*. Among them, 19 aromatic, 36 heterozygous and 13 non-aromatic progenies were identified. 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 with standard checks by Adaptive Research Division, BRRI. cDNA was synthesized from RNA of treated and control *Oryza rufipogon* plant to observe the expression level and to clone dehydration responsive element binding (DREB) gene. The experiment was conducted to observe the expression level of *DREB* gene under drought and cold condition at different time points (0, 1, 3, 6, 12 and 24 hours). In all conditions, the expression of *DREB* gene was same while using RT-PCR (Fig 5.). *DREB* gene expression under both the control and stressed condition indicated its presence in all conditions. That is why; DNA was isolated from 24 rice genotypes to identify the variation of *DREB* gene sequence in those rice genotypes. *DREB* gene was amplified with genomic DNA of 24 rice genotypes and sequenced. Multiple alignment of *DREB* sequence was performed using CLASTALW by Bio Edit software. The nucleotide sequences of *DREB* gene of 24 genotypes were highly conserved and three conserved region was identified. Among 24 genotypes, 22 were separated into four groups: group I consisted of seven genotypes, group II consisted of five genotypes, group III consisted of four genotypes and group IV consist of six genotypes. But Pokkali and Bina dhan10 did not make cluster with any group.

After transformation with *GlyI and GlyII* genes five plants were confirmed by GlyI and GlyII primers and sequencing. Fifteen T3 seeds were harvested for further evaluation. *AeMDHAR* salt tolerant gene (from mangrove plant) containing transgenic MT24 was crossed with BRRI dhan28, BRRI dhan29, BRRI dhan67, BRRI dhan86 and BINA dhan10 to introgress *AeMDHAR salt* tolerant gene. Four BC_2F_1 plants of BRRI dhan28 were confirmed by gene specific primer. A construct was made by using vacuolar ATPase (*PVA*) from a wild rice, *Porteresia coarctata* to develop salt tolerant transgenic rice variety. Regeneration system was optimized for three newly developed rice varieties e.g. BRRI dhan86, BRRI dhan87 and BRRI dhan89 for future transformation study with Vacuolar ATPase (PVA) construct using different media combinations. For developing aromatic high yielding rice variety, two unique 20 nucleotide sequences from *BADH2* gene were selected for genome editing site using BLAST. Six primers

were designed for three reactions based on selected 20 nucleotide sequences and the sequence of plasmid vector. Also the cloning vector, with two inserts, was designed with SnapGene software. For developing high yielding blast resistant rice variety, *OsEFR922* gene sequence was collected from NCBI. Two unique 20 nucleotide sequences from *OsEFR922* gene were selected for genome editing site using BLAST. Six primers were designed for three reactions based on selected 20 nucleotide sequences and the sequence of plasmid vector. Also the cloning vector, with two inserts, was designed with SnapGene software for developing blast tolerant rice variety. Six thousand *Setaria* seeds were treated with 20 mM NMU solution in three time points (2 hours, 3 hours and 4 hours) and transplanted to field to get M1 plants. Besides, M2 seeds from 695 M1 generation plants were harvested (499 plants with 2 hours NMU treatment, 171 plants for three hours treatment and 25 plants for 4 hours treatment).

DEVELOPMENT OF DOUBLE HAPLOID RICE THROUGH ANTHER CULTURE

Low glycemic index (GI) rice variety

In T. Aman, 41 doubled haploids were grown in two OTs (Fig. 1). Among them seven lines were selected for PYT. In Boro 2019-20, seven doubled haploids were grown as PYT and among them two lines were selected.

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

Salt tolerant rice variety

A total of 5,799 and 7,011 hybrid anthers from 12 crosses were plated on N6 and M10 media. In total 11 calli were obtained. No green plants were regenerated yet. Six double haploid fixed lines from BRRI dhan28/ BRRI dhan61 cross were evaluated during Boro 2019-20 as OT. Among them three lines were selected for further evaluation (Table 1).

Investigator: Nilufar Yasmin Shaikh, Shahanaz Sultana, Shampa Das Joya and Md. Enamul Hoque.

Premium quality rice variety

A total of 7,328 and 8,306 hybrid anthers from eight crosses were plated on N6 and M10 media. In total, 22 calli were obtained but no green plant was regenerated. Fifteen crosses and a backcross were done and in total 648 seeds were harvested for future anther culture programme. Nineteen doubled haploid (DH_2) lines were evaluated in T. Aman 2019. Among them 7 and 10 plants were selected from BRRI dhan38/Bashful and BRRI dhan50/Bashful cross.

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

High yielding Aus rice variety

A total of 259 F_1 seeds were harvested from eight crosses for further anther culture.

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

Antioxidant enriched black rice variety

In Boro 2019-20, a total of 156 double haploid lines derived from a cross between BRRI dhan28 and Padi Kool were grown in the field. Among them 95 lines were selected for further evaluation.

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

Fig. 1. Field view of double haploid line of BR(Bio)10381-AC11-7-1.

Table 1. Agronomic characteristics of anther culture derived materials during Boro 2019-20 (OT).

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR(Bio)11310-AC1-1	98	147	5.44
BR(Bio)11310-AC1-2	94	143	6.65
BR(Bio)11310-AC1-3	97	149	5.34
BR(Bio)11310-AC2-1	94	142	6.43
BR(Bio)11310-AC2-2	95	143	6.54
BR(Bio)11310-AC2-3	96	149	5.27
BRRI dhan28	91	142	6.04
BRRI dhan61	98	149	6.33
BRRI dhan86	96	143	6.51
		Mean	6.06
		SD	0.56
		CV	9.25

High yielding favourable Boro rice variety

During Boro 2019-20, four anther culture derived doubled haploid lines were evaluated in a PYT with standard checks to select agronomically desirable and high yield potential materials. Among them three lines were selected depending on the duration and comparable yield with checks for further evaluation.

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

DEVELOPMENT OF RICE VARIETY THROUGH SOMACLONAL VARIATION

Somaclonal variants using EMS treated rice seed

In Aus and T. Aman 2019, a total of 85, 148 and 105 EMS treated somaclonal plants (M_1SC_4) were selected from BRRI dhan48, BR11 and, Tilbajal respectively. On the other hand in Boro 2019-20, a total of 52, 16, 111 and 25 EMS treated somaclonal plants (M_1SC_4) were selected from BRRI dhan28, BRRI dhan29, BRRI dhan86 and BRRI dhan92 respectively.

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

High yielding Aus variety

A total of 165 somaclone lines (SC_4) developed from BRRI dhan48 were evaluated during Aus 2019. From them 65 plants were selected for further evaluation. Nine fixed somaclonal lines were evaluated during Aus 2019 season as PYT. From them, five lines were selected for further evaluation.

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

Somaclone of BRRI dhan47

In Boro 2019-20, six somaclonal lines developed from BRRI dhan47 were evaluated as PYT. Among them, four lines were selected for further evaluation.

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

Antioxidant enriched black rice variety

A total of 161 (SC_4) and 82 (SC_3) antioxidant enriched plants were selected during T Aman 2019. On the other hand, a total of 66 (SC_3) and 81 (SC_2) antioxidant enriched plants were selected during Boro 2019-20.

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

DEVELOPMENT OF RICE VARIETY THROUGH WIDE HYBRIDIZATION

Wide hybridization followed by embryo rescue

In total 35 pedigree lines developed from wide hybridization were grown during T. Aman 2019. From them, 72 plants were selected (Table 2). Eleven back crosses were done with previously embryo rescued plants to reduce hybrid sterility and 424 BC_1F_1 seeds were harvested.

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

ALLELE MINING

Identification of QTLs for taller seedling height

Genotyping was done using 20 polymorphic primers with 184 F_2 individuals developed from a cross between BR11 × Sadamota (acc. no. 1576) (Fig. 2). From the mapping population a total of 186 pedigree lines were grown in T. Aman 2019 and from them 11 plants were selected for further evaluation.

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

Table 2. List of embryo rescue plant selected during T. Aman 2019.

Cross	Generation	No. of lines grown	No. of plants selected
BRRI dhan28/*O. nivara* (103821)	BC_1F_1	2	8
	BC_1F_2	5	12
	BC_1F_4	2	2
	BC_1F_5	4	14
BRRI dhan28/*O. glaberrima* (105190)	F_4	5	13
BRRI dhan87/*O. glaberrima* (105190)	F_4	5	6
BRRI dhan48/*O. glaberrima* (105190)	F_4	12	17
	Total	35	72

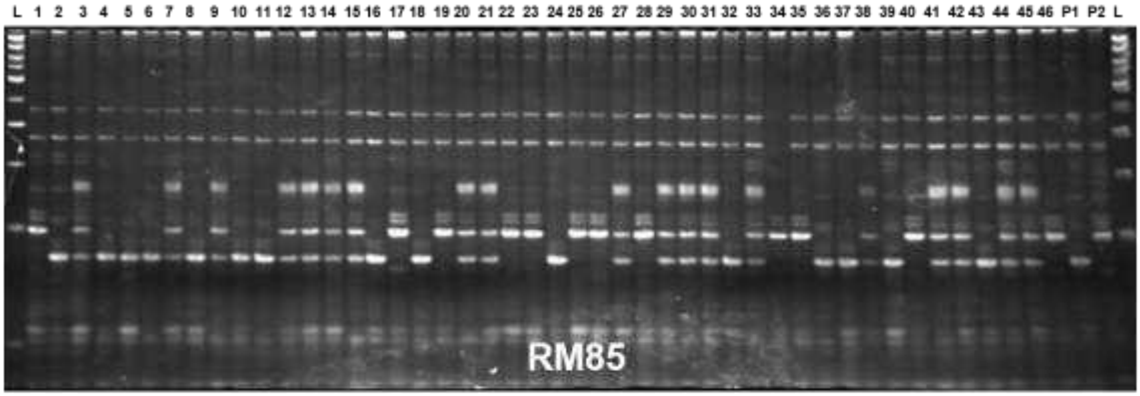


Fig. 2. Genotyping of F_2 population (BR11 x Sadamota acc. no. 1576) with primer RM85.

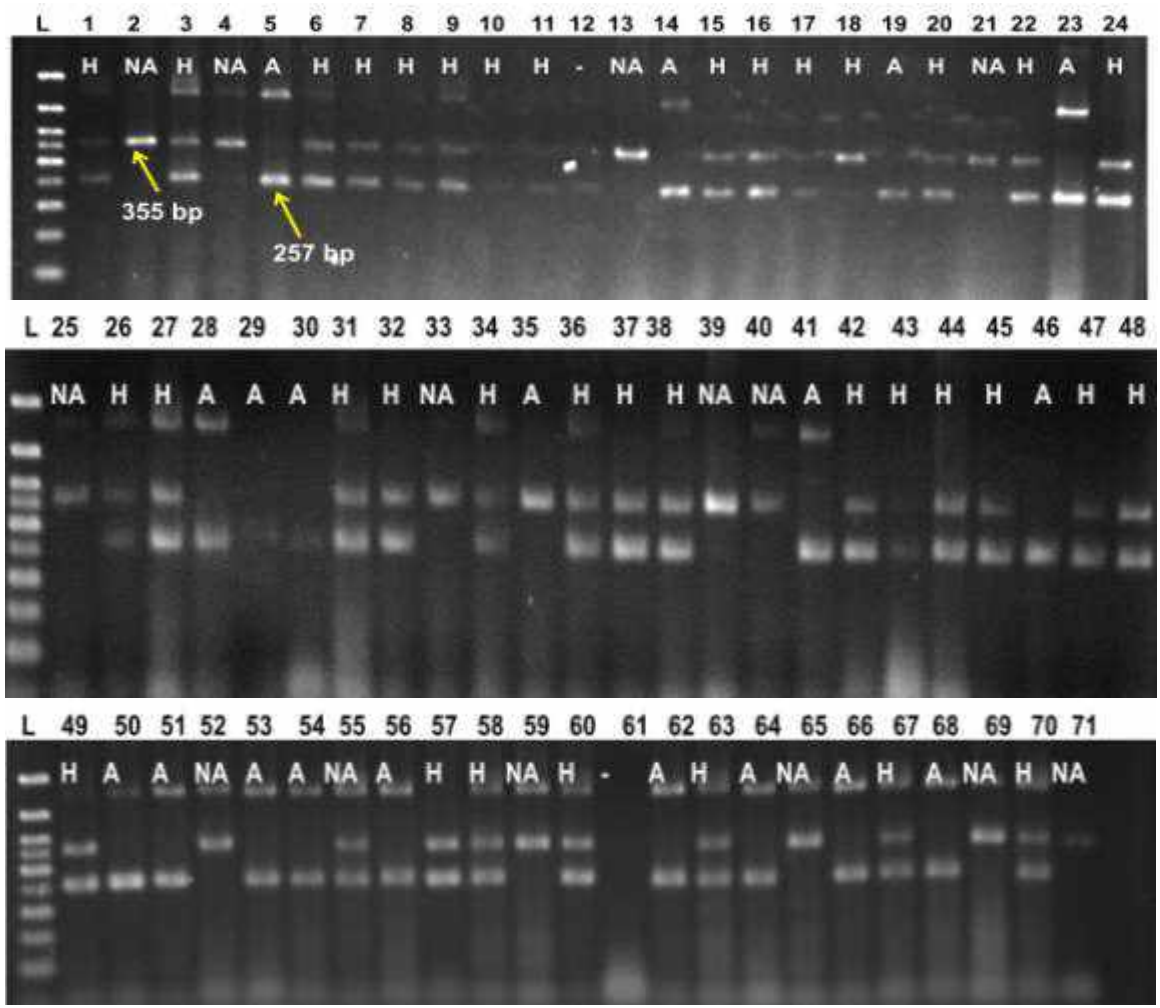


Fig 3. Identification of aromatic genotypes with simple functional markers for fragrance in F_2 population of BRRI dhan87 and Kalizira.

Validation of a simple functional marker for fragrance in non-Basmati fragrant rice varieties

A total of 71 selected F_2 progenies were developed from a cross between BRRI dhan87 and Kalizira were screened against functional marker of fragrance gene *BADH2* (Fig. 3). Among them 19 aromatic, 36 heterozygous and 13 non-aromatic progenies were identified.

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

H= Heterozygous, A=Aromatic (5, 14, 19, 23, 28-30, 35, 41, 46, 50, 51, 53, 54, 56, 62, 64, 66, 68), NA=Non Aromatic

Determination of aromatic genotypes (SYT-1, Plant Breeding) with Functional marker for *BADH2* gene

Among 18 SYT materials supplied by the Plant Breeding Division, eight lines were identified as aromatic using functional marker (Fig. 4).

Newly released variety: Advanced line BR(Bio)9787-BC2-63-2-2 developed from yield enhancement QTL study

A short duration high yielding and protein enriched (10.80%) rice variety for Boro season has been developed. National Seed Board of Bangladesh approved the proposed line BR(Bio)9787-BC2-63-2-2 as BRRI dhan96. The variety produced 0.8 ton/ha higher yield than BRRI dhan28 with similar growth duration of BRRI dhan28 (Table 3). The average yield of BRRI dhan96 is 7 ton/ha.

GENE PYRAMIDING

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 2019-20 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 treated and control *Oryza rufipogon* plant to observe the expression level and to clone dehydration responsive element binding (*DREB*) gene. The experiment was conducted to observe the expression level of *DREB* gene under drought and cold condition at different time points (0, 1, 3, 6, 12 and 24 hours). In all conditions, the expression of *DREB* gene was same while using RT-PCR (Fig 5.). *DREB* gene expression under both the control and stressed condition indicated its presence in all conditions. That is why, DNA was isolated from 24 rice genotypes to identify the variation of *DREB* gene sequence in those rice genotypes. *DREB* gene was amplified with genomic DNA of 24 rice genotypes (Fig. 6) and then sequenced. Multiple alignment of *DREB* sequence was performed using CLASTALW by BioEdit software (Fig. 7). The nucleotide sequences of *DREB* gene of 24 genotypes were highly conserved and three conserved region was identified. Among 24 genotypes, 22 were separated into four groups: group I consisted of seven genotypes, group II consisted of five genotypes, group III consisted of four genotypes and group IV consisted of six genotypes. But Pokkali and Bina dhan10 did not make cluster with any group (Fig. 8).

Investigator: Shahanaz Sultana, Jannatul Ferdous and Md Enamul Hoque

Table 3. Characteristics of BRRI dhan96.

Designation/Variety	PH (cm)	GD (day)	Yield (t/ha)	Grain characteristics						
				MO (%)	Decorticated grain			Amy (%)	ER	Protein (%)
					Length (mm)	L/B ratio	Size and shape			
BRRI dhan96 BR(Bio)9787-BC2-63-2-2	87	145	9.91	70.3	6.2	2.8	MB	28.0	1.6	10.8
BRRI dhan28 (ck)	97	146	6.08	71	6.4	3.2	MS	28.0	1.5	8.6

NB: MO= Milling outturn, PH= Plant height, GD= Growth duration, L= Length, B= Breadth, SS= Size and shape, Amy= Amylose, MB= Medium bold, LS=Long slender, ER =Elongation ratio.

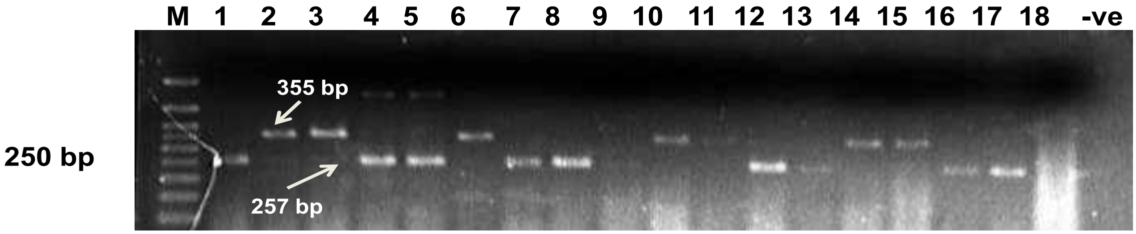


Fig 4. Identification of aromatic genotypes with simple functional markers for fragrance

Sl	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A/NA	A	NA	NA	A	A	NA	A	A	A	NA	NA	A	A	NA	NA	ck(A)	ck(A)	ck(A)
PL(bp)	257	355	355	257	257	355	257	257	257	355	355	257	257	355	355	257	257	257

Aromatic=A, Non aromatic=NA, PL= Product length
Investigator: Jannatul Ferdous, and Md. Enamul Hoque

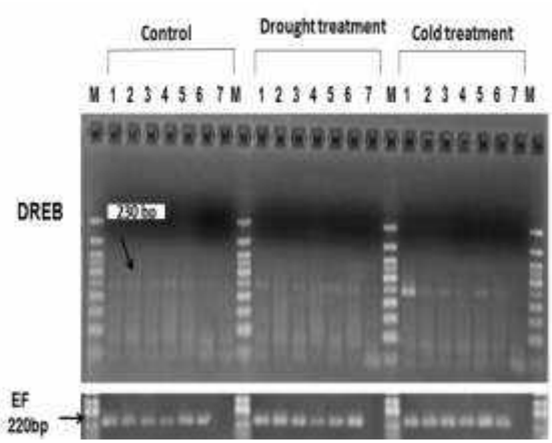


Fig. 5. RT-PCR with DREB and housekeeping gene EF , M: 50 bp DNA ladder, lane 1:0h, lane 2:1h, lane 3:3h, lane 4:6h, lane 5:12h, lane 6:24h, lane, 7: negative control.

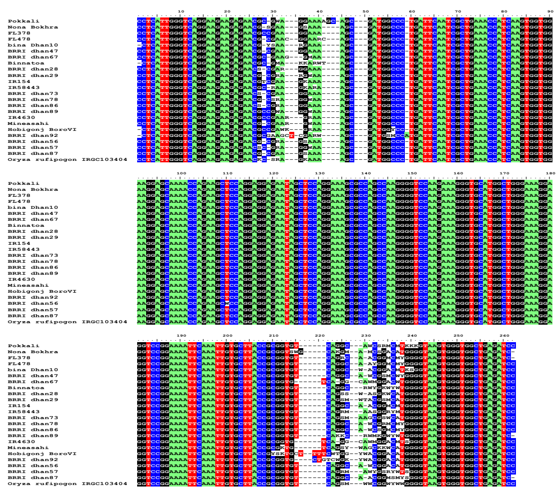


Fig. 7. Multiple alignment of DREB sequence of 24 different genotypes with reference.

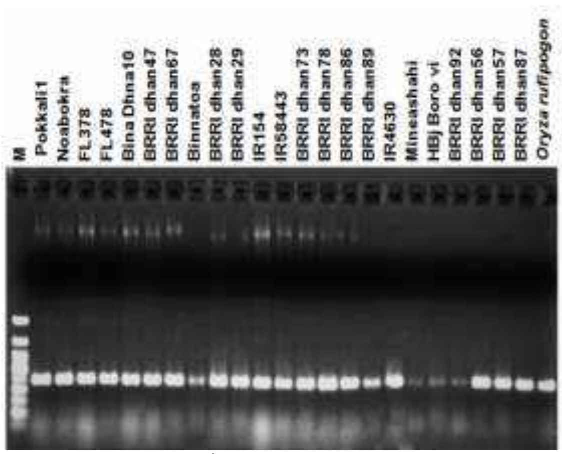


Fig. 6. Genomic DNA was amplified with DREB primer.

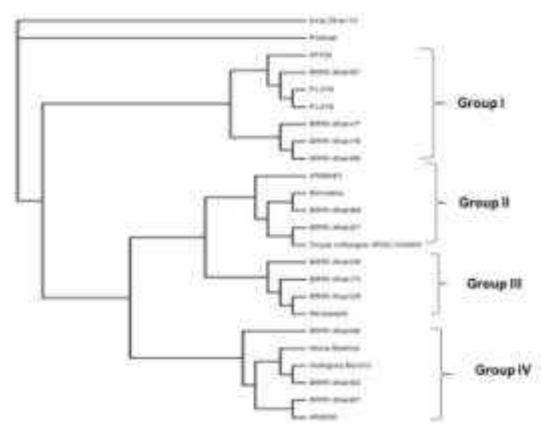


Fig. 8. Phylogenetic Tree using partial sequence of DREB gene by bioedit software.

RICE TRANSFORMATION

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

After transformation with *GlyI and GlyII* genes five plants were confirmed by GlyI and GlyII primers and sequencing. Fifteen T_3 seeds were harvested for further evaluation.

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

Introgression of salt tolerant mangrove gene

AeMDHAR salt tolerant gene (from mangrove plant) containing transgenic MT24 was crossed with BRRI dhan28, BRRI dhan29, BRRI dhan67, BRRI dhan86 and BINA dhan10 to introgress *AeMDHAR salt* tolerant gene. Four BC_2F_1 plants of BRRI dhan28 were confirmed by gene specific primer.

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

Development of salt tolerant transgenic rice with *PVA*

A construct was made by using vacuolar ATPase (*PVA*) from a wild rice, *Porteresia coarctata* to develop salt tolerant transgenic rice variety. Established of regeneration system is essential for any transformation study. That is why regeneration system was optimized for three newly developed rice varieties e.g. BRRI dhan86, BRRI dhan87 and BRRI dhan89 for future transformation with Vacuolar ATPase (PVA) construct using different media combination.

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

GENOME EDITING THROUGH CRISPR

Development of high yielding aromatic rice lines through genome editing

Two unique 20 nucleotide sequences from *BADH2* gene were selected for genome editing site using BLAST. Six primers were designed for three reactions based on selected 20 nucleotide sequences and the sequence of plasmid vector. Also the cloning vector (Fig. 9) with two inserts was designed with Snap Gene software.

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

OsEFR922 gene sequence was collected from NCBI. Two unique 20 nucleotide sequences from *OsEFR922* gene were selected for genome editing site using BLAST. Six primers were designed for three reactions based on selected 20 nucleotide sequences and the sequence of plasmid vector. Also the cloning vector (Fig. 9) with two inserts was designed with SnapGene software.

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

C4 RICE DEVELOPMENT

Identification of *Setaria* mutants losing C4 properties

This study is a background work for identifying major genes controlling C4 photosynthetic property. *Setaria italica* (Kaoun), being a C4 crop was chosen for this study since this is a C4 crop having comparatively smaller size and short life span. Therefore, we can handle more plants in small areas. Also more generations can be carried out in shorter time. Other C4 crop such as sugarcane or maize has long duration and larger size requiring larger space and longer time to maintain several generations. Considering all these, a number of 6,000 *Setaria* seeds were treated with 20 mM NMU solution in three time points (2 hours, 3 hours and 4 hours) and transplanted to field to get M1 plants (Fig. 10). Besides, 2000 seeds were planted untreated as control. Therefore, 6,000 M1 generation of *Setaria* plants were grown in the nethouse. Due to mutation stress, some plants died afterwards in the plot. Higher the exposure time to the NMU created more death to the plants. Eventually, M_2 seeds were harvested from 695 M_1 generation plants (499 plants with two hours NMU treatment, 171 plants for three hours treatment and 25 plants for four hours treatment).

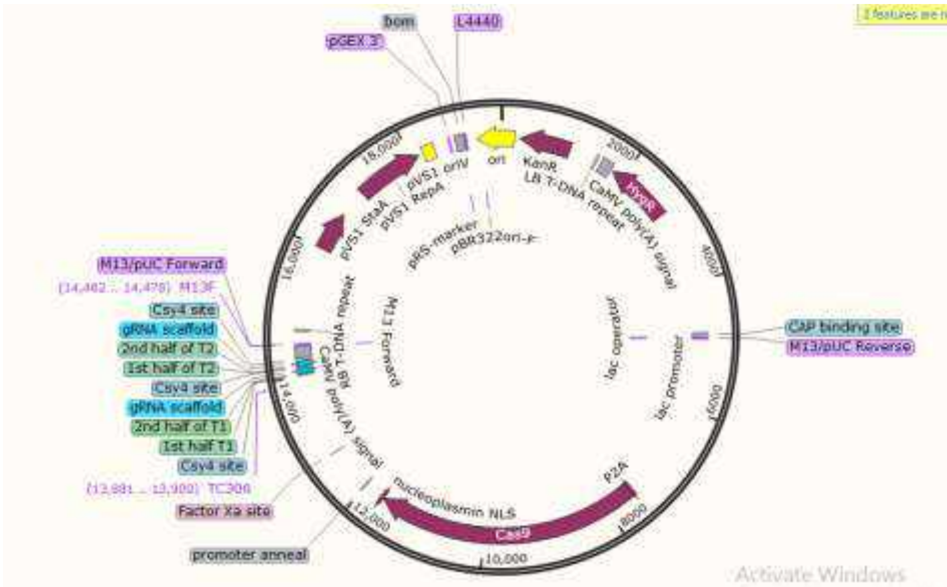


Fig. 9. Clonging vector with two inserts designed with Snap Gene software.

Fig. 10. Field evaluation of M_1 generation of *Setaria* plants.

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

Genetic Resources and Seed Division

SUMMARY

In total, 144 rice germplasm of which two in Aus, 54 *Jhum* rice from hilly areas, 82 in T. Aman and six in Boro seasons were collected from different districts of Bangladesh. Fifty-five germplasm accessions in T. Aman and 53 in Boro seasons were characterized against 51 morpho-agronomic traits. Characterization of 50 local germplasm for boosting yield through trait discovery in changing climatic conditions were also completed under KGF project and five superior germplasm were selected. Besides, 168 newly collected germplasm were also characterized for safeguarding from biopiracy under PBRG-NATP-2 project. Molecular characterization of 48 Boro germplasm using 55 SSR markers under PBRG-NATP-2 project along with 73 pigmented T. Aman germplasm using 28 SSR markers were performed. The highest PIC values were found in RM 206 (0.78) out of 55 and RM252 (0.76) out of 28 SSR markers and confirmed them as the best markers for the studied germplasm respectively.

Rejuvenation of 2,732 accessions were completed of which 531 in T. Aus 2019, 1,545 in T. Aman 2019 and 656 in Boro 2019-20. A total of 2,076 accessions of which 531 in Aus 2019 and 1,545 in T. Aman 2019 were processed and stored in short-term storage. Similarly, 150 and 228 accessions in Aus and 420 and 490 accessions in T. Aman were stored in medium and long-term storages respectively. Apart from this, 26 new germplasm were registered as new accessions (from accession number 8,579 to 8,604) in BRRI Genebank. Besides, 1,910 samples of rice germplasm and BRRI developed varieties were supplied to different users. Moreover, 400 accessions were entered into the database with collected available information during the reporting year.

One hundred and four BRRI developed and recommended rice varieties were maintained along with nucleus seed. Besides, nucleus seed stocks of 60 varieties were produced for the source of breeder seed. In total, 181.97 tons of breeder seed with tags of which 115.05 tons of 23 Boro varieties, 12.33 tons of 11 Aus varieties and 54.59 tons of 31 T. Aman varieties were produced. At the same time, 155.371 tons of breeder seed of which 92.709 tons of 21 Boro varieties, 11.69 tons of 11 Aus varieties and 50.972 tons of 31 T. Aman varieties were distributed among 1,000 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

Germplasm collection and acquisition. Three collection missions were made during the reporting year and 144 rice germplasm of which two in Aus, 54 *Jhum* rice, 82 in T. Aman and six in Boro seasons were collected from different districts of Bangladesh including hilly areas (Fig. 1).

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 2,732 germplasm of which 531 accessions in T. Aus 2019, 1,545 accessions in T. Aman 2019 and 656 accessions in Boro 2019-20 were rejuvenated in field for getting fresh seed and on average 500 g of seeds per accession were produced.

Morphological characterization of germplasm. Two experiments were conducted to characterize 108 rice germplasm (accessions as well as new collections) through 51 agro-morphological traits (both quantitative and qualitative characters) using the Rice Germplasm Descriptors and Evaluation Form, GRSD, BRRI at GRSD, BRRI, Gazipur. 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. 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 T. Aman 2019, 55 germplasm were characterized through 20 quantitative characters. Among them nine genotypes had short (<120 days), eight had medium (120-130 days) and 38 had long (>130 days) growth duration (Table 1).

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

Twenty-three germplasm were found with short (<110 cm), 12 moderate (110-130 cm) and the rest (20) with long (>130 cm) plant height. Thirty-five germplasm were found with medium (20-25 cm), 15 had long (26-30 cm) and two had very long (>30 cm) panicle length. Seventeen genotypes were found in total tiller number with the range of 10-15 and 38 were found within the range of less than 10. For 1000-grain weight (TGW), four germplasm had very low (≤15 g), eight with low (16-19 g), 18 had medium (20-23 g), 13 with high (24-27 g) and 12 had very high (>27 g) TGW. Eighteen germplasm had moderate yield (5-10 g/hill) and most of them (36) possessed higher (>10 g) yield per hill.

The shortest growth duration (98 days) was observed in Chubu-125 (N/C13) and the longest (143 days) in Chinri gushi-Barisal-1 (BRRI Acc. no.12) and Ronjit (N/C17). The shortest plant height (62.8 cm) was observed in Takanari (N/C12) and the longest (160.8 cm) in Jhosua (Acc. 358). The lowest number of effective tillers (5) was observed in Khato Indian babu (N/C5) and Gojol goria (Acc. 347), while the highest (12) was in Hybrid-HBJ.A.VII.AC.9-50 (Acc. 28). Japan black rice (N/C15) and Hybrid-HBJ.A.VII.AC.9-50 (Acc. 28) had the highest (34 g) and Kalijira 3 (Acc. 247) had the lowest (13 g) TGW. The highest yield per hill (19.4 g) was observed in Hybrid-HBJ.A.VII.AC. 9-50 (Acc. 28) and the lowest (4.6 g) in Koshihikari (N/C9).

In Boro 2019-20, 53 germplasm were characterized on the bases of 20 quantitative characters. Among them 14 germplasm had medium (135-150 days) and 39 had long (>150 days) growth duration (Table 2). Twenty-three germplasm were found with short (<110 cm), 28 moderate (110-130 cm) and the rest (2) with long (>130 cm) plant height. Two had short (<20 cm) panicle length, 48 were found with medium (20-25 cm) and three had long (26-30 cm) panicle length. Thirty-six germplasm had total tiller number with the range of 11-15, and 17 had low (<10). Considering the decorticated grain length-breadth ratio, 44 germplasm were medium slender (2.1-3.0), seven were bold (1.1-2.0) and two were slender (>3.0) types grain. For TGW, five germplasm had low (16-19 g), 31 had medium (20-23 g) and 17 had high (24-27g) TGW. One had moderate (5-10 g/hill) and 52 had higher (>10 g) yield per hill.

The shortest growth duration (147 days) was observed in Boro 34/1 (Acc. 2213) and the longest (162 days) in Kanihati (NC). The shortest plant height (88.2 cm) was observed in Kanihati-31(NC) and the longest (131 cm) in Boro-1120 (Acc. 2240). The highest number of tillers (14) was observed in Boro-507 germplasm (Acc. 2236) and the lowest (7) in Boro-1120 (Acc. 2240). Boro-1275 (Acc. 2242) had the lowest (16.0 g) and Kanihati-32 had the highest (27 g) TGW. The highest yield per hill (25 g) was observed in Dhali Boro 74/2 (Acc. 2244) and the lowest (10 g) in Tupa (Acc. 2257). In conclusion, the variety having higher yield would be utilized in a crossing programme, if other characters satisfy the breeder’s objectives.

Characterization of germplasm for boosting yield through trait discovery in changing climatic conditions. A total of 50 T. Aman rice germplasm were studied for different traits to select the suitable/ desired/ superior germplasm. Five germplasm *viz.* Marich Ful, Mulai, Agar Sail, Kuisari and Tapo Aman were selected on the basis of their morpho-agronomic traits (Table 3). One of the selected germplasm, 'Mulai' showed highest panicle length (32 cm) with minimum unfilled grain per panicle (8.97%). Dry grain weight for five hills of the selected germplasm showed the difference from the local germplasm and it was 35.3 g for Marich Ful. The maximum dry grain weight of the studied germplasm was 38.8 g and the minimum was 10.2 g. However, all of the germplasm are short to long durated considering days to maturity (160 days maximum). Finally, the utmost important point is the filled grain number per panicle (85.41% in Marich Ful), which is higher in all selected germplasm along with minimum unfilled grain.

Molecular characterization of rice germplasm. Forty-eight Boro rice germplasm were studied in the Molecular Laboratory of Genetic Resources and Seed Division of 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 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). Fifty-eight SSRs of well distributed over all 12 chromosomes of rice were used, in which 55 were found to be polymorphic for diversity analysis. Most of these markers were obtained from a panel of standard SSR markers proposed by CGIAR for rice diversity analysis (Roy *et al.*, 2016; Islam *et al*., 2018).

A total of 228 alleles were identified. The average number of alleles per locus was 4.15, ranged from 2 (RM133, RM145, RM212, RM316, RM320, RM338, RM411, RM452, RM455 and RM484) to 10 (RM206). The gene diversity ranged from 0.04 to 0.81, with an average of 0.39. The polymorphism information content (PIC) for the SSR loci ranged from 0.04 (RM455) to 0.78 (RM206). Primer RM206 had the highest PIC value (0.78) and the highest number of alleles (10). Therefore, RM206 was detected as the highest level of polymorphism and RM206 is supposed to be the best marker for characterizing the 48 Boro rice germplasm. The frequency of the most common allele at each locus ranged from 29.17% (RM206) to 97.92% (RM455). On average, 73.83% of the 48 rice germplasm shared a common major allele at any given locus. Figure 2 shows the DNA profiles of 48 Boro rice germplasm with RM536 SSR marker. The genetic distance-based results seen in the unrooted neighbour-joining tree revealed that the 48 Boro rice germplasm were grouped into four major clusters (Fig. 3).The highest number of germplasm (37) were found in cluster I followed by clusters II (4), III (4) and the lowest in cluster IV (3).

Germplasm processing, registration and storage. In total 3,364 germplasm were processed and conserved with respective accession number in different storages of Genebank during reporting year. The germplasm were cleaned and dried with a seed moisture content of less than 9% for short-term storage.

In details, 2,076 accessions of which 531 in Aus 2019 and 1,545 in T. Aman 2019 were processed and stored in short-term storage. Similarly, 150 and 228 accessions in Aus and 420 and 490 accessions in T. Aman were stored in medium and long-term storages respectively during

Table 1. Some important features of characterized germplasm in T. Aman 2019.

Growth duration (days)		Plant height (cm)		Panicle length (cm)		No. of tiller		No. of Filled grain/panicle		Days to 50% flowering		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	8	<110	23	<20	3	<10	38	<100	15	<100	17	≤15	4	<5	1
120-130	8	110-130	12	20-25	35	10-15	17	100-150	33	100-125	38	16-19	8	5-10	18
>130	39	>130	20	26-30 >30	15 2	>15	0	>150	7	>125	0	20-23 24-27 >27	18 13 12	>10	36
Shortest (98)	Chubu-125 (N/C13)	Shortest (62.8)	Takanari (N/C12)	Shortest (14.6)	Chubu-125 (N/C13)	Lowest (5)	Khato indian babu (N/C5), Gojol goria (347)	Lowest (42)	Koshi hikari (N/C9)	Shortest (70)	Chubu-125 (N/C13))	Lowest (13.0)	Kali jira 3 (247)	Lowest (4.61)	Koshi hikari (N/C9)
Longest (143)	Chinri gushi-Barishal-1(12), Ronjit(N/C17)	Longest (160.8)	Jhosua (358)	Longest (33.4)	Jhosua (358)	Highest (12)	Hybrid-HBJ.A.VIII.AC. 9.50(28)	Highest (194)	Dhamine (N/C6)	Longest (114)	Ronjit (N/C17), Chinri gushi-Barisal-1(12)	Highest (34.0)	Japan black rice (N/C15), Hybrid-HBJ.A.VII I.AC. 9.50 (28)	Highest (19.38)	Hybrid-HBJ.A.VIII.AC. 9.50(28)
Mean	130.75	114.95		24.14		8.69		115.35		101.47		23.41		11.59	
Std. Dev	11.59	25.32		3.48		1.60		33.43		11.60		5.27		3.61	
CV	8.86	22.03		14.41		18.38		28.99		11.43		22.50		31.16	
LSD	3.06	6.69		0.92		0.42		8.83		3.06		1.39		0.95	

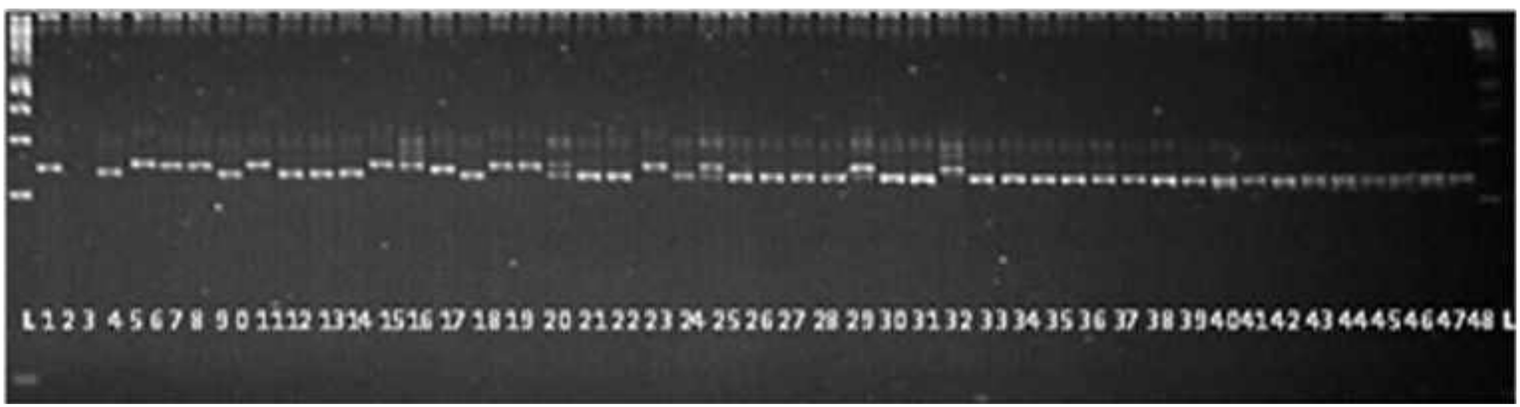
Table 2. Some important features of characterized germplasm in Boro 2019-20.

Growth duration (day)		Plant height (cm)		Panicle length (cm)		No. of tiller		No. of effective tiller		Decorticated grain LB ratio (L:W)		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	0	<110	23	<20	2	<10	17	<6	0	>3.0	2	<15	0	<5	0
135-150	14	110-130	28	20-25	48	11-15	36	6-10	40	2.1-3.0	44	16-19	5	5-10	1
>150	39	>130	2	26-30 >30	3 0	>15	0	>10	13	1.1-2.0 <1.1	7 0	20-23 24-27 >27	31 17 0	>10	52
Shortest (147)	(Boro 34/1) Acc. 2213	Shortest (88.2)	(Kanihati-31) NC	Shortest (19.00)	(Boro-522) Acc. 2237	Lowest (7)	(Boro-1120) Acc. 2240	Lowest (6)	(Boro-1120) Acc. 2240	Lowest (1.86)	(Tupa) Acc. 2257	Lowest (16)	(Boro1275) Acc. 2242	Lowest (10)	(Tupa) Acc. 2257
Longest (162)	(Kanihati) NC	Longest (131)	(Boro-1120) Acc. 2240	Longest (27.20)	(Dhali Boro 105/2) Acc. 2248	Highest (14)	(Boro-507) Acc. 2236	Highest (12)	(Boro-507) Acc. 2236	Highest (3.19)	(Kanihati-32) NC	Highest (27)	(Kanihati-32) NC	Highest (25)	(Dhali Boro 74/2) Acc. 2244
Mean	153	111		23.00		11		9		2		21.92		12.25	
Std. Dev.	3.24	8.80		2.09		1.60		1.35		0.25		3.61		3.98	
CV	2.12	7.90		9.05		15.07		14.42		11.27		16.47		30.95	
LSD	0.87	2.37		0.56		0.43		0.36		0.07		1.02		1.06	

Table 3. Performance of five selected T. Aman rice germplasm from 50 Genebank accession.

Sl no	Acc. no.	Acc. Name	SH (cm)	LGL (mm)	CL (cm)	TPH	ETN/ hill	DTM	PL (cm)	FGPP	UFGPP	LL (cm)	LW (mm)	TGW (g)	CD (mm)	Fresh Biomass (g, 5 hill)	Fresh GrainWt (g, 5hill)	Dry Biomass (g, 5Hill)	Dry GrainWt (g, 5Hill)	GL (mm)	GB (mm)	Grain L/B ratio
1	74	Marich Ful	43.6	10.6	112.8	14.8	13.0	122	27.2	192.0	32.8	69.2	10.3	29.8	6.13	153.13	46.09	46.47	35.32	8.88	2.92	3.04
2	672	Mulai	32.6	20.4	116.2	12.8	11.4	147	32.0	151.6	13.6	63.8	10.3	24.3	6.28	167.5	47.18	66.62	34.48	6.76	2.65	2.55
3	895	Agar Sail	32.0	22.4	103.8	13.6	11.8	151	30.4	148.8	18.4	66.6	10.2	22.8	5.51	131.38	36.31	49.16	29.9	6.85	3.02	2.27
4	617	Kuisari	28.8	16.4	108.8	16.4	12.2	154	26.8	125.6	10.0	72.4	10.4	26	6.91	175.58	39.4	73.74	29.72	7.97	3.06	2.60
5	962	Tapo Aman	43.4	18.2	112.6	18.6	16.2	150	30.4	96.2	14.0	73.8	6.40	26.8	6.29	190.28	35.66	72.04	27.54	8.54	3.07	2.78
Maximum (50 Acc.)			52.4	28.4	171.2	22.8	17.6	160	35.6	202.2	50.2	73.8	10.6	30.8	7.87	249.2	48.8	84.8	38.8	9.54	3.32	4.00
Minimun (50 Acc.)			28.8	10.4	65.0	10.4	7.8	117	19.8	65.8	3.2	45.2	2.7	10.7	4.32	65.2	14.4	22.5	10.2	5.55	1.77	1.93
Mean (50 Acc.)			37.9	16.2	115.5	15.7	12.0	142	28.6	122.2	16.3	63.7	9.6	22.7	6.07	135.0	30.64	52.8	24.4	7.79	2.72	2.89
LSD			2.32	1.53	6.49	1.08	0.69	4.12	1.15	12.97		2.46	0.63	1.95		15.95	3.06	5.42	2.58	0.41		0.17
CV			17.0	26.2	20.2	19.2	16.0	8.1	11.2	29.6		10.7	18.3	24.0		32.8	27.8	28.5	29.4	14.9		16.5

Legend: SH= Seedling height, LL=Leaf length, LW=Leaf width, LGL= Ligule length, CL=Culm length, CD=Culm diameter, TTN= Tiller per hill, ETN=Effective tiller number, DTM=Days to maturity, PL=Panicle length, FGPP=Filled grain per panicle, UFGPP=Un-filled grain per panicle, TGW=Thousand grain weight, GL=Grain length and GB=Grain breadth.



Legend: 1. Mi-pajang, 2. Dholiboro, 3. Kumri Boro, 4. Bairagi sail, 5. Tepikhorch, 6. Pankaich, 7. Borodeshi, 8.Gopal beshi, 9. Borail, 10. Boro 6/2, 11. Kali Boro, 12. Sonar geye, 13. Joya Boro, 14. Am Boro 2 (golden), 15. Batti Boro, 16. Madhabsail, 17. Jagli, 18. Jagli, 19. Local Boro, 20. Saita, 21. Dud Saita, 22. Bogra Boro, 23. Deshi Boro, 24. Jagli (Deshi Boro), 25. Borodhan, 26. Borojagli, 27. Jagli, 28. Deshi Boro, 29. Borodhan, 30. Boro (sunga), 31. Jala Boro, 32. Kali Boro 2/2, 33. Kali Boro 4/1, 34. Kali Boro 26, 35. Kali Boro 41/1, 36. Kali Boro 48/1, 37. Kali Boro 80/3, 38. Kali Boro 80/5, 39. Kali Boro 109/4, 40. Kali Boro 138/2, 41. Kali Boro 139/2, 42. Kali Boro 200, 43. Kali Boro 208, 44. Kali Boro 259, 45. Kali Boro 266, 46. Kali Boro 576, 47. Kali Boro 600, 48. Kali Boro 704.

Fig. 2. DNA profile of 48 Boro rice germplasm with SSR marker RM536.

the reporting year. Apart from this, 26 new germplasm were registered as new accessions (from accession number 8,579 to 8,604) 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. One hundred accessions in Aus, 225 in T. Aman and 120 in Boro seasons were checked randomly for viability (germination %) test in short-term storage. Among the randomly selected 445 stored germplasm, 192 had viability between 80-90% and 145 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 and long-term storages for October 2019 and March 2020 were found ranging from 79 to 96% and 79 to 98%, respectively, indicating the viability condition of stored germplasm in respective storages.

Seed viability of the germplasm just before storage in the Genebank was also monitored. The germination of 375 germplasm just before storage in short-term was carried out of which 100 were for Aus, 150 were T. Aman and 125 were Boro seasons. Among them, 237 had germination between 80-90% and 81 had above 90%. The germplasm that possessed less than 80% germination will be grown in the following season for safe keeping.

Germplasm distribution/exchange. A total of 1,910 samples were supplied to different users in the reporting year. Among the samples, 1,448 germplasm accessions were supplied for research purpose and 462 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.

Documentation of germplasm. Four hundred accessions were entered into the database with collected available information of the accession during the reporting year. The information, can be retrieved any time, if necessary.

SEED PRODUCTION AND VARIETY MAINTENANCE

Variety maintenance and nucleus seed production. One hundred and four BRRI developed and recommended rice varieties including 14 local 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.

Nucleus seed stock production. Sixty-four BRRI developed rice varieties of which 38 in T. Aman and 26 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

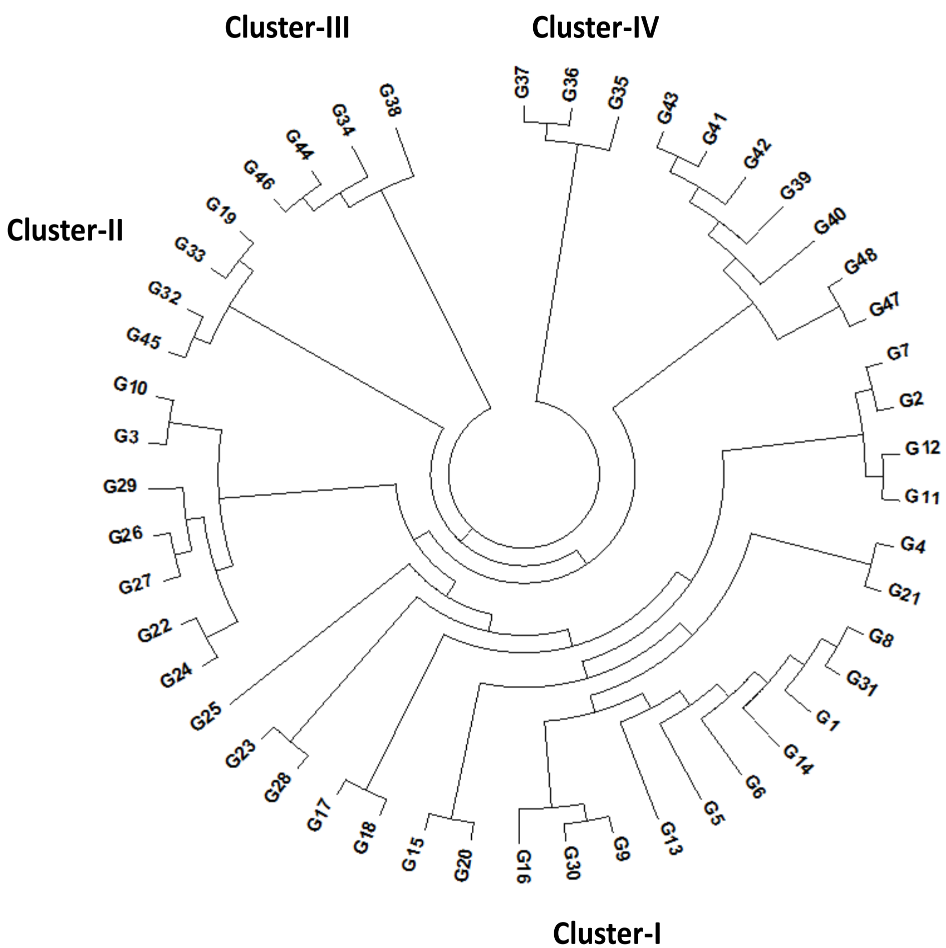


Fig. 3. An unrooted neighbour-joining tree showing the genetic relationships among 48 Boro rice germplasm.

Fig. 4. Pictorial views of monitoring breeder seed/ foundation seed production plots.

Table 4. List of BRRI developed and recommended rice varieties maintained during 2019-20.

Season	Type	Number	Variety
T. Aman	MV	50	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
	LIV	8	Nizersail, Latisail, Rajasail, Kalijira, Kataribhog, Basmati-D, Patnai23, Tilockkachari
Boro	MV	40	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
	LIV	6	Hbj Boro II, Hbj Boro IV, Hbj Boro VI, Hbj Boro VIII, Purbachi, IR8
Total		104	

then offered as seed lot for getting ‘tag’ from Seed Certification Agency (SCA) which is required for distribution.

A total of 181.97 tons of breeder seed with tags of which 115.05 tons of 23 Boro varieties, 12.33 tons of 11 Aus varieties and 54.59 tons of 31 T. Aman varieties and were produced during 2019-20 (Tables 5, 6 and 7). On the other hand, 155.37 tons of breeder seed of which 92.71 tons of 21 Boro varieties, 11.69 tons of 11 Aus varieties and 50.97 tons of 31 T. Aman varieties were distributed among the ‘Rice Seed Network’ partners (about 1000) during 2019-20 (Tables 8, 9 and 10).

Monitoring seed production plots and farms. Breeder seed production plots of BRRI regional stations (RSs) at Rangpur, Rajshahi, Habiganj, Bhanga, Cumilla and Sirajganj (Fig. 4) along with foundation seed production farms of BADC (Kashimpur, Mymensingh), ACI (Rangpur) and Doel Traders (Bogura) were visited to observe the varietal purity and performances of breeder and foundation seeds. During the visit, no major insect-pest damage was noticed in the plots. Varietal purity (%) was observed as average of more than 99% in all the varieties. The crops were found almost free from weeds. Isolation distance was properly maintained. Foundation seed (FS) producers were advised to discard three meters boundari lines, where isolation distance was not maintained. Overall crop conditions and management was satisfactory. The seed producers were also advised for thorough roguing by themselves for one more time before harvesting.

Table 5. Production of breeder seed (with tag) of Boro varieties during 2019-20.

Variety	BR3	BR14	BR16	BR26	BRRI dhan28	BRRI dhan29	BRRI dhan36	BRRI dhan47	BRRI dhan50	BRRI dhan55	BRRI dhan58	BRRI dhan59	BRRI dhan60	BRRI dhan61	BRRI dhan63	BRRI dhan64	BRRI dhan67	BRRI dhan68	BRRI dhan69	BRRI dhan74	BRRI dhan84	BRRI dhan88	BRRI dhan89	Total
Quantity	120	300	890	3,970	41,710	26,130	240	2,550	5,500	110	14,360	160	30	80	3,850	20	7,620	210	250	3,970	1,840	200	940	115,050

Table 6. Production of breeder seed (with tag) of Aus varieties during 2019-20.

Variety	BR3	BR14	BR16	BR26	BRRI dhan42	BRRI dhan43	BRRI dhan48	BRRI dhan55	BRRI dhan65	BRRI dhan82	BRRI dhan83	Total
Quantity	140	100	110	7,400	70	230	3,370	110	240	300	260	12,330

Table 7. Production of breeder seed (with tag) of T. Aman varieties during 2019-20.

Variety	BR10	BR11	BR22	BR23	BRRI dhan30	BRRI dhan32	BRRI dhan33	BRRI dhan34	BRRI dhan39	BRRI dhan41	BRRI dhan44	BRRI dhan46	BRRI dhan49	BRRI dhan51	BRRI dhan52	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 dhan80	BRRI dhan87	BRRI dhan90	BRRI dhan91	Total
Quantity	2,400	7,260	160	4,850	1,700	160	240	3,520	350	60	40	170	11,120	1,570	3,630	1,680	70	380	280	30	1,430	300	190	2,760	1,900	1,660	80	640	5,760	100	100	54,590

Table 8. Distribution (in kg) of breeder seed for Boro 2019-20.

Variety	BR3	BR14	BR16	BR26	BRRI dhan28	BRRI dhan29	BRRI dhan36	BRRI dhan47	BRRI dhan50	BRRI dhan55	BRRI dhan58	BRRI dhan59	BRRI dhan61	BRRI dhan63	BRRI dhan67	BRRI dhan68	BRRI dhan69	BRRI dhan74	BRRI dhan84	BRRI dhan88	BRRI dhan89	Total
Quantity	120	300	873	2,200	34,261	25,937	140	601	4,137	101	14,116	51	01	2,421	2,131	11	51	2,236	1,871	200	950	92,709

Table 9. Distribution (in kg) of breeder seed for Aus 2020.

Variety	BR3	BR14	BR16	BR26	BRRI dhan42	BRRI dhan43	BRRI dhan48	BRRI dhan55	BRRI dhan65	BRRI dhan82	BRRI dhan83	Total
Quantity	10	10	10	7,380	30	10	3370	110	240	310	210	11,690

Table 10. Distribution (in kg) of breeder seed for T. Aman 2020.

Variety	BR10	BR11	BR22	BR23	BRRI dhan30	BRRI dhan32	BRRI dhan33	BRRI dhan34	BRRI dhan39	BRRI dhan41	BRRI dhan44	BRRI dhan46	BRRI dhan49	BRRI dhan51	BRRI dhan52	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 dhan80	BRRI dhan87	BRRI dhan90	BRRI dhan91	Total
Quantity	2,360	5,723	140	4,135	1,690	180	240	3,571	350	60	40	150	11,240	1,620	3,580	1,460	70	225	230	30	1,460	310	180	2,635	1,250	1,490	80	600	5,705	68	100	50,972

EXPLORATORY AND GENETIC STUDIES

Preliminary yield trial (PYT) of Jirasail genotype. Jirasail accessions collected from Bogura, Jashore, Rajshahi, Naogaon and Tangail along with BRRI dhan70 for T. Aman and BRRI dhan81 for Boro seasons as standard checks were evaluated as Preliminary Yield Trial (PYT) at BRRI Gazipur during T. Aman 2019 and Boro 2019-20. The highest grain yield (4.9 t ha^{-1}) was obtained in Jirasail (Bogura), followed by Jirasail (Madhupur) as 3.63 t ha^{-1}, Jirasail (Rajshahi) as 2.95 t ha^{-1} and the lowest (2.58 t ha^{-1}) in Jirasail (Jashore) along with 3.96 t ha^{-1} for BRRI dhan70 as check during T. Aman 2019 (Table 11). During Boro 2019-20, the highest grain yield (6.3 t ha^{-1}) was also observed in Jirasail (Bogura), followed by Jirasail (Naogaon) with 5.5 t ha^{-1}, Jirasail (Rajshahi) with 4.7 t ha^{-1}, Jirasail (Madhupur) with 4 t ha^{-1}, and the lowest (2.1 t ha^{-1}) in Jirasail (Jashore) along with 4.3 t ha^{-1} for BRRI dhan81 as check (Table 12).

PYT of popular rice germplasm of southern region. Balam (Acc. 516, 1011), Jesso-Balam TAPL (Acc. 2464, 2472, 2473), Sada Mota (Acc. 7888) and Lal Mota (Acc. 7889) along with BRRI dhan70 and BRRI dhan80 as standard checks were evaluated for PYT during T. Aman 2019. The highest panicle length was found as 27.5 cm in Jesso-Balam (Acc. 2472). The highest number of filled grain (260) and grain yield per hill (26.4 g) were observed in Balam (Acc. 516). But, the highest grain yield per pot (6 sq. m) were observed with 1.94 kg in Jesso-Balam (Acc. 2473), followed by 1.9 kg in Sada Mota (Acc. 7888). Finally, Acc. 516, 2472 and 2473 along with BRRI dhan70 and BRRI dhan80 as checks and Acc. 7888 and 7889 along with BRRI dhan76 and BRRI dhan77 as checks were selected for two SYT during next T. Aman 2020.

PYT of aromatic rice germplasm. Eleven aromatic rice germplasm accessions *viz*. Chinigura, Kalijira, Jirakatari, Radhunipagol, Dudsail, Kataribhog, Sakkorkhana, Chinisail, Chiniatop,

Table 11. Yield and other characters of four Jirasail rice germplasm during T. Aman 2019.

Genotype	Plant height (cm)	No. of effective tiller	Filled grain/ panicle	Un-filled grain/ panicle	Thousand grain weight (g)	Growth duration (day)	Yield (t ha^{-1})
Jirasail (Bogura)	92.7	10	106	14	18.5	111	4.90
Jirasail (Jashore)	117.3	9	129	15	8.875	127	2.58
Jirasail (Rajshahi)	83.6	7	91	17	18.5	110	2.95
Jirasail (Madhupur)	82.8	7	115	18	18	106	3.63
BRRI dhan70 (ck)	89.6	8	90	16	22	127	3.96
CV	15.12	15.90	15.55	9.88	28.58	8.64	25.22
LSD	12.55	1.16	14.71	1.41	4.37	8.94	0.81
Max	117.3	10	129	18	22	127	4.90
Min	82.8	7	90	14	8.875	106	2.58

Table 12. Yield and other characters of four Jirasail rice germplasm during Boro 2019-20.

Genotype	Plant height (cm)	No. of effective tiller	Filled grain /panicle	Un-filled grain /panicle	Thousand grain weight (g)	Growth duration (day)	Yield (t ha^{-1})
Jirasail (Bogura)	97	9	147	21	15	127	6.3
Jirasail (Jashore)	96	10	141	17	11	133	2.1
Jirasail (Rajshahi)	96	10	121	13	20	129	4.7
Jirasail (Madhupur)	99	10	105	15	20	136	4.0
Jirasail (Naogaon)	103	10	113	16	20	136	5.5
BRRI dhan81 (ck)	105	10	102	13	22	135	4.3
CV	3.94	4.38	15.33	18.00	22.51	2.95	32.21
LSD	2.89	0.32	13.78	2.10	2.97	2.89	1.07
Max	105	10	147	21	22	136	6
Min	96	9	102	13	11	127	2

Dhonia, Ranisalute and BRRI dhan34 as standard checks were evaluated as PYT during T. Aman 2019. Table 13 presents the detailed yield performance of the germplasm for the studied parameter. The highest grain yield (4.5 t ha^{-1}) was observed in Chinisail, followed by 4.12 t ha^{-1} in Chiniatop, 4.07 t ha^{-1} in Chinigura, 3.17 t ha^{-1} in Dhonia and 3.06 t ha^{-1} in Jirakatari along with 3.57 t ha^{-1} for BRRI dhan34.

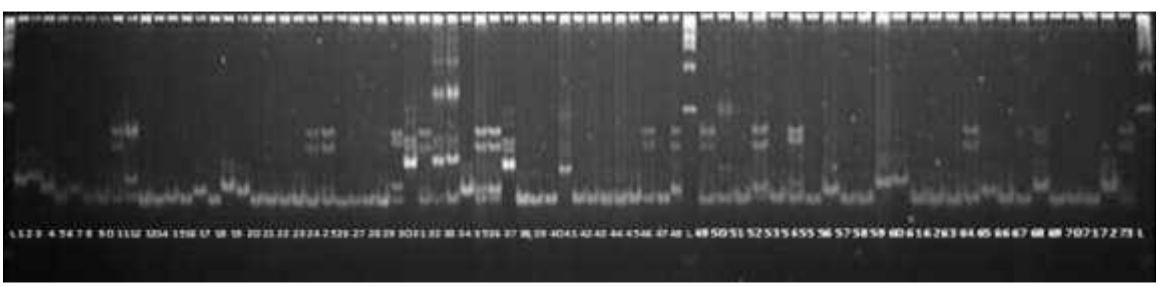
Characterization of pigmented rice germplasm using SSR markers. Seventy-three pigmented T. Aman rice germplasm were studied using 28 trait link SSR markers during T. Aman 2019. DNA extracted, PCR products, temperature profiles, gel documentation and data analysis were performed as same as described earlier in molecular characterization experiment under Germplasm Conservation and Management section. Twenty-eight trait link SSRs (simple sequence repeats) were used for diversity analysis.

All the 28 microsatellite primers revealed polymorphism between germplasm and 130 alleles were identified. The average number of alleles per locus was 5, ranging from 2 (RM213) to 8 (RM252). The gene diversity ranged from 0.08 to 0.79 with an average of 0.51. The PIC for the SSR loci ranged from 0.08 (RM201) to 0.76 (RM252). Primer RM252 had the highest PIC value (0.76) and was considered to be the best marker for the studied T. Aman rice germplasm. The frequency of the most common allele at each locus ranged from 35.62% (RM1) to 95.89% (RM201). On average, 64.73% of the73 pigmented rice germplasm shared a common major allele at any given locus. Figure 5 presents the DNA profiles of 73 pigmented T. Aman germplasm with SSR marker RM208. The genetic distance-based results seen in the unrooted neighbour-joining tree revealed that the studied germplasm were grouped into four major clusters using Mega software (Fig. 6). The highest numbers of germplasm (21) were found in cluster I, followed by cluster IV and cluster II. The cluster III contained the lowest (13) number in germplasm.

Identification and selection of sticky rice from *Jhum* rice germplasm. Thirty-four *Jhum* rice germplasm were characterized to study the selection criteria during Aus 2019. The highest grain yield per hill (17.9 g) was observed in Kutkutta Binni, followed by 17 g in Kala Binni and Binni-11, 16.8 g in Kernaicha, 16.7 g in May May (Binni), 16.5 g in Horin Binni and the lowest (5.1 g) in Badia. Finally data for amylose content is being processed for selection.

OUT RESEARCH ACTIVITIES

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 73, 8 and 92 partners before Boro 2019-20, Aus 2020 and T. Aman 2020 seasons, respectively for distributing breeder seed through BRRI 'Rice Seed Network'.



Legend: 1. Padi kool, 2. Padi Bengai, 3. Padichelum, 4. Selasih. 5. Lanran, 6. Kalodhan, 7. BW -1, 8. BW-4, 9. BW-5, 10. BW-17, 11. BW-46, 12. BW-48, 13. BW-56, 14. Khesail, 15. Ghora, 16. Ghora Dhan, 17. Jhora, 18. Ranga Binni, 19. Medi, 20. Kaisa Binni, 21. Biroi, 22. Forty dhan, 23. Urichetra, 24. Talmuri, 25. Birpala, 26. Lal Biroi, 27. Boro Haji, 28. Gochi, 29. Depa, 30. Hijol Digha, 31. Baradinga, 32. Hiday, 33. Shorshori, 34. Rakhi, 35. Degha, 36. Leda Binni, 37. Dhut Kachu, 38. Beni Gocha, 39. Shitagarol, 40. Hatisail, 41. Bushi Hara, 42. Chua Thai, 43. Bundamithi, 44. Bandail, 45. Bara Sail, 46. Khudra, 47. Kach Kolom, 48. Ghoro Kajal, 49. Uri Chadra, 50. Ranga Aman, 51. Betti Jona, 52. Bohi Trimota, 53. Shada Gabura, 54. Sotam, 55. Lal Binni, 56. Lal Mota, 57. Gabura(3), 58. Purple black (BR), 59. Purple sada (Cu), 60. Purple dhan-1, 61. Purple dhan-2, 62. Purple dhan-3, 63. Purple dhan-4, 64. Ijol Diga (1), 65. Bawoi Jhak (2), 66. Chini Sagar, 67. Banshapur, 68. Roshon Bok, 69. Purabinni (3), 70. Telot, 71. Joli Aman, 72. Molla Digha, 73. Netpasha and Ladder=1Kb.

Fig. 5. DNA profile of 73 pigmented T. Aman rice germplasm with SSR marker RM208.

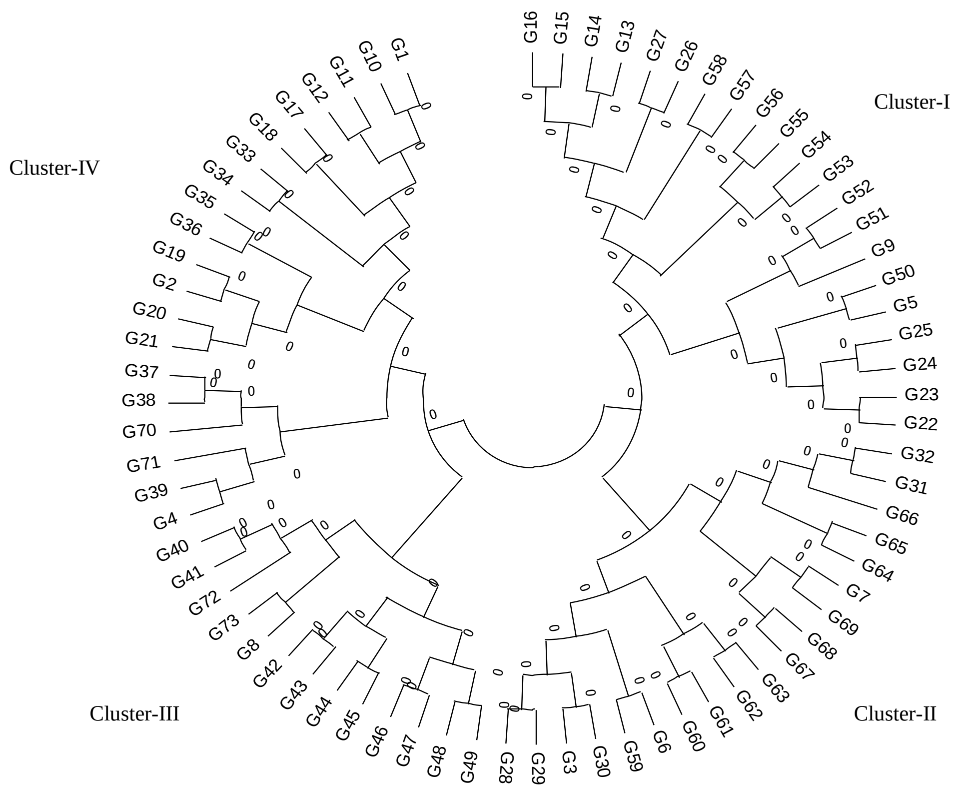


Fig. 6. Unrooted neighbor-joining tree showing distribution 73 pigmented T. Aman rice germplasm using 28 SSR markers.

Table 13. Performance of 11 aromatic rice germplasm for various yield contributing traits.

Genotype	Plant height (cm)	Growth duration (day)	Filled grain /panicle	Un-filled grain /panicle	Thousand grain weight (g)	Yield (t ha^{-1})
Chinigura	126.60	111	185	18	12.10	4.07
Kalijira	141.80	120	178	16	10.13	2.75
Jirakatari	130.90	110	197	23	12.95	3.06
Radunipagal	128.80	123	153	11	12.00	2.00
Dudsail	125.80	112	187	11	13.13	2.82
Kataribhog	111.47	116	116	13	13.67	2.72
Sakkorkhana	118.60	127	124	10	10.00	1.94
Chinisail	122.70	115	162	18	11.13	4.50
Chiniatop	115.60	111	178	16	9.83	4.12
Dhonia	124.70	100	134	15	18.90	3.17
Ranisalute	131.40	127	100	14	19.39	2.70
BRRI dhan34	115.70	115	199	12	10.25	3.57
CV	6.75	6.79	21.11	25.69	25.37	26.01
LSD	4.71	4.39	18.83	2.13	1.82	0.45
Max	141.80	127.00	198.60	23.30	19.39	4.50
Min	111.47	100.00	99.70	9.80	9.83	1.94

Grain Quality and Nutrition Division

SUMMARY

A total of 128 breeding lines were analyzed, among them 22 had more than 70% milling outtern, 22 had more than 60% head rice recovery, 13 have shown translucent (Tr) grain, 78 had long grain, 36 had more than 3.0 L/B ratio, 42 had more than 25.0% amylose content, 22 had more than 9.0% protein content, eight had more than 1.5 elongation ratio and 48 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 2,957 transforming breeding lines were evaluated for physicochemical and cooking properties for superior quality. Based on the performance on grain quality, we recommend 21 preliminary yield trial lines for further advancement.

Twenty newly developed BRRI HYVs from BRRI dhan70 to BRRI dhan89 were characterized by amino acid composition, mineral, fatty acid and antioxidant profiling. Essential amino acid compositions such as aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, histidine, lysine and arginine were evaluated for selected 20 BRRI HYVs. Few amino acids have some correlation with tastiness such as aspartic acid, glutamic acid, histidine and arginine. BRRI dhan77 possess the highest level of aspartic acid (0.55%), glutamic acid (1.12%), histidine (1.50%) and arginine (0.57%) among all the tested HYVs. Antioxidant profiling including FRAP, TPC and TAC parameters were measured for 20 BRRI HYVs. BRRI dhan82 possesses the lowest level of TAC (34.65%) and BRRI dhan88 possesses the highest level of TAC (108.44 µM AAE) followed by BRRI dhan87 (TAC 98.17 µM AAE) and BRRI dhan84 (TAC 101.52 µM AAE). BRRI dhan84 has the highest Zn content of 26.4 ppm followed by BRRI dhan72 of 20.2 ppm and BRRI dhan88 of 19.2 ppm. BRRI dhan84 possess the highest level of Fe (9.2 ppm), Ca (33.1 ppm) and P (3.4 gKg-1). We did not get any trace amount of heavy metals including Pb and As in our BRRI HYV samples at ppm level. BRRI dhan75 possesses the lowest saturated fatty acid (18.91% SFA) among all the tested HYVs. Its mono unsaturated fatty acid % is 37.79 and Poly unsaturated fatty acid% is 43.28% including 42.63% linoleic acid and 0.65% linolenic acid. RBO of BRRI dhan71 possesses the highest content of gamma oryzanol 1759 mg100g-1. These scientific information on BRRI HYVs will be helpful to promote these nutraceutical enriched HYVs in Bangladesh.

Puffed and flattened rice were produced from 10 BRRI varieties to evaluate the quality of the indigenous products. Comparing few parameters such as fully puffed rice weight, length and breadth of puffed rice, increased percentage of length and breadth with BR16 (Std), it is ascertained from the results that BRRI dhan81is better in producing whole puffed rice followed by BRRI dhan80, BRRI dhan84 and BRRI dhan88. Among the tested varieties, in terms of weight of broken flattened rice, thickness, increased percentage of length, and volume of 50 g flattened rice, BRRI dhan84 showed the best performance comparing with standard BR16 and other varieties.

GRAIN QUALITY CHARACTER

Determination of physicochemical and cooking properties of breeding lines

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 of BRRI divisions and outside 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 83 samples, 22 had more than 70% milling outtern and 22 had more than 60% head rice recovery. Out of 88 samples, 13 have shown translucent (Tr) grain that means 0% chalkiness, 43 have shown less than 10% chalkiness, 21 have shown between the range of 10.0-20.0% chalkiness and only one have shown more than 20% chalkiness. Out of 128 samples, 78 had long grain, 45 had medium grain and five had short grain. Among these samples, 36 had more than 3.0 L/B ratio, whereas 92 had between the range of 2.0-3.0 L/B ratio. Out of 83 samples, 0nly 0ne sample had more than 30.0 g 1000-grain wt. (TGW), 59 had between the ranges of 20.0-30.0 g TGW and 23 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 128 samples, 42 had more than 25.0% amylose, 82 had between the range of 20.0-25.0% amylose and only four had less than 20% amylose. Nutritional quality is measured by protein content. Out of 68 samples, 22 had more than 9.0% protein, 45 had between the range of 7.0-9.0% protein and only one 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 68 samples, two had more than 20 min. cooking time, 62 had between the range of 15-20 min. cooking time and only four had less than 15 min. cooking time. The samples, having more than 20 min. cooking time may give comparatively hard cooked rice. Among these samples, eight had more than 1.5 elongation ratio, 46 had between the range of 1.4-1.5 elongation ratio and 14 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, 48 had between the range of 4.0-5.0 volume expansion ratio and 20 had less than 4.0 volume expansion ratio (Table 2).

Table 1. Physical properties of rice samples.

Range	Sample no.
Milling outturn (%) (Total sample no. 83)	
>70.0	22
68.0-70.0	41
<68.0	20
Head rice recovery (%) (Total sample no. 83)	
>60.0	22
50.0-60.0	41
<50.0	20
Chalkiness (%) (Total sample no. 88)	
0 (Tr)	13
<10.0	43
10.0-20.0	21
>20.0	1
Length (mm) (Total sample no. 128)	
Long	78
Medium	45
Short	5
L/B ratio (Total sample no. 128)	
3.0>	36
2.0-3.0	92
<2.0	-
1000-grain wt. (g) (Total sample no. 83)	
>30.0	1
20.0-30.0	59
<20.0	23

Table 2. Chemical and cooking properties of rice samples.

Range	Sample no.
Alkali spreading Value (Total sample no. 66)	
6-7	5
4-5	52
<4	9
Amylose content (%) (Total sample no. 128)	
>25.0	42
20.0-25.0	82
<20.0	4
Protein content (%) (Total sample no. 68)	
>9.0	22
7.0-9.0	45
<7.0	1
Cooking time (mim.) (Total sample no. 68)	
>20	2
15.0-20	62
<15.0	4
Elongation ratio (Total sample no. 68)	
>1.5	8
1.4-1.5	46
<1.4	14
Volume expansion ratio (Total sample no. 68)	
>5.0	-
4.0-5.0	48
<4.0	20

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).
PI: M A S; **CI:** M A H, S S D, N F, T K S and H B S

Determination of physicochemical and cooking properties of transforming rice breeding lines
Grain quality is an important component for consumer's preference and profitability. For the transforming rice breeding project on rice grain quality screening, 2,957 (LST- line stage trial 2,603, OT-observational trial 137 and PYT-preliminary yield trial 217) were received, processed and evaluated.

A total of 2,740 LST and OT materials were analyzed for size, shape and amylose content. Grain length and length to breadth ratio determine the grain size and shape. Out of 2,740 LST and OT brown rice lines, 44 were extra long slender, followed by one extra long medium, 703 were long slender, 1,445 were long medium, 27 were medium slender, 501 were medium medium, one were medium bold, three were short medium, three were short bold and 12 were 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 2,342 lines, 1,931 had more than 25.0% amylose, 399 lines had amylose content between the range of 20.0-25.0% and 12 lines had less than 20.0% amylose (Table 4).

Milling is one of the parameters determining milled rice yield per unit paddy weight. Among 217 advanced lines 1,823 had high (>70%) and 32 lines had intermediate (68.0-70.0%) milling yield. On the contrary, 130 lines had within 50 to 60% head rice yield. Chalkiness in grain is not a positive quality factor for the unparboiled rice consumers. Around 181 lines had translucent grains. One hundred eighty lines had long (>6.0mm), 33 had medium (5.0-6.0 mm) and only four had short (< 5.0 mm) grains. One hundred fifty lines had long slender grain (Table 5).

Table 3. Physicochemical properties of promising samples.

AC #	Variety/Lines	Milling outturn (%)	Head rice recovery (%)	Chalkiness	Size & Shape	1000 grain wt. (g)	Alkali Spreading Value	Amylose (%)	Protein (%)	ER	IR
14572	BR9571-4-1-2-2-1	72	65	Tr	MB	17.7	4.7	25.8	8.8	1.4	3.9
14573	BR9571-4-2-6-1-1	70	59	Tr	MB	19.3	4.3	25.8	9.9	1.4	4.3
14576	BR9573-28-2-5-1-1	72	63	Tr	MB	16.9	4.3	26.9	8.8	1.3	4.3
14579	BR9571-13-1-9-1-1	72	67	Tr / Wb5 (few)	MB	16.4	5.0	26.9	8.3	1.5	4.5
14585	BR9574-9-5-3-1-1	72	68	Tr / Wb9 (few)	MB	19.4	4.8	28.0	8.9	1.4	4.5
14604	BR9868-19-40-3-B	71	64	Tr / Wb9 (few)	MB	19.1	4.5	27.4	8.3	1.5	4.5
15032	BR8526-38-2-1-HR1	70	64	Tr	MB	17.5	4.8	27.6	8.4	1.6	4.1
15033	Lata balam	67	53	Tr	Extra-LS	26.1	7.0	28.0	9.8	1.1	4.2
15109	BR(Bio)1144 7-3-10-7-1	70.3	59.5	Tr =Wb9	LS	27.5	5.0	25.6	8.4	1.4	3.7
15337	BRH13-2-4-6-4B	72	62	Tr /Opaque (few)	MS	16.3	3.1	22.5	8.0	1.4	4.5

Table 4. Physicochemical properties of Transforming Rice Breeding (LST and OT) rice sample.

Parameter and total number of sample	Classification	Number of Sample
Size and shape (Brown rice) (Total sample no. 2740)	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	12
Amylose content (%) (Total sample no. 2342)	High	1931
	Intermediate	399
	Low	12

Table 5. Physical properties of Transforming Rice Breeding (PYT) rice sample.

Range	Properties and sample number
	Milling outturn (%) (Total sample no. 217)
>70.0	183
68.0-70.0	32
<68.0	2
	Head rice recovery (%) (Total sample no. 217)
>60.0	-
50.0-60.0	130
<50.0	87
	Length (mm) (Total sample no. 217)
>6.0	180
5.0-6.0	33
<5.0	4
	L/B ratio (Total sample no. 217)
3.0>	150
2.0-3.0	66
<2.0	1
	Chalkiness (%) (Total sample no. 217)
(0) Tr	181
<10	15
10.0-20.0	11
<20.0	8
Opaque	2

Amylose content determines the quality of cooked rice. Out of 217 lines, 157 had high (>25%), 44 had intermediate (20-25%) and 16 had low (<20%) amylose content. Low amylose rice is not acceptable to our people. Protein content measures the nutritional value of rice. Out of 217 lines, 83 had high (9.0%) protein content, 105 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, 167 had intermediate and 27 had high gelatinization temperature (Table 6).

High volume expansion of rice is a positive quality factor for low-income group of people. All 36 had low (<3.5) volume expansion ratio. Elongation ratio is the important quality indicator. The grain that elongates more looks finer. On the contrary, the grain that expands more in girth looks coarse. Among 36 lines three had high (1.5) and 33 had intermediate (1.3-1.5) elongation ratio (Table 6).

PI: S S D; **CI:** M A S

Table 6. Chemical and cooking properties Of Transforming Rice Breeding (PYT) rice samples.

Range	Properties and sample no.
	Amylose content (%) (Total sample no. 217)
>25.0	157
20.0-25.0	44
<20.0	16
	Protein content (%) (Total sample no. 217)
>9.0	83
7.0-9.0	105
<7.0	29
	Alkali Spreading Value (Total sample no. 217)
1.0-3,0	27
3.1- 5.9	167
> 6.0	23
	Cooking time (min.) (Total sample no. 36)*
> 20	1
15-20	35
	Elongation ratio (Total sample no. 36)*
>1.5	3
1.3-1.5	33
	Volume expansion ratio (Total sample no. 36)*
□3.5	36

***Sample cannot analyze due to hotplate out of order.**

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) transforming breeding lines.

Genotype	Head rice (%)	Size and shape	Amylose content (%)
BR9945-39-4-3-1	68.2	LS	27.8
TP 30596	67,3	LS	26.1
TP 30598	68.6	LS	25.2
IR15A3628	67.0	LS	27.3
IR16A2287	653	LS	26.1
IR15A3248	66.9	LS	26.6
IR 108000-B-B RGA-B RGA-185-1	65.0	LS	26.6
IR 106236-B-B-B-PRN B-PRN B-PRN 261	65.8	LS	25.2
IR 103306-B-B RGA-B RGA-345	67.1	LS	25.3
IR 106236-B-B-B-PRN B-PRN B-PRN 50	66.1	LS	27.7
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-89	69.1	LS	25.8
BR10707-5R-179	69.0	LS	25.3
BR10715-5R-9	67.4	LS	27.2
IR100723-B-B-B-B-61	67.3	LS	25.5
BR9989-23-CS1-1-CS2-16-1-7	66.9	LS	28.5
BR9945-28-7-3	66.6	LS	25.0
BR8905-17-2-3-3-1-4	67.9	LS	27.4
BR8910-B-6-3-CS1-5-CS2-P3-1-5	65.3	LS	27.5

NUTRITIONAL QUALITY ASSESSMENT OF RICE

Nutraceutical properties of BRRI HYVs

A total of 14 essential amino acid compositions such as aspartic acid, threonine, serine, glutamic acid, glycine, alanine, valine, methionine, isoleucine, leucine, tyrosine, histidine, lysine and arginine were evaluated for selected 20 BRRI HYVs. Few amino acids have some correlation with tastiness such as aspartic acid, glutamic acid, histidine and arginine. BRRI dhan77 possesses the highest level of aspartic acid (0.55%), glutamic acid (1.12%), histidine (1.50%) and arginine (0.57%) followed by BRRI dhan83 (Aspartic acid 0.54%, glutamic acid 1.10%, histidine 1.47% and arginine 0.55%) and BRRI dhan71 (Aspartic acid 0.54%, glutamic acid 1.10%, histidine 1.49% and arginine 0.56%) among all tested HYVs. On the other hand BRRI dhan89 possesses the lowest level of aspartic acid (0.42%, glutamic acid (0.85%), histidine (1.13%) and arginine (0.42%) (Table 8).

Antioxidant profiling including FRAP, TPC and TAC parameters were measured for 20 BRRI HYVs. BRRI dhan82 possesses the lowest level of TAC (34.65%) and BRRI dhan88 possesses the highest level of TAC (108.44 µM AAE) followed by BRRI dhan87 (TAC 98.17 µM AAE) and BRRI dhan84 (TAC 101.52 µM AAE). These HYVS also possesses higher content of phenolic compound. In addition mineral profiling such as Zn, Fe, Ca, P and heavy metals such as Pb and As were evaluated for these 20 BRRI HYVs. BRRI dhan84 has the highest Zn content of 26.4 ppm followed by BRRI dhan72 of 20.2 ppm and BRRI dhan88 of 19.2 ppm. BRRI dhan84 possesses the highest level of Fe (9.2 ppm), Ca (33.1 ppm) and P (3.4 gKg^{-1}). We did not get any trace amount of heavy metals including Pb and As in our BRRI HYV samples at ppm level (Table 9).

In context of rice bran oil (RBO), we have examined thorouly for 20 newly released BRRI HVYs from BRRI dhan70 to BRRI dhan89. In this regards we have extracted RBO from the bran samples of respected rice HYVs and then analyzed fatty acid profiling including SFA%, MUFA% PUFA% and precious antioxidant named Gamma Oryzanol. BRRI dhan75 possesses the lowest saturated fatty acid (18.91% SFA) among all the tested 20 BRRI HYVs. Its mono unsaturated fatty acid% is 37.79 and poly unsaturated fatty acid % is 43.28% including 42.63% linoleic acid and 0.65 % linolenic acid. On the other hand, BRRI dhan80 possess the highest saturated fatty acid (27.39% SFA) among all tested 20 BRRI HYVs. Its mono unsaturated fatty acid percentage is 40.64% and poly unsaturated fatty acid percentage is 31.95% including 31.57% linoleic acid and 0.38% linolenic acid. Gamma oryzanol content which is the only antioxidant present in only RBO, varied a wide ranges from 360.65 to 1,759 $mg100g^{-1}$ in the tested BRRI varieties. BRRI dhan71 possess the highest content of gamma oryzanol 1,759 mg 100 g^{-1} and BRRI dhan84 possesses the lowest content of gamma oryzanol 360.65 mg 100 g^{-1} (Table 10).

PI: H B S; **CI:** M A S

Table 8. Essential amino acid composition of newly released BRRI HYVs from BRRI dhan70 to BRRI dhan89.

Essential Amino Acid	BRRI dhan70	BRRI dhan71	BRRI dhan72	BRRI dhan73	BRRI dhan74	BRRI dhan75	BRRI dhan76	BRRI dhan77	BRRI dhan78	BRRI dhan79	BRRI dhan80	BRRI dhan81	BRRI dhan82	BRRI dhan83	BRRI dhan84	BRRI dhan85	BRRI dhan86	BRRI dhan87	BRRI dhan88	BRRI dhan89
Asp	0.48	0.54	0.46	0.50	0.45	0.46	0.52	0.55	0.53	0.44	0.52	0.46	0.45	0.54	0.49	0.45	0.46	0.44	0.47	0.42
Thr	0.18	0.20	0.17	0.19	0.17	0.18	0.22	0.23	0.22	0.16	0.19	0.16	0.17	0.20	0.19	0.17	0.18	0.15	0.18	0.14
Ser	0.26	0.31	0.26	0.27	0.25	0.25	0.31	0.32	0.29	0.24	0.29	0.25	0.24	0.30	0.26	0.24	0.25	0.23	0.25	0.22
Glu	0.98	1.10	0.94	1.04	0.91	0.93	1.07	1.12	1.08	0.90	1.07	0.95	0.92	1.10	0.97	0.89	0.91	0.88	0.95	0.85
Gly	0.31	0.35	0.31	0.33	0.29	0.29	0.34	0.35	0.33	0.29	0.34	0.30	0.29	0.35	0.31	0.28	0.29	0.28	0.30	0.27
Ala	0.36	0.40	0.36	0.38	0.33	0.34	0.39	0.42	0.38	0.32	0.39	0.34	0.33	0.41	0.36	0.32	0.34	0.33	0.35	0.32
Val	0.42	0.48	0.37	0.45	0.40	0.41	0.47	0.48	0.47	0.39	0.46	0.40	0.39	0.47	0.41	0.37	0.39	0.37	0.40	0.36
Met	1.18	1.33	1.14	1.27	1.10	1.12	1.30	1.34	1.30	1.09	1.29	1.14	1.11	1.32	1.17	1.08	1.10	1.06	1.15	1.02
Isoleu	0.29	0.34	0.27	0.30	0.26	0.27	0.31	0.32	0.31	0.26	0.31	0.28	0.27	0.33	0.29	0.26	0.27	0.25	0.28	0.24
Leu	0.60	0.66	0.60	0.63	0.55	0.56	0.64	0.66	0.64	0.54	0.63	0.56	0.54	0.65	0.58	0.53	0.54	0.52	0.57	0.50
Tyr	0.26	0.30	0.25	0.27	0.24	0.25	0.29	0.30	0.29	0.24	0.28	0.26	0.24	0.30	0.27	0.25	0.26	0.25	0.27	0.24
His	1.32	1.49	1.27	1.40	1.24	1.25	1.45	1.50	1.45	1.22	1.45	1.28	1.24	1.47	1.31	1.21	1.23	1.18	1.26	1.13
Lys	0.19	0.20	0.18	0.20	0.17	0.17	0.20	0.21	0.20	0.16	0.19	0.17	0.16	0.20	0.18	0.15	0.16	0.15	0.17	0.14
Arg	0.49	0.56	0.48	0.52	0.47	0.48	0.54	0.57	0.54	0.45	0.53	0.47	0.46	0.55	0.50	0.46	0.47	0.44	0.48	0.42

Table 9. Antioxidant and mineral profiling of newly released BRRI HYVs from BRRI dhan70 to BRRI dhan89.

HYVS	FRAP µM AAE	TPC mM GAE	TAC µM AAE	Zn ppm	Fe ppm	Ca ppm	P gKg^{-1}	Pb ppm	As ppm
BRRI dhan70	0.594	2.01	73.15	16.2	3.4	32.6	2.1	<0.01	<0.01
BRRI dhan71	0.593	4.15	80.29	15.8	5.2	23.3	1.9	<0.01	<0.01
BRRI dhan72	0.593	2.19	61.77	20.6	5.9	33.1	2.6	<0.01	<0.01
BRRI dhan73	0.593	2.25	36.40	15.3	4.1	24.8	2.5	<0.01	<0.01
BRRI dhan74	0.599	2.99	39.97	21.5	6.1	32.1	3.1	<0.01	<0.01
BRRI dhan75	0.602	3.36	37.71	13.5	4.2	21.8	2.8	<0.01	<0.01
BRRI dhan76	0.604	2.16	66.57	17.8	3.8	24.5	2.3	<0.01	<0.01
BRRI dhan77	0.596	3.88	78.25	14.4	3.4	23.5	2.1	<0.01	<0.01
BRRI dhan78	0.589	2.79	72.22	17.1	4.2	26.2	2.6	<0.01	<0.01
BRRI dhan79	0.598	3.32	59.79	12.5	3.1	19.6	3.1	<0.01	<0.01
BRRI dhan80	0.595	2.51	59.66	18.6	3.6	22.6	3.2	<0.01	<0.01
BRRI dhan81	0.590	4.18	82.86	18.3	3.9	21.5	3	<0.01	<0.01
BRRI dhan82	0.594	2.90	34.65	12.3	3.2	19.5	3.1	<0.01	<0.01
BRRI dhan83	0.596	1.07	53.47	15.2	3.1	15.3	2.4	<0.01	<0.01
BRRI dhan84	0.564	7.38	101.52	26.4	9.2	33.1	3.4	<0.01	<0.01
BRRI dhan85	0.593	2.04	43.81	14.6	3.1	17.3	1.7	<0.01	<0.01
BRRI dhan86	0.597	2.44	40.71	12.1	5.3	15.9	1.9	<0.01	<0.01
BRRI dhan87	0.603	4.56	98.14	12.6	3.4	17.3	1.5	<0.01	<0.01
BRRI dhan88	0.574	5.90	108.44	19.2	4.6	21.3	3.1	<0.01	<0.01
BRRI dhan89	0.605	1.83	36.45	17.4	4.2	19.5	2.9	<0.01	<0.01

COMMERCIAL RICE BASED PRODUCTS

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

Physical properties viz length, breadth, thickness, increased length and breadth, volume of rice product such as puffed and flattened rice were determined. This study aims to screen out the BRRI released varieties that are suitable for popular snack food products: puffed and flattened rice for instances. Comparing with the standard variety (BR16), it is ascertained from the results that BRRI dhan81 is better in producing whole puffed rice (136.04g) followed by BRRI dhan80 (131.08g), BRRI dhan84 (119.13g), BRRI dhan88 (120.11g) in terms of weight of fully puffed rice. Considering overall parameters, BRRI dhan81 yielded better results: puffed rice length =13.54 mm, increased percentage of puffed rice length =93.70% and volume =552 ml followed BRRI dhan80, (puffed rice length =12.87 mm, increased percentage of length =87.98%, volume =575 ml), BRRI dhan84 (length =12.46 mm, increased percentage of length =99.78%, volume =518 ml), and BRRI dhan88 (length =12.06 mm, increased percentage of length =96.09%, volume =547 ml) respectively (Table 11). Results of correlation matrix for relationships among parameters indicated that puffed rice length is highly significant and positively correlated with volume ($r=0.891$, $p<0.01$) and negatively correlated with breadth ($r=-0.549$), while there is no

Table 10. Fatty Acid profiling of newly released BRRI HYVs from BRRI dhan70 to BRRI dhan89.

HYVs	SFA%	Myristic Acid%	Palmitic Acid%	Stearic Acid%	Arachidic Acid%	MUFA%	Palmitoleic Acid%	Oleic Acid%	PUFA%	Linoleic Acid%	Linolenic Acid%	Gamma Oryzanol mg100g^{-1}
BRRI dhan70	25.38	0.26	23.71	1.40	-	39.21	0.24	38.96	35.40	34.29	1.10	1478.00
BRRI dhan71	22.94	0.35	20.09	1.79	0.70	39.39	-	39.39	37.66	36.55	1.10	1759.00
BRRI dhan72	22.70	0.24	20.34	2.12	-	40.50	-	40.50	36.78	35.88	0.90	1239.00
BRRI dhan73	25.64	-	22.49	2.48	0.66	42.90	-	42.90	31.44	31.29	0.15	385.00
BRRI dhan74	25.04	0.38	22.53	1.70	0.42	39.07	-	39.07	35.88	35.03	0.84	1175.00
BRRI dhan75	18.91	-	16.75	1.82	0.33	37.79	-	37.79	43.28	42.63	0.65	1339.00
BRRI dhan76	19.70	0.17	17.72	1.71	0.10	39.97	0.02	39.94	40.31	39.45	0.86	1380.00
BRRI dhan77	20.53	0.25	18.28	1.55	0.44	38.63	0.07	38.55	40.82	40.05	0.77	1385.00
BRRI dhan78	25.90	0.13	23.02	2.11	0.63	41.12	-	41.12	31.97	31.95	1.02	1319.00
BRRI dhan79	23.30	0.28	21.76	0.99	0.26	35.00	-	35.00	41.68	40.34	1.34	1464.00
BRRI dhan80	27.39	0.23	23.76	2.51	0.89	40.64	0.06	40.58	31.95	31.57	0.38	586.00
BRRI dhan81	24.98	0.13	22.23	2.02	0.59	41.68	-	41.68	33.32	33.13	0.19	397.16
BRRI dhan82	22.81	0.25	20.55	1.98	0.03	43.88	-	42.99	33.29	33.01	0.28	707.57
BRRI dhan83	22.22	0.24	20.82	1.03	0.12	42.17	0.018	41.34	35.59	35.37	0.22	670.06
BRRI dhan84	27.27	-	25.22	1.82	0.22	43.07	-	43.07	29.65	29.65	-	360.56
BRRI dhan85	22.12	-	20.42	1.70	-	45.99	-	45.99	33.32	37.87	-	662.84
BRRI dhan86	21.52	-	20.00	1.52	-	39.56	-	39.56	38.9	37.43	1.47	640.81
BRRI dhan87	20.21	0.23	17.3	2.04	0.63	45.60	-	45.6	34.17	33.98	0.19	407.91
BRRI dhan88	24.09	0.31	21.79	1.98	-	43.33	-	43.33	32.57	32.57	-	390.51
BRRI dhan89	24.77	0.27	21.79	2.14	0.55	38.92	-	38.92	36.3	35.72	0.58	515.76

significant correlation between puffed rice breadth and volume (r= -0.105). On the other hand, the length of puffed rice is highly significant and positively correlated with increased percentage of puffed rice breadth (r=0.819, p<0.01). However, there is no significant correlation between length and increased percentage of length (r=0.227) of puffed rice. Moreover, breadth is negatively correlated with increased percentage of length and breadth (r=-0.274 and r=-0.227), respectively (Table 12).

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 and broken flattened rice as well as percentage of length increased, BRRI dhan84 showed the best performance followed by BRRI dhan80 and BRRI dhan89. Moreover, the results demonstrated that BRRI dhan84 showed higher potential in producing flattened rice considering thickness of flattened rice and volume of 50 g sample (th=0.51mm, vol=188ml) which is better than the standard as of BR16 (th=0.57mm, vol=173ml) and other varieties considered for this study (Table 13). Results of correlation matrix for relationships among parameters displayed that flattened rice length is positively correlated with volume (r=0.458) but, there is no significant correlation between length and volume. Similarly, there is a positive but no significant correlation between flattened rice breadth and volume (r=0.416). However, the increased percentage of flattened rice length is highly significant and positively correlated with volume of 50 g flattened rice (r=0.752, p<0.05). The results also showed that there is significant and negative correlation between flattened rice breadth and thickness (r=-0.761, p<0.05) (Table 14).

PI: M A H; **CI:** N F, T K S, H B S and M A S

Table 11. Physical properties of puffed rice of BRRI developed modern varieties.

Variety name	Fully puffed rice wt (g)	Partially puffed rice wt (g)	Puffed rice L (mm)	Puffed rice B (mm)	Increased puffed rice L (%)	Increased puffed rice B (%)	Thousand puffed rice wt (g)	Volume of 50g puffed rice (ml)
BR16	81.713D	118.23B	11.497DE	3.8133BC	73.143C	67.99 DE	15.87B	500D
BRRI dhan80	131.08AB	68.857DE	12.877B	3.9567AB	87.98B	86.637AB	18.62A	575A
BRRI dhan81	136.04A	63.823E	13.54A	3.6D	93.707AB	92.513A	16.26AB	551.67AB
BRRI dhan82	14.943E	184.78A	10.233F	3.9467AB	89.86AB	63.763E	15.69B	457.67E
BRRI dhan84	119.13ABC	80.497CDE	12.467BC	3.5733D	99.787A	72.623CD	15.55B	518.33CD
BRRI dhan86	103.23C	96.967C	12.703B	3.72CD	89.32B	91.753A	16.25AB	550AB
BRRI dhan87	115.0BC	84.877CD	11.95 CDE	3.72CD	86.43B	80.583BC	16.65AB	531.67BC
BRRI dhan88	120.11ABC	79.8CDE	12.06CD	3.6333D	96.097AB	80.763BC	14.61B	546.67B
BRRI dhan89	109.24C	90.593C	11.463 E	4.01A	96.29AB	82.273B	15.10B	553.33AB
Mean± SD	103.39±36.77	96.491±90.59	12.088±0.965	3.7748±0.165	90.29±7.802	79.878±10.044	16.07±1.220	531.59±35.293
SE	8.8374	8.874	0.2836	0.0832	4.9203	3.9519	1.1902	11.935
CV%	10.47	11.26	2.87	2.7	6.67	6.06	9.07	2.75

Table 12. Correlation among the physical properties of puffed rice of BRRI developed modern varieties.

Correlations										
Parameter	Fully puffed rice wt (g)	Partially puffed rice wt (g)	Milled rice length L (mm)	Milled rice breadth B (mm)	Thousand puffed rice wt (g)	Puffed rice L (mm)	Puffed rice B (mm)	Increased puffed rice L (%)	Increased puffed rice B (%)
Partially puffed rice wt (g)	-1.000**								
Milled rice length, L (mm)	.701*	-.699*							
Milled rice breadth, B (mm)	-.810**	.809**	-.691*						
Thousand puffed rice wt g	.240	-.239	.605	-.073					
Puffed rice L (mm)	.867**	-.866**	.865**	-.896**	.451				
Puffed rice B (mm)	-.444	.445	-.395	.712*	.319	-.549			
Increased puffed rice L (%)	.302	-.304	-.292	-.362	-.344	.227	-.274		
Increased puffed rice B (%)	.746*	-.744*	.659	-.843**	.348	.819**	-.227	.279	
Volume of 50g (ml)	.891**	-.889**	.623	-.714*	.355	.776*	-.105	.280	.880**

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

Table 13. Physical properties of flattened rice of BRRI developed modern varieties.

Variety name	Fully flattened rice wt (g)	Broken 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 (%)	Thickness of flattened rice (mm)	1000 flattened rice wt (g)	volume of 50 gm flattened rice (ml)
BR16	213.16A	36.09DE	6.9C	2.29B	13.32BC	4.29C	91.38D	84.91D	0.57CD	18.59	173.33BC
BRRI dhan80	156.14A	15.85F	7.07B	2.16C	12.29DEF	3.81E	72.95E	73.33E	0.64AB	19.50B	131.67D
BRRI dhan81	176.59A	72.79A	7.21A	1.90E	12.85CD	3.25F	76.56E	71.05E	.0.66A	17.79D	166.67C
BRRI dhan82	189.15A	60.08B	5.79G	2.46A	11.77F	4.98A	103.40B	103.54B	0.56CDE	17.80D	188.33A
BRRI dhan84	219.60A	29.80E	6.86C	2.16C	14.23A	4.50B	106.03AB	106.57B	0.51E	17.81D	188.33A
BRRI dhan86	200.80A	48.65C	6.64D	1.74F	13.48B	4.22C	100.99BC	138.80A	0.59BC	20.01A	181.67AB
BRRI dhan87	182.14A	66.67AB	6.51E	2.05D	12.23EF	4.04D	88.20D	94.23C	0.63AB	17.60ED	133.33D
BRRI dhan88	210.59A	38.87D	6.53DE	1.96E	12.63DE	4.14CD	92.92CD	108.21B	0.53DE	17.23E	183.33A
BRRI dhan89	214.39A	35.01DE	6.34F	2.19C	13.32BC	3.74E	113.52A	69.53E	0.65A	19.68AB	185.00A
Mean±SD	195.84±21.30	44.87±18.64	6.72±0.428	2.11±0.216	12.91±0.761	4.11±0.491	93.99±13.47	94.46±22.16	0.59±0.055	18.44±1.034	170.19±22.49
SE	36.48	4.08	0.05	0.04	0.28	0.07	4.20	3.68	0.02	0.16	4.23
CV%	22.81	11.13	1.07	2.36	2.68	2.21	5.48	4.78	5.02	1.10	3.04

Table 14. Correlation among the physical properties of flattened rice of BRRI modern varieties.

Correlation

Parameter	Fully flattened rice wt (g)	Broken 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 (%)	Thickness of flattened rice (mm)	1000 flattened rice wt (g)
Broken rice wt (g)	-1.000**									
Brown rice Length (mm)	.226	-.224								
Brown rice Breadth (mm)	.211	-.215	-.456							
Flattened rice length (mm)	.350	-.349	.408	-.284						
Flattened rice breadth (mm)	.095	-.098	-.660	.533	-.072					
Increased flattened rice L (%)	.087	-.088	-.650	.237	.420	.523				
Increased flattened rice B (%)	-.096	.096	-.309	-.372	.200	.585	.377			
Thickness of flattened rice (mm)	-.254	.254	.253	-.198	-.302	-.761*	-.419	-.616		
1000 flattened rice wt (g)	.442	-.440	.113	-.162	.263	-.197	.147	.001	.415	
50 g volume (ml)	.001	.003	-.393	.098	.458	.416	.752*	.388	-.571	-.052

**. 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.

Hybrid Rice Division

SUMMARY

In T. Aman season 2019, a total of 169 test crosses and 336 (A × R) crosses were made from source nursery. One hundred forty-eight test crosses (F_1s) were evaluated for their pollen fertility status of which two 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 CMS lines in the next season. Twenty-seven entries were found completely sterile and their corresponding male parents were regarded as suspected maintainer lines. One backcross generation was advanced as new CMS line. Other backcross generations were advanced to next generations except one BC_2 generation was found unstable in terms of pollen sterility and hence discarded. Eighty-eight CMS lines along with their respective maintainer lines were maintained by hand crossing.

A total of 110 test crosses and 521 (A × R) crosses were made using 11 CMS lines in Boro season 2019-20. Fifty-six test crosses (F_1s) were evaluated for their pollen fertility status. Among them ten entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, five entries have been selected for their high yielding ability compared with check varieties. All backcross entries were advanced for next generations except for two BC_1 generations. One hundred eight 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 248 test hybrids under observational trials three hybrid combinations were selected based on yield, duration and grain type and produced more than 31-39% yield advantage over check variety BRRI hybrid dhan4, 18-25% over BRRI hybrid dhan6 and 48-56 % over BRRI dhan49 but with 3 to 4 weeks earlier growth duration than the inbred check variety BRRI dhan49. In Boro, out of 376 test hybrids 28 hybrid combinations were selected based on yield, duration and grain type. The selected hybrid combinations expressed 10-44% yield advantage over BRRI hybrid dhan3, 1-26% over BRRI hybrid dhan5, 26-66% over SL8H and 1-33% over Teea. The heritability obtained from plant height, growth duration and grain yield were 57%, 72% and 86% respectively, indicating high level of precision in this experiment.

In T. Aman preliminary yield trials nine hybrids were selected out of 49 and showed yield advantage ranging from 3-8% over BRRI hybrid dhan6, 16-29% over Tej Gold and 11-23% over Dhanny Gold. In T. Aman under multi-location trials three hybrids out of fifteen produced more than 14% yield advantage over BRRI hybrid dhan6, 25-27% over Tej Gold and 12-14% over Dhanny Gold. In Boro, sixteen hybrids were evaluated along with two BRRI developed hybrid and eight company hybrids as check variety. Five hybrids were selected based on growth duration, at per yield with best check variety and phenotypic acceptability at vegetative and maturity stage.

Adaptability under saline condition of BRRI released and popular company hybrids along with popular saline tolerant inbred check BRRI dhan67 was done at three coastal location of Satkhira. None of the tested entries survived at Kaliganj, Satkhira due to very high-water salinity (25.86 ds/m). We found that the top three highest yielding genotypes were BRRI hybrid dhan5 (8.20 t ha^{-1}), BRRI hybrid dhan3 (7.66 t ha^{-1}) and BRRI hybrid dhan6 (7.20 t ha^{-1}) followed by Heera (7.19 t ha^{-1}), BRRI hybrid dhan2 (7.13 t ha^{-1}), IT (6.32 t ha^{-1}), Janokraj (6.31 t ha^{-1}), BRRI hybrid dhan7 (6.20 t ha^{-1}), BRRI hybrid dhan4 (6.11 t ha^{-1}), Tejgold (6.10 t ha^{-1}), SL-8 (5.93 t ha^{-1}) and BRRI dhan67 (5.70 t ha^{-1}). Therefore, we can conclude that BRRI hybrid dhan5, 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 6 dS/m.

National hybrid rice yield trials were conducted through SCA in T. Aman 2019 and Boro 2019-20, which included 23 and 54 hybrids along with one hybrid check variety. Results were compiled by SCA. Seed yield of 120 kg/plot (0.4 t ha^{-1}), 80 kg/plot (0.4 t ha^{-1}), 252 kg/plot (0.32 t ha^{-1}) and 150 kg/plot (0.5 t ha^{-1}) were obtained from BRRI11A, IR58025A, BRRI7A and IR79156A respectively in T. Aman 2019. Seed yield was very poor due to heavy rainfall during flowering time. On the other hand, in Boro 2019-20, CMS seed yield of 1425 kg (2.23 t ha^{-1}), 430kg (1.43 t ha^{-1}) and 320 kg (1.6 t ha^{-1}) were obtained from BRRI11A, BRRI7A and IR58025A respectively. A

total of 175 kg (1.2 t ha^{-1}), 230 kg (1.3 t ha^{-1}) and 130 kg (1.3 t ha^{-1}) hybrid seeds were produced from BRRI hybrid dhan4 (IR58025A/BRRI10R), BRRI hybrid dhan5 (BRRI7A/BRRI31R) and BRRI hybrid dhan6 (IR79156A/BRRI20R) respectively during T. Aman 2019. In Boro 2019-20, a total of 690 kg (1.73 t ha^{-1}) from BRRI hybrid dhan5, 1480 kg (2.1 t ha^{-1}) from BRRI hybrid dhan6 and 640 kg (2.6 t ha^{-1}) from BRRI hybrid dhan7 were obtained. Experimental F_1 seed production was done ranging 3 to 8 kg/plot from selected promising hybrid combinations during T. Aman 2019 which was equivalent to 1.2 to 3.04 t ha^{-1} having unit plot size $25m^2$. Seed yield got from selected promising CMS lines were 34 kg/plot (0.49 t ha^{-1}), 66 kg/plot (0.83 t ha^{-1}), 73 kg/plot (1.04 t ha^{-1}), 179 kg/plot (1.49 t ha^{-1}), 3.6 kg/plot (0.9 t ha^{-1}), 5 kg/plot (0.83 t ha^{-1}). 11 kg/plot (1.10 t ha^{-1}), 4.4 kg/plot and (0.44 t ha^{-1}) from BRRI13A, BRRI35A, BRRI48A, BRRI99A, BRRI110A, IR105687A, IR105688A and IR79125A during T. Aman 2019. Seed amount got from selected promising CMS lines ranging from 0.89 to 2.43 t ha^{-1} during Boro 2019-20. We had also F_1 seed production programme in Barishal and Ishwardi during Boro 2019-20 through contract growers. From Barishal, we got 1200 kg (1.5 t ha^{-1}) of BRRI hybrid dhan3 and 2400 kg (1.2 t ha^{-1}) seeds of BRRI hybrid dhan5. From Ishwardi we obtained seeds of 1380 kg (2.16 t ha^{-1}) from BRRI hybrid dhan2, 2000 kg (2.5 t ha^{-1}) from BRRI hybrid dhan3, 1690 kg (2.6 t ha^{-1}) from BRRI hybrid dhan4, 1580 kg (1.58 t ha^{-1}) from BRRI hybrid dhan5, 1020 kg (1.3 t ha^{-1}) from BRRI hybrid dhan6 and 520 kg (2.6 t ha^{-1}) from BRRI hybrid dhan7.

A total of 1,06,800 kg F_1 seeds were produced during Boro 2019-20 with the technical assistance from BRRI to BADC, 22 seed companies and regional stations of BRRI. In the reporting year, hybrid rice division supplied 10,750 kg of parental lines and F_1 seeds to 90 farmers, 22 seed companies, scientists, extension people and staffs of BRRI.

DEVELOPMENT OF PARENTAL MATERIALS

Source Nursery

One hundred and sixty-nine test crosses and 336 (A × R) crosses were made using nine CMS lines during T. Aman season 2019. One hundred and ten crosses and 521 (A × R) crosses were made using 11 CMS lines during Boro season 2019-20.

Test cross nursery

In. Aman 2019, out of 148 testcrosses (F_1s) two entries have been found heterotic over check varieties expressing 48-62% yield advantage over the check BRRI dhan49 with 3-4 weeks earlier growth duration, 35-56 % over Tej Gold and 17-29% over BRRI hybrid dhan6 and twenty-seven entries were found completely sterile. Pollen parents of those heterotic combinations were regarded as suspected restorers and pollen parents of completely sterile combinations were regarded as suspected maintainer lines.

In Boro 2019-20, out of 56 testcrosses (F_1s), ten tested entries showed complete sterility and immediately backcrossed with their corresponding male parents for conversion. On the other hand, five entries have been selected for their high yielding ability compared with check variety.

Back cross nursery

In T. Aman 2019, one BC_6 generation was stable in terms of pollen sterility and other desired agronomic traits and hence shifted to CMS maintenance and evaluation nursery as new CMS lines. Other generations were advanced for next generation except for one BC_2 generation. It was discarded due to fluctuation in pollen fertility.

In Boro 2019-20, all the backcross entries were advanced for next generations except for two BC_1 generations.

CMS maintenance and evaluation nursery

Eighty-eight CMS lines were maintained by hand crossing for seed increase and genetic purity in T. Aman 2019 and in Boro 2019-20, a total of 108 CMS lines were maintained through hand crossing for seed increase and genetic purity.

EVALUATION OF PARENTAL LINES AND HYBRIDS

In T Aman 2019, out of 248 test hybrids under observational trials three hybrid combinations were selected based on yield, duration and grain type and produced more than 31-39% yield advantage over check variety BRRI hybrid dhan4, 18-25% over BRRI hybrid dhan6 and 48-56 % over BRRI dhan49 but with 3 to 4 weeks earlier growth duration than the inbred check variety BRRI dhan49 (Table 1). 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 376 test hybrids 28 hybrid combinations were selected based on yield, duration and grain type. The selected hybrid combinations expressed 10-44% yield advantage over BRRI hybrid dhan3, 1-26% over BRRI hybrid dhan5, 26-66% over SL8H and 1-33% over Teea. The heritability obtained from plant height, growth duration and grain yield were 57%, 72% and 86%, indicating high level of precision in this experiment (Table 2).

Preliminary yield trials of promising hybrids

Under preliminary yield trials nine hybrids were selected out of 49 and showed yield advantage ranging from 3-8% over BRRI hybrid dhan6, 16-29% over Tej Gold and 11-23% over Dhanny Gold in T. Aman 2019 (Table 3). In Boro 2019-20, eight hybrids were selected out of 16 hybrids based on yield, grain type and growth duration. All the selected hybrids showed yield advantage ranging from 2-9 % over BRRI hybrid dhan5, 17-25% over Tej Gold, 14-22% over Heera-2 and 0.1-26 % over SL8H. All the selected hybrids out yielded popular company hybrids by more than one ton. The heritability obtained from plant height, growth duration and grain yield were 68%, 88% and 82% respectively, indicating high level of precision in this experiment (Table 4).

Multi-location yield trials of promising hybrids

In T Aman 2019, out of 15 hybrids, three combinations exhibited yield advantage more than 14 % over BRRI hybrid dhan6, 25-27% over Tej Gold, 12-14% over Dhanny Gold with one to three weeks earlier in growth duration. Barishal experiment was abandoned due to flood water and rat damage (Table 5). In Boro 2019-20, sixteen hybrids were evaluated along with two BRRI developed hybrid and eight company hybrids as check variety. Five hybrids were selected based on growth duration, at per yield with best check variety and phenotypic acceptability at vegetative and maturity stage (Table 6).

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

Ten new R × R and five B × B crosses were made for new recombinant line development with broad genetic base and high amylose. These fifteen cross combinations will be confirmed under on going T Aman season 2020.

Evaluation of Fatema dhan

Ten lines of Fatema dhan were evaluated in T. Aman 2019 and made some crosses with available best CMS lines. All the tested lines were with low tillering ability, panicle exertion rate was very low, flower blooms inside the leaf sheath with long awn.

Table 1. List of experimental hybrids found heterotic over check variety during T. Aman 2019.

Sl.	Hybrid	PH (cm)	E/T	SF (%)	DTM	Yield ($t\ ha^{-1}$)	Yield advantage over checks (%)		
							Ck-1	Ck-2	Ck-3
1	BRRI50A/BAU521R	138	7	78	102	7.41	47.61	31.38	17.62
2	BRRI53A/S-1203R	130	5	81	101	7.74	54.18	37.23	22.86
3	BRRI72A/AsadR	113	8	88	115	7.85	56.37	39.18	24.60
Ck-1	BRRI dhan49	107	9	79	135	5.02			
Ck-2	BRRI hybrid dhan4	114	8	79	112	5.60			
Ck-3	BRRI hybrid dhan6	114	9	82	115	6.30			
LSD		2.86	1.07	2.38	2.20	1.07			
Heritability (0.05)		0.97	0.81	79	82	0.92			

DS: 08 Jul 2019; DT: 28 Jul 2019

Legend: DTM =Days to maturity; SF (%) = Spikelet fertility; E/T= No. of effective tillers; PH (cm) = Plant height in centimeter

Table 2. List of the hybrid combinations found heterotic from observational nursery during Boro season 2019-20.

Sl.	Designation	PHT (cm)	GD (day)	Plot yield (kg/plot)	Yield (t h^{-1})	Heterosis (%)			
						ck-1	Ck-2	Ck-3	Ck-4
1	BRRI7A/FengleR	104	150	2.0	10.00	10	-	26	1
2	BRRI7A/CTR-3	106	149	2.43	12.15	34	17	53	23
3	BRRI13A/Win2R	105	146	2.25	11.25	24	8	42	14
4	BRRI13A/S-1203R	100	143	2.56	12.82	41	24	62	30
5	BRRI35A/EL255R	109	148	2.06	10.29	13	-	30	4
6	BRRI35A/EL262R	104	149	2.09	10.45	15	1	32	6
7	BRRI35A/S-1203R	109	149	2.23	11.15	23	7	41	13
8	BRRI35A/CTR-1	98	144	2.42	12.10	33	17	53	22
9	BRRI35A/IR85538-2-1-1-1-1-1-1R	117	152	2.51	12.56	38	21	58	27
10	BRRI35A/IR86515-19-1-1-1-1-1R	105	146	2.45	12.25	35	18	55	24
11	BRRI48A/CTR-2	103	149	2.07	10.34	14	-	30	5
12	BRRI97A/EL255R	101	147	2.32	11.60	28	12	46	17
13	BRRI97A/EL262R	105	148	2.37	11.84	31	14	49	20
14	BRRI97A/CHA15R	102	150	2.41	12.03	33	16	52	22
15	BRRI97A/Win2R	112	156	2.52	12.59	39	21	59	27
16	BRRI97A/FengleR	104	157	2.62	13.10	44	26	65	32
17	BRRI97A/CTR-1	102	147	2.25	11.25	24	8	42	14
18	BRRI97A/IR86515-19-1-1-1-1-1R	103	152	2.32	11.58	28	12	46	17
19	BRRI99A/EL254R	101	149	2.63	13.13	45	27	66	33
20	BRRI99A/EL262R	103	148	2.55	12.77	41	23	61	29
21	BRRI99A/R Line7	105	150	2.49	12.43	37	20	57	26
22	BRRI99A/Win1R	104	152	2.42	12.12	34	17	53	23
23	BRRI99A/Win2R	107	147	2.62	13.09	44	26	65	32
24	BRRI99A/FengleR	121	145	2.32	11.61	28	12	46	17
25	BRRI99A/CTR-3	115	148	2.33	11.64	28	12	47	18
26	BRRI99A/IR98206-4-2-2-1-1-1-1-1R	117	143	2.23	11.15	23	7	41	13
27	BRRI99A/IR86625-8-1-1-1-3-1-1-1R-1-1	113	143	2.13	10.66	18	3	34	8
28	IR79156A/CTR-3	113	144	2.10	10.51	16	1	33	6
Ck-1	BRRI hybrid dhan3	106	153	1.81	9.07				
Ck-2	BRRI hybrid dhan5	105	155	2.08	10.38				
Ck-3	SL8H	103	152	1.59	7.93				
Ck-4	Teea	107	148	1.98	9.89				
LSD (0.05)		9.23	4.37		1.8				
Heritability (%)		0.57	0.72		0.86				

DS: 9 Dec 2019; DT: 17 Jan 2020; Plot size: 2 m^2

Table 3. Results of preliminary yield trials in T. Aman 2019.

Sl.	Designation	PHT (cm)	GD (day)	GT	Yield (t h^{-1})	Heterosis (%)		
						Ck-1	Ck-2	Ck-3
01(11)	IR79156A/EL262R	104	108	MS	6.99	5.6	25.9	20.9
02 (12)	IR79156A/CHA15R	106	107	MS	6.79	2.6	22.3	17.5
03 (21)	BRRI48A/Win1R	96	110	MS	6.88	3.9	24.0	19.0
04 (35)	IR107834H	104	118	S	6.43	-	15.9	11.2
05 (36)	IR106619H	104	130	S	6.82	3.0	22.9	20.0
06 (37)	IR106631H	104	128	S	6.64	-	19.6	14.9
07 (40)	IR116294H	105	130	S	6.89	4.1	24.1	19.2
08 (43)	IR111678H	104	131	S	7.06	6.6	27.2	22.1
09 (48)	IR112998H	108	122	S	7.13	7.7	28.5	23.4
ck-1	BRRI hybrid dhan6	103	113	S	6.62			
ck-2	Tej Gold	105	130	S	5.55			
ck-3	Dhanny Gold	108	133	S	5.78			
LSD (0.05)		8.76	5.64		1.23			
Heritability		0.81	0.97		0.8			

DS: Jul 11 2019; DT: 3 Aug 2019; Plot size=10 m^2; PHT (cm) = Plant height (cm); GD = Growth duration; GT= Grain type; S=Slender, M=Medium, MS=Medium slender

Table 4. Results of preliminary yield trials in Boro 2019-20.

Sl.	Designation	PHT (cm)	GD (day)	Yield (t h^{-1})	Heterosis (%)			
					ck-1	ck-1	ck-1	ck-1
1	BRRI7A/EL254R	101	151	8.03	-	-	-	-
2	IR79156A/EL254R	110	150	8.01	-	-	-	-
3	BRRI7A/EL255R	106	148	8.09	-	-	-	-
4	BRRI13A/EL255R	111	150	8.02	-	-	-	-
5	BRRI48A/EL255R	102	151	8.10	-	-	-	-
6	BRRI72A/EL255R	100	152	7.65	-	-	-	-
7	IR79156A/EL255R	107	153	8.10	-	-	-	-
8	BRRI99A/EL260R	107	153	10.45	7	23	20	24
9	BRRI35A/EL262R	104	154	9.93	2	17	14	18
10	BRRI48A/EL262R	106	147	8.41	-	-	-	0.1
11	BRRI99A/EL262R	111	149	10.5	8	24	21	25
12	BRRI99A/CHA15R	114	152	10.6	9	25	22	26
13	BRRI48A/Win1R	112	157	10.3	6	21	18	23
14	BRRI13A/109R	118	154	10.08	4	19	16	20
15	BRRI99A/109R	117	155	10.37	7	22	19	23
16	BRRI7A/CHA15R	107	151	10.2	6	21	18	22
ck-1	BRRI hybrid dhan5	107	161	9.74				
ck-2	Tej Gold	107	157	8.5				
ck-3	Heera-2	109	163	8.7				
ck-4	SL8H	103	164	8.4				
LSD (0.05)		7.63	3.71	1.04				
Heritability (%)		0.68	0.88	0.82				

DS: 7 Dec 2019; DT: 15 Jan 2020; Plot size: 30 m^2

Table 5. Results of multi-location yield trials during T Aman 2019.

Hybrid	PH	DTM	Yield			Aver yield Advantage over Ck (%)		
			Gazipur	Ishwardi	Aver	Ck-1	Ck-2	Ck-3
BRR35A/EL254R	107.3	99	6.7	6.3	6.5	-	10.2	-
IR79156A/EL254R	109.0	97	5.7	6.1	5.9	-	-	-
BRRI35A/EL255R	110.0	105	7.3	6.4	6.9	6.2	16.9	4.5
BRR48A/EL255R	105.6	101	6.4	5.7	6.1	-	3.4	-
IR79156A/EL255R	115.3	119	7.4	7.6	7.5	15.4	27.1	13.6
BRRI35A/EL262R	108.7	102	5.8	5.7	5.8	-	-	-
BRRI48A/EL262R	103.0	101	6.3	5.7	6.0	-	1.7	-
IR79156A/ CHA15R	116.0	115	7.3	7.7	7.5	15.4	27.1	13.6
IR79156A/R line7	118.0	110	6.2	5.5	5.9	-	-	-
IR79156A/Win1R	112.6	110	7.3	7.7	7.5	15.4	27.1	13.6
BRRI35A/CHH32R	107.0	101	7.2	7.5	7.4	13.8	25.4	12.1
IR79156A/CHH32R	111.3	111	5.6	5.1	5.4	-	-	-
BRRI48A/LPH14R	106.2	99	5.2	5.5	5.4	-	-	-
IR79156A/LPH14R	116.3	112	4.9	5.6	5.3	-	-	-
IR79156A/BasmatiR	113.6	110	5.6	5.4	5.5	-	-	-
BRRI hybrid dhan6(Ck-1)	108.2	116	6.2	6.7	6.5			
Tej Gold (Ck-2)	110.5	119	5.7	6.1	5.9			
Dhanny Gold (Ck-3)	107.6	124	6.5	6.7	6.6			
Mean	110.3	108.4	6.3	6.3	6.3			
CV (%)	3.8	7.5	12.8	13.7	12.5			
LSD (0.05%)	2.5	4.9	0.5	0.5	0.5			

DS: 11 Jul 2019; DT: 29 Jul 2019; Unit plot size: 30 m^2

Table 6. Results of multi-location yield trials during Boro 2019-20.

Combination	PH (cm)	N/T	SF (%)	DTM	PHA		Yield (t ha^{-1})			AverYld (t ha^{-1})
					Veg	Mat	Gaz	Bari	Ishw	
BRRI35A/EL254R	109	10.0	85.3	147	5	5	8.21	7.31	8.62	8.05
BRRI99A/EL254R	107	12.0	88.3	145	2	3	9.40	9.60	9.7	9.57
BRRI35A/EL255R	110	9.0	84.6	153	5	5	7.87	6.84	9.0	7.90
BRRI99A/EL255R	109	12.0	87.1	147	3	3	8.87	8.67	9.5	9.01
IR79156A/EL255R	113	11.0	83.5	151	4	5	7.84	8.80	9.0	8.55
BRRI35A/EL260R	105	10.0	83.9	150	3	4	8.86	8.66	9.5	9.01
BRRI48A/CHA15R	111	11.0	83.8	150	4	5	8.31	9.31	9.0	8.87
BRRI99A/CHA15R	109	10.0	89.9	148	2	2	8.94	9.94	11.0	9.96
IR79156A/CHA15R	113	10.0	86.6	151	3	4	9.32	8.82	9.3	9.15
IR79156A/R line7	120	11.0	86.3	150	4	5	9.29	8.45	10.5	9.41
BRRI35A/Win1R	115	12.0	84.2	155	4	5	8.51	8.01	10.5	9.00
BRRI99A/Win1R	107	12.0	87.2	155	2	3	9.25	9.33	10.0	9.53
IR79156A/Win1R	109	12.0	87.3	153	3	4	8.67	9.67	10.5	9.61
BRRI35A/109R	112	9.0	83.7	149	4	5	8.65	8.15	9.3	8.70
BRRI99A/BRRI31R	109	12.0	87.5	148	3	3	8.87	9.36	10.5	9.58
IR79156A/BRRI31R	118	12.0	86.8	148	2	3	9.38	9.14	10.5	9.67
H-2264	120	12.0	81.3	152	4	5	8.81	8.14	8.66	8.54
H-386	122	13.0	82.0	151	3	4	8.30	9.59	9.65	9.18
BRRI hybrid dhan3	111	11.0	84.6	147	3	3	8.79	8.73	9.0	8.84
BRRI hybrid dhan5	107	11.0	88.7	148	2	3	8.86	10.02	9.8	9.62
Tej Gold	112	11.0	80.3	149	3	5	7.89	7.79	8.0	7.89
Jhonok Raj	110	11.0	83.6	152	3	4	8.63	8.30	9.5	8.81
Heera-2	111	10.0	84.0	157	3	4	8.77	8.52	9.5	8.86
Gold	108	12.0	83.1	149	4	5	8.32	8.74	9.3	8.79
Teea	107	9.0	81.3	144	3	4	8.42	7.81	8.3	8.18
SL8H	109	11.0	82.6	150	4	5	7.28	8.98	9.0	8.42
Mean	111.3	11.0	84.9	149.9			8.63	8.72	9.51	8.95
CV (%)	3.98	9.96	2.93	2.04			6.12	9.08	7.93	6.41
LSD (0.05%)	2.24	0.55	1.26	1.55			0.27	0.40	0.38	0.29

Gazipur: DS: 7 Dec 2019; DT:16 Jan 2020; Barishal: DS: 15 Dec 2019; DT:20 Jan 2020
Ishwardi: DS: 10 Dec 2019; DT: 25 Jan 2020;
PH (cm) = Plant height; N/T = No. of effective tillers; SF (%) = Spikelet fertility; DTM = Days to maturity; PHA = Phenotypic acceptability at vegetative and maturity stage. Unit plot =20 m^2

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 single panicle was harvested from each plant for next season. In Boro 2010-20, 20 lines were selected based on red stigma, white stigma, awn less and awn present.

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 released and popular company hybrids along with popular saline tolerant inbred check BRRI dhan67 was done at three coastal location of Satkhira. None of the tested entries survived at Kaliganj, Satkhira due to very high-water salinity (25.86 ds/m). We found that the top three highest yielding genotypes were BRRI hybrid dhan5 (8.20 t ha^{-1}), BRRI hybrid dhan3 (7.66 t ha^{-1}) and BRRI hybrid dhan6 (7.20 t ha^{-1}) followed by Heera (7.19 t ha^{-1}), BRRI hybrid dhan2 (7.13 t ha^{-1}), IT (6.32 t ha^{-1}), Janokraj (6.31 t ha^{-1}), BRRI hybrid dhan7 (6.20 t ha^{-1}), BRRI hybrid dhan4 (6.11 t ha^{-1}), Tejgold (6.10 t ha^{-1}), SL-8 (5.93 t ha^{-1}) and BRRI dhan67(5.70 t ha^{-1}). Therefore, we can conclude that BRRI hybrid dhan5, 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 6 dS/m (Table 7 and Fig. 1).

SEED PRODUCTION OF PARENTAL LINES AND HYBRIDS

CMS line multiplication of released hybrids

Seed yield of 120 kg/plot (0.4 t ha^{-1}), 80 kg/plot (0.4 t ha^{-1}), 252 kg/plot (0.32 t ha^{-1}) and 150 kg/plot (0.5 t ha^{-1}) were obtained from BRRI11A, IR58025A, BRRI7A and IR79156A respectively in T. Aman season 2019 (Table 8). On the other hand, in Boro 2019-20, CMS seed yield of 1425 kg (2.23 t ha^{-1}), 430kg (1.43 t ha^{-1}) and 320 kg (1.6 t ha^{-1}) were obtained from BRRI11A, BRRI7A and IR58025A respectively (Table 9).

Table 7. Yield and agronomic performance of twelve genotypes from adaptive trial in Boro 2019-20.

Genotype	PH (cm) Predicted mean	GD (Days) Predicted mean	Yield (t ha^{-1})			No. of panicle/m^2	SF (%)	PAcp veg	PAcp mat
			Ass	Deb	Predicted mean				
BRRI hybrid dhan2	93	142	6.82	7.46	7.13	279	86	3	3
BRRI hybrid dhan3	96	141	7.19	8.15	7.66	265	84	3	3
BRRI hybrid dhan4	95	140	5.83	6.38	6.11	268	83	3	3
BRRI hybrid dhan5	96	141	8.06	8.40	8.20	284	84	3	3
BRRI hybrid dhan6	96	141	6.74	7.68	7.20	267	84	3	3
BRRI hybrid dhan7	95	144	5.95	6.44	6.20	278	85	3	3
Janokraj	96	143	5.90	6.70	6.31	269	83	5	5
Heera	93	139	6.75	7.65	7.19	269	83	3	3
Tejgold	95	140	5.71	6.47	6.10	257	81	5	7
SL-8	95	139	5.53	6.31	5.93	265	83	5	5
BRRI dhan67	99	142	5.43	5.94	5.70	272	95	3	3
IT	95	143	5.85	6.78	6.32	298	78	5	5
LSD (0.05)	6.04	1.12	0.31	0.35	0.29	10.10	2.67		
H^2 (0.05)	0.51	0.95	0.98	0.98	0.99	0.95	0.95		

PH= Plant height, GD= Growth duration, Ass= Assasuni, Deb= Debhata, SF= Spikelet fertility

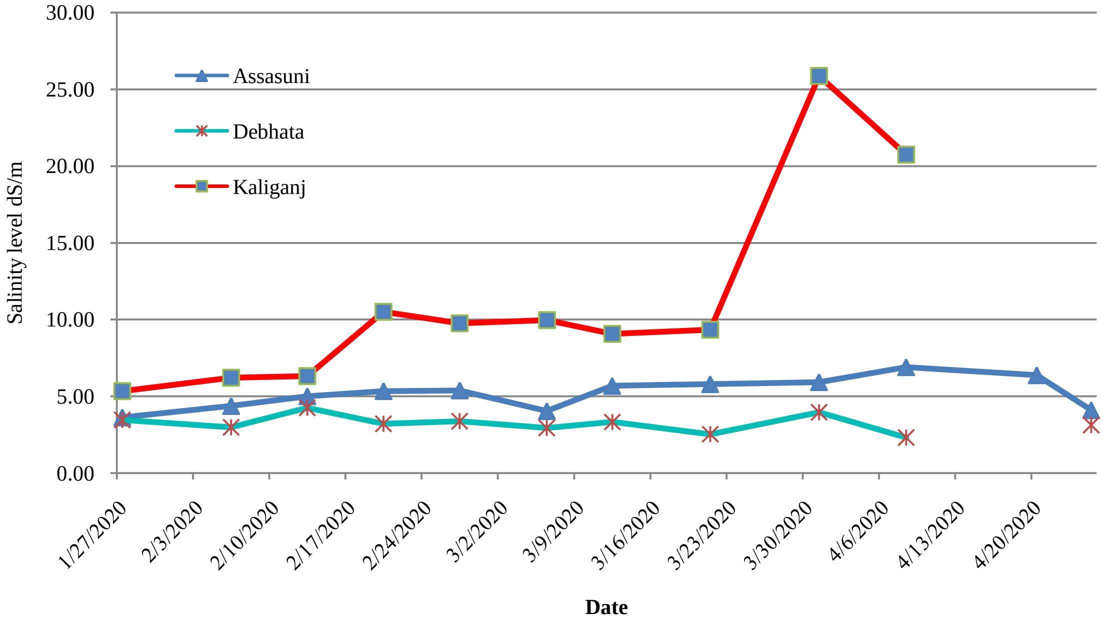


Fig. 1. Water salinity levels of different experimental plots in Boro 2019-20 at Asasuni, Kaliganj, Debhata in Satkhira.

Table 8. CMS lines multiplication of BRRI11A, IR58025A, BRRI7A and IR79156A in T. Aman 2019.

Combination	Plant height (cm)		50% flowering date		PER (%)	OCR (%)	Yield		Remarks
	A line	B line	A line	B line			Kg /plot	(t ha^{-1})	
BRRI11A/B	80	83	73	71	66	35	120	0.4	Poor seed yield due to rainfall during supplementary pollination
IR58025A/B	101	103	91	90	65	34	80	0.4	
BRRI7A/B	95	98	87	86	69	33	252	0.32	
IR79156A/B	91	93	89	86	69	37	150	0.5	

DS: B_1=9 Jun 2019, A/B_2=12 Jun 2019, B_3=14 Jun 2019; DT: A/B=7 Jul 2019
DS: B_1= 9 Jun 2019, A/B_2=12 Jun 2019, B_3=14 Jun 2019; DT: A/B=13 Jul 2019
DS: B_1=12 Jun 2019, A/B_2=15 Jun 2019, B_3=18 Jun 2019; DT: A/B=15 Jul 2019
DS: B_1=12 Jun 2019, A/B_2=15 Jun 2019, B_3=18 Jun 2019; DT: A/B=15 Jul 2019

PER = panicle exertion rate, OCR = out crossing rate.

Table 9. CMS multiplication of BRRI hybrid dhan3, BRRI hybrid dhan4 and BRRI hybrid dhan5 during Boro 2019-20.

Designation	Plant height (cm)		50% flowering (day)		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/ plot)	Seed yield (t ha^{-1})
	A line	B line	A line	B line	A line	A line			
BRRI11A/B	90	92	122	121	79	51	6400	1425	2.23
IR58025A/B	91	93	126	125	69	46	2000	320	1.60
BRRI7A/B	94	97	120	118	78	47	3000	430	1.43

DS: B_1 =7 Dec 2019; A/B_2 = 10Dec 2019; B_3 = 13 Dec 2019; DT: A/B = 13 Jan 2020.
DS: B_1 =30 Nov 2019; A/B_2 = 3Dec 2019; B_3 = 6 Dec 2019; DT: A/B = 3 Jan 2020.
DS: B_1 =5 Dec 2019; A/B_2 = 8 Dec 2019; B_3 = 11Dec 2019; DT: A/B = 8 Jan 2020.

PER=Panicle exertion rate, OCR= Out crossing rate.

F_1 seed production of BRRI hybrid dhan4, BRRI hybrid dhan5 and BRRI hybrid dhan6 in T. Aman 2019 and BRRI hybrid dhan5, BRRI hybrid dhan6 and BRRI hybrid dhan7 in Boro 2019-20

A total of 175 kg (1.2 t ha^{-1}), 230 kg (1.3 t ha^{-1}) and 130 kg (1.3 t ha^{-1}) hybrid seeds were produced from BRRI hybrid dhan4 (IR58025A/BRRI10R), BRRI hybrid dhan5 (BRRI7A/BRRI31R) and BRRI hybrid dhan6 (IR79156A/BRRI20R) respectively during T. Aman 2019 (Table 10). In Boro 2019-20, a total of 690 kg (1.73 t ha^{-1}) from BRRI hybrid dhan5, 1480 kg (2.1 t ha^{-1}) from BRRI hybrid dhan6 and 640 kg (2.6 t ha^{-1}) from BRRI hybrid dhan7 were obtained (Table 11).

Seed production of promising CMS lines and hybrids

Experimental F_1 seed production ranging 3 to 8 kg/plot from selected promising hybrid combinations during T. Aman 2019 which was equivalent to 1.2 to 3.04 t/ha having unit plot size 25m^2 (Table 12).

F_1 seed production through contract growers

We had F_1 seed production programme in Barishal and Ishwardi through contract growers during Boro 2019-20. From Barishal, we got 1200 kg (1.5 t ha^{-1}) of BRRI hybrid dhan3 and 2400 kg (1.2 t ha^{-1}) seeds of BRRI hybrid dhan5. The amounts of seeds obtained from Ishwardi was 1380 kg (2.16 t ha^{-1}), 2000 kg (2.5 t ha^{-1}), 1690 kg (2.6 t ha^{-1}), 1580 kg (1.58 t ha^{-1}), 1020 kg (1.3 t ha^{-1}) and 520 kg (2.6 t ha^{-1}) respectively from BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6 and BRRI hybrid dhan7 (Table 15).

Table 10. F_1 seed production of BRRI hybrid dhan4, BRRI hybrid dhan5 and BRRI hybrid dhan6 during T Aman 2019.

Hybrid	PHT (cm)		D50%F		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg/ plot)	Seed yield (t ha^{-1})
	A Line	R Line	A Line	R Line					
IR58025A/ BRRI10R (BHD4)	95	105	86	90	65.7	40.2	1500	175	1.2
BRRI7A/ BRRI31R (BHD5)	91	103	87	105	71.3	41.2	1800	230	1.3
IR79156A/ BRRI20R (BHD6)	96	102	90	94	72.7	45.2	1000	130	1.3

DS: R_1=14 Jul 2019; A =17 Jul 2019; R_2=20 Jul 2019; DT: R&A=8 Aug 2019
DS: R_1 = 23 Jun 2019; R_2 = 30 Jun 2019; A = 14 Jul 2019; DT: R = 27 Jul 2019; A = 10 Aug 2019
DS: R_1=10 Jul 2019; R_2 =19 Jul 2019; A=15 Jul 2019; DT: R&A=5 Aug 2019
PER (%) = panicle exertion rate, OCR (%) = Out crossing rate

Table 11. F_1 seed production of BRRI hybrid dhan5, BRRI hybrid dhan6 and BRRI hybrid dhan7 during Boro 2019-20.

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	690	1730
IR79156A/BRRI20R	85	94	126	129	89	47	1480	2100
IR75608A/BRRI31R	89	96	123	129	72	51	640	2600

DS: R_1 = 30 Nov 2019; R_2 = 7 Dec 2019; A = 26 Dec 2019; DT: R = 7 Jan 2020; A = 24 Jan 2020.
DS: R_1 = 20 Dec 2019; R_2 = 29 Dec 2019; A = 23 Dec 2019; DT: R & A = 20 Jan 2020.
DS: R_1 = 30 Nov 2019; R_2 = 7 Dec 2019; A = 21 Dec 2019; DT: R = 12 Jan 2020; A=27 Jan 2020.
PER (%) = panicle exertion rate, OCR (%) = Out crossing rate

Table 12. Experimental seed yield obtained from promising hybrid combinations

Designation	Seed amount (kg)	Yield (t ha^{-1})	Grain type	Status
BRRI7A/EL254R	4.3	1.72	M	
BRRI13A/EL254R	4.0	1.60	S	
BRRI35A/EL254R	6.2	2.48	M	Promising
BRRI99A/EL254R	4.2	1.68	S	
IR79156A/EL254R	7.8	3.12	S	Promising
BRRI35A/EL255R	5.8	2.32	M	Promising
BRRI72A/EL255R	4.0	1.60	M	
IR79156A/EL255R	7.6	3.04	S	Promising
BRRI35A/EL260R	4.4	1.76	M	
BRRI48A/ CHA15R	3.5	1.40	S	
BRRI35A/ Win1R	3.1	1.24	MS	
BRRI99A/ Win1R	3.0	1.20	S	
IR79156A/ Win1R	4.0	1.60	S	

Plot size: 25 m^2

Seed yield 34 kg/plot (0.49 t ha^{-1}), 66 kg/plot (0.83 t ha^{-1}), 73 kg/plot (1.04 t ha^{-1}), 179 kg/plot (1.49 t ha^{-1}), 3.6 kg/plot (0.9 t ha^{-1}), 5 kg/plot (0.83 t ha^{-1}). 11 kg/plot (1.10 t ha^{-1}), 4.4 kg/plot and (0.44 t ha^{-1}) were obtained from BRRI13A, BRRI35A, BRRI48A, BRRI99A, BRRI110A, IR105687A, IR105688A and IR79125A during T. Aman 2019 (Table 13). Seed amount got from selected promising CMS lines ranging from 0.89 to 2.43 t ha^{-1} during Boro 2019-20. (Table 14).

Table 13. Multiplication of promising CMS lines during T. Aman 2019.

Designation	PHT (cm)		D50%F		PER (%)	OCR (%)	Plot area (m^2)	Yield (kg /plot)	Seed Yield (t ha^{-1})
	A Line	B Line	A Line	B Line					
BRRI13A/B	91.2	93.5	81	80	72.3	33.2	700	34	0.49
BRRI35A/B	86.0	87.5	82	81	76.0	40.5	800	66	0.83
BRRI48A/B	93.0	94.2	87	85	69.7	46.3	700	73	1.04
BRRI99A/B	88.0	90.2	85	82	72.5	48.5	1200	179	1.49
BRRI110A/B	95.0	97.0	88	85	71.2	44.4	40	3.6	0.90
IR105687A/B	86.0	88.2	75	74	70.6	45.2	60	5.0	0.83
IR105688A/B	93.0	95.5	82	81	69.5	47.6	100	11	1.10
IR79125A/B	94.0	96.3	87	85	70.4	45.4	100	4.4	0.44
Average	90.8	92.8	83.4	81.6	71.5	43.9	462.5	47.0	0.9
$Lsd_{(0.05)}$	3.3	3.4	3.9	3.4	1.9	4.5		54.9	0.3
CV (%)	4.0	4.0	5.2	4.5	2.6	11.3		128.1	37.9

DS: A/B_1= 8 Jun 2019, B_2= 11 Jun2019, B_3= 14 Jun2019; DT: A/B= 4 Jul2019.
DS: A/B_1= 9 Jun2019, B_2= 12 Jun2019, B_3= 15 Jun2019; DT: A/B= 7 Jul2019.
DS: A/B_1= 10 Jun 2019, B_2= 13 Jun2019, B_3= 16 Jun2019; DT: A/B= 6 Jul2019.
DS: A/B_1= 12 Jun 2019, B_2= 15 Jun2019, B_3= 18 Jun2019; DT: A/B= 8 Jul2019.
PER = Panicle exertion rate; OCR = Out crossing rate

Table 14. Seed amount got from selected promising CMS lines during Boro 2019-20.

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					
BRRI7A/B	100	101.3	121	118	70.0	51.3	50	6.9	1.4
BRRI50A/B	95.0	93.5	119	116	67.3	47.2	250	26.3	1.05
BRRI72A/B	101	100	120	117	68.5	46.3	250	22.2	0.89
BRRI110A/B	102.4	100.5	124	121	68.2	45.2	150	20.0	1.33
IR105687A/B	97.0	95.5	119	116	76.0	53.5	150	34.0	2.3
IR105688A/B	100	98.5	117	115	75.7	52.3	400	73.0	1.8
IR79125A/B	89.0	90.3	131	128	71.6	51.2	150	31.0	2.07
BRRI99A/B	98.0	96.5	131	128	72.3	54.0	2000	485	2.43
Average	97.8	97.01	122.75	119.88	71.20	50.13	425.00	87.30	1.66
Lsd $_{(0.05)}$	3.89	3.48	4.99	4.86	3.04	3.11		147.62	0.53
CV (%)	4.36	3.93	4.46	4.45	4.68	6.79		185.38	34.79

DS: B_1=3 Dec 2019; B_2/A = 6 Dec 2019; B_3= 9 Dec 2019; DT: 7 Jan 2020; PER (%) = panicle exertion rate, OCR (%) = Out crossing rate

Table 15. F_1 seed production of BRRI developed hybrids through contract growers during Boro 2019-20.

Variety	Contract grower	Location	Area (Acre)	Seed Yield (kg)	Seed yield (t ha^{-1})	Remarks
BRRI hybrid dhan3	Md. Jalal Akand	Babuganj Barishal	2.0	1200	1.5	
BRRI hybrid dhan5	Md. Jalal Akand	Babuganj Barishal	5.0	2400	1.2	
BRRI hybrid dhan2	Aus Bangla Agro	Potirajpur Ishwardi	1.4	1380	2.5	
BRRI hybrid dhan3	Aus Bangla Agro	Potirajpur Ishwardi	2.0	2000	2.5	
BRRI hybrid dhan4	Aus Bangla Agro	Potirajpur Ishwardi	1.6	1690	2.6	
BRRI hybrid dhan5	Aus Bangla Agro	Potirajpur Ishwardi	2.5	1580	1.6	
BRRI hybrid dhan6	Aus Bangla Agro	Potirajpur Ishwardi	2.0	1020	1.3	
BRRI hybrid dhan7	Aus Bangla Agro	Potirajpur Ishwardi	0.5	520	2.6	
		Total=	17	11790	15.8	

Table 16. Amount of parental line and hybrid seeds supplied to different organization.

Recipient	Nos.	F_1 (kg)	A line (kg)	B line (kg)	R line (kg)
Seed companies	22	1200.0	1200.00	-	550.00
Farmers	90	700.0	350.00	-	150.00
BRRI scientists + staffs +DAE	19	4500.0	-	-	-
BRRI, RS (5) +SPIRA	6	2100.0	-	-	-
Total	137	8500.00	1550.00	0.00	700.00
Grand total				10750.00	

Investigator: All staff of hybrid rice division.

Dissemination of Hybrid rice technology

In the reporting year, Hybrid Rice Division supplied 10750 kg of parental lines and F_1 seeds to 90 farmers, 22 seed companies, scientists, extension people and BRRI staffs (Table 16). A total of 1,06,800 kg F_1 seeds were produced during Boro 2019-20 with the technical assistance from BRRI to BADC, 22 seed companies and regional stations of BRRI (Table 17).

Table 17. Seed production activities of BRRI developed hybrids during Boro 2019-20 both at private and public sectors.

Organization/person	Location	Var	Area (acre)	Yield achieved (ton)	Remark
Jalal Akand Contact growers BRRI	Babuganj Barishal	BHD3	2.0	1.2	Experienced
		BHD5	5.0	2.4	
Md Shaidul Islam Setu seed company	Domer Nilphamari	BHD3	1.0	0.8	Experimental
		BHD5	1.0	0.8	
M/S Shahid Biz Vander	Pakundia Kishoreganj	BHD4	1.0	0.8	Experimental
		BHD5	1.0	0.7	
		BHD6	1.0	1.3	
ARM Agro Care Abdulla Al Masud Mondol	Ghorghat Dinajpur	BHD3	3.0	2.8	Experienced
Bangladesh Seed Company Md Jalal Hossain	Raninagar Naogaon	BHD3	3.0	2.5	Experienced
Rashel Seed Store Mokasdesh Ali	Domer Nilphamari	BHD2	1.0	1.1	Experienced
		BHD3	2.0	2.2	
		BHD5	2.0	1.7	
Sumaya Seed Company	Kurigram	BHD3	2.0	1.8	Experienced
Raja Seed Company Md Aminul Islam Razzak	Pirgasha Rangpur	BHD3	1.0	1.1	Experienced
		BHD6	1.0	1.0	
Nilshagar Seeds and Tissue Culture Ltd. Md Joynul Abedin Chowdhury	Nilphamari	BHD3	1.0	0.9	Experienced
		BHD5	1.0	0.8	
		BHD6	1.0	1.1	
Ahasan Seeds and Agro Tech	Ghafforgaon Mymensingh	BHD2	2.0	2.1	Experienced
		BHD3	1.0	1.0	
		BHD4	10.0	8.5	
		BHD6	8.0	9.5	
Shajalal Seed Company Kbd Jahangir Alam	Rupganj Nararyanganj	BHD2	0.5	0.6	Experienced
		BHD4	1.0	0.8	
		BHD6	1.0	1.1	
Foloboti Seed Company Md Borhanuddin	Dumuria Khulna	BHD3	1.0	1.2	Experienced
Abtaf Bhaumukhi Farms Ltd Kbd Md Fazlul Haque	Kishoreganj	BHD5	1.0	0.8	Experienced
Aus Bangla Agro	Mission gate Bogura	BHD3	2.0	2.2	Experienced
		BHD5	2.0	1.6	
Aus Bangla Agro Contact Growers BRRI	Mission gate Bogura	BHD2	1.4	1.38	Experienced
		BHD3	2.0	2.0	
		BHD4	1.6	1.68	
		BHD5	2.0	1.58	
		BHD6	2.0	1.02	
		BHD7	0.5	0.52	
Mojadadia Vander Md Sharif Hossain	Assasuni Satkhira	BHD5	1.0	0.7	Experimental
Asha Agro Md Abdur Razzak	Sayedpur Nilphamari	BHD5	1.0	0.8	Experienced
JF Agro Md Jamaluddin	Savar Dhaka	BHD3	8.0	9.0	Experience
		BHD5	3.0	2.6	
		BHD6	1.0	0.7	
Sumon Hasan	Bokshiganj Jamalpur	BHD4	1.0	0.8	Experimental
Northern Agricultural & Industrial Company Ltd (NICOL)	Thakurgaon	BHD6	2.0	2.1	Experienced

Table 17. Continued.

Organization/person	Location	Var	Area (acre)	Yield achieved (ton)	Remarks
Abdur Rahman Agro Company Mohammad Barek Hossain	Uttara Dhaka	BHD5	10	9.2	Experience
Dr Adil Badsha PSO & Head, BRRI RS, Rangpur	Rangpur	BHD5	0.5	0.3	Experienced
Md Waziuddin	Chokoria Cox's Bazar	BHD6	2.0	1.5	Experimental
Supreme Seed Company	Valuka Mymensingh	BHD6	12.0	11.0	Experienced
Md Salim Mia	Shorupkhati Barishal	BHD3	2.0	1.5	Experimental
BADC	Kashempur Madhupur	BHD5	1.5	1.2	Experienced
	Gazipur BRRI HQ	BHD5	1.0	0.69	
Gazipur, BRRI HQ	BARI	BHD7	0.2	0.6	Experienced
	BSRI	BHD6	1.5	1.5	
	Total=		116.7	106.8	

Legend: 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

SUMMARY

BRRI dhan48 planted on May 10th produced about 0.5 t ha^{-1} higher grain yield than the check varieties viz, BR26 and BRRI dhan82 with 112 days growth duration. Rainfed lowland rice (RLR) line, BR8841-38-1-2-2 transplanted in 15 July produced the highest grain yield (5.40 t ha^{-1}) within 127 days. Zinc enriched rice (ZER) line BR8436-7-4-2-3-1 planted on 15 July produced the highest grain yield (5.56 t ha^{-1}) followed by BR8442-12-1-3-1-B7 (5.50 t ha^{-1}) with growth duration 126 days and 136 days respectively. Biotechnology ALART lines didn't produced higher grain yield over the check BRRI dhan71 and BRRI dhan87. Biotechnology RYT line BR (Bio)10376-AC11-3-1 produced identical grain yield with BRRI dhan71 from 1 August to 16 September with delaying 2-3 days. Biotechnology ALART, PQR linesBR8862-29-1-5-3, BR8995-2-5-5-2-1 were statistically identical with BRRI dhan50 and matured 1-5 days delayed. Biotechnology ALART, ZER line didn't produced higher grain yield than the check. Advanced line for Haor region grown at Gazipur gave lower grain yield than the check variety, but matured 4-20 days earlier than BRRI dhan28. In Haor region BRRI dhan67 followed by BRRI dhan89 produced the highest grain yield transplanted on December. In Boro, BRRI dhan84 and BRRI hybrid dhan5 produced the highest tiller number and highest grain yield 8.44 t ha^{-1} and 8.01 t ha^{-1} respectively with 45 days old seedling. In T. Aman, BRRI dhan71 and BRRI dhan87 produced higher grain yield 6.04 t ha^{-1} and 5.52t ha^{-1} respectively with 25-day-old seedling. Economic fertilizer rate for BR26, BRRI dhan48 and BRRI dhan82 was determined as 88, 86 and 60 kg ha^{-1} respectively. BRRI dhan89 produced significant grain yield (7.30 t ha^{-1}) with 16% higher urea fertilizer in four equal splits and 1/3 MoP applied with 3rd top dress of urea along with BRRI recommended fertilizer management at BRRI farm Gazipur. BRRI recommended management and treatment with 29.5 kgha^{-1}as basal + 29.5 kgha^{-1}at 15 DAT + 10 kg ha^{-1} at heading stag produced significantly higher grain yield, panicle m^{-2} and sterility (%). Line transplanting with logo method (line gap) after six, eight or ten lines with 20 cm × 15 cm or 15 cm × 15 cm spacing had no significant effect on grain yield and panicle number in T.Aman season. BRRI dhan48 (4.53 t ha^{-1}) and BRRI dhan85 (4.43 t ha^{-1}) produced significant higher grain yield over BRRI dhan82 (3.46 t ha^{-1}) with integrated crop management (ICM) followed by BRRI recommended fertilizer (BRF) management. In T. Aman season BR23 followed by BRRI dhan39 and in Boro season BR17 followed by BRRI dhan45 and BRRI hybrid dhan5, hybrid Mollica and SL8 had higher ability to suppress weed in initial stage of rice growth. Mungbean (BARI Mung-6)- T. Aus (BRRI dhan48)-T. Aman -Potato (Cardinal) cropping pattern was found more profitable in stress prone area Alimgonj (drought) and Amtoli (salinity) without losing the soil health/ fertility with proper agronomic practices.

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 and selection of genotypes having high yield potential in T. Aus; T. Aman and Boro season.

T. Aus Season, 2019

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 Gazipur.

BRRI dhan48 produced the highest grain yield (3.5-4.0 t ha^{-1}) within 109-112 days in all planting time. Higher number of panicles m^{-2}, higher grains panicle^{-1} and heavier grain weight (data not shown) contributed to higher grain yield of BRRI dhan48 (Table 1). The best planting time for all varieties was 10 May. Crop yield was partially damaged by bird during ripening stage.

T. Aman season, 2019

Four rainfed low land rice (RLR) lines BR8521-30-3-1, BR8841-38-1-2-2, BR8526-38-3-2-1-HR2, BR8526-38-3-2-1-HR8 were transplanted with check BRRI dhan49 and BRRI dhan87 on 15 July, 30 July, 15 August and 30 August 2019. RLR line BR8841-38-1-2-2 produced the highest grain yield when planted on 15 July (5.40 t ha^{-1}) followed by

30 July (5.26 t ha^{-1}). Decreasing trend of grain yield was observed in all the tested entries when transplanted after 30 July. The tested entries mature 4-6 days earlier than BRRI dhan49 (Table 2).

Three Zinc Enriched Rice (ZER) lines BR8436-7-4-2-3-1, BR8442-12-1-3-1-B7, IR 90210-100-2-3-1-P4 were tested with the checks BRRI dhan72, BRRI dhan49 and BRRI dhan87 on 15 July, 30 July, 15 August and 30 August 2019. BR8436-7-4-2-3-1 produced the highest grain yield (5.56 t ha^{-1}) followed by BR8442-12-1-3-1-B7 (5.50 t ha^{-1}) planted on 15 July with growth duration 126 days and 136 days respectively (Table 2). The yield gradually decreased and growth duration gradually increased after mid July transplanting. Mid duration (BR8436-7-4-2-3-1 and IR 90210-100-2-3-1-P4) produced similar yield with check BRRI dhan72 and BRRI dhan87, whereas long duration BR8442-12-1-3-1-B7 produced similar yield with BRRI dhan49 in mid July transplanting.

Table 1. 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 2019 at BRRI HQ farm, 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	3.3	3.5	2.9	3.5	116	115	114	112
BRRI dhan48	3.6	4.0	3.5	3.6	113	112	111	109
BRRI dhan82	3.1	3.4	2.9	3.0	102	105	103	100
LSD $_{(0.05)}$	ns	1.03	0.63	0.48				
CV (%)	11.8	2.1	1.0	6.3				
	Panicle m^{-2}				Grain panicle^{-1}			
BR26	272	287	263	264	34	42	24	41
BRRI dhan48	235	307	237	231	54	71	38	44
BRRI dhan82	203	244	239	223	55	67	27	42
LSD $_{(0.05)}$	50.22	ns	ns	ns	12.65	3.45	ns	ns
CV (%)	9.4	20.8	14.5	12.6	11.7	10.0	33.7	21.4

Table 2. Effect of planting time on grain yield (t ha^{-1}) and growth duration (day) of advanced rainfed lowland rice (RLR) and zinc enriched rice (ZER) lines in T. Aman 2019 at BRRI Gazipur.

Variety/line	Grain yield (t ha-1)				Growth Duration (Day)			
	15 Jul	30 Jul	15 Aug	30 Aug	15 Jul	30 Jul	15 Aug	30 Aug
Rainfed lowland rice (RLR)								
BR8521-30-3-1	5.21	5.01	4.20	2.38	127	128	132	135
BR8841-38-1-2-2	5.40	5.26	4.45	2.70	127	129	131	136
BR8526-38-3-2-1-HR2	4.97	5.16	4.41	3.05	130	130	132	136
BR8526-38-3-2-1-HR8	4.98	4.90	4.40	2.46	129	131	133	137
BRRI dhan49 (ck)	5.10	5.10	4.52	3.83	134	136	137	137
BRRI dhan87(ck)	5.22	5.15	3.98	2.59	127	129	131	135
LSD (0.05)	0.846				2.343			
CV (%)	11.6				1.1			
Zinc Enriched Rice (ZER)								
BR8436-7-4-2-3-1	5.56	4.85	4.53	2.87	126	128	132	136
BR8442-12-1-3-1-B7	5.50	5.09	4.60	2.49	136	137	139	143
IR 90210-100-2-3-1-P4	5.14	4.81	4.69	3.25	128	129	132	137
BRRI dhan72 (ck)	5.42	5.24	4.40	2.86	124	125	129	133
BRRI dhan49 (ck)	5.10	5.10	4.52	3.83	134	136	137	141
BRRI dhan87 (ck)	5.22	5.15	3.98	2.59	128	129	131	135
LSD (0.05)	0.781				0.878			
CV (%)	10.6				o.8			

Table 3. Effect of planting time on grain yield and growth duration of Biotechnology advanced ALART and RYT lines in T. Aman 2019 season at BRRI farm Gazipur.

Variety/line	Grain yield (t ha-1)				Growth Duration (Day)			
	1 Aug	16 Aug	1 Sep	16 Sep	1 Aug	16 Aug	1 Sep	16 Sep
ALART lines from Biotechnology Div.								
BR(Bio)9786-BC2-161-1-2	5.08	4.97	3.42	2.58	117	119	123	125
BR(Bio)9786-BC2-80-1-1	4.93	4.37	4.30	3.28	120	121	123	128
BRRI dhan71 (ck)	5.08	5.04	4.41	3.21	117	118	120	126
BRRI dhan87 (ck)	5.29	5.08	4.30	2.59	128	129	131	135
LSD (0.05)	0.756				0.794			
CV (%)	10.5				0.9			
RYT lines from Biotechnology Div.								
BR(Bio)10376-AC4-1-3	4.44	3.98	3.97	RD	115	116	119	RD
BR(Bio)10376-AC9-1-3	4.27	4.21	4.10	2.89	113	116	120	125
BR(Bio)10376-AC11-3-1	5.24	5.09	4.76	2.83	120	122	125	129
BRRI dhan71 (ck)	5.08	5.04	4.41	3.21	117	118	120	126
LSD (0.05)	0.678				0.983			
CV (%)	10.1				0.5			

RD= Rat damage

Two ALART lines BR(Bio)9786-BC2-161-1-2 and BR (Bio) 9786-BC2-80-1-1 were transplanted with the checks BRRI dhan71 and BRRI dhan87 on four planting times i e 1 August, 16 August, 1 September and 16 September 2019. None of the tested lines produced higher grain yield over the slandered check varieties (Table 3). Furthermore, none of the tested lines matured earlier than BRRI dhan71 (ck) but about ten days earlier than BRRI dhan87 (ck).

Three RYT lines BR(Bio)10376-AC4-1-3, BR(Bio)10376-AC9-1-3, BR (Bio) 10376-AC11-3-1 were tested with BRRI dhan71 (ck) transplanted on 01 August, 16 August, 1 September and 16 September 2019. BR(Bio)10376-AC11-3-1 line produced ideal grain yield with BRRI dhan71 from 1 August to 16 September with delaying 2-3 days (Table 3).

Boro season, 2019-2020

Three advanced lines for Haor region such as BRRI dhan29-SC3-P8 (Hbg), BRRI dhan29-SC3-P11 (Hbg), BR8845-18-1-1-1 (SP21) were transplanted with check BRRI dhan28 on 5 December, 15 December, 25 December 5 January and 15 January 2019-2020 in BRRI farm, Gazipur. Although the tested lines produced lower grain yield than the check variety, they matured 4-20 days earlier than the shortest duration BRRI dhan28. In Haor region, where early crop harvesting is very important issue. BRRI dhan29-SC3-P8 (Hbg) line could further check in the particular area with planting time on 5 December 15 December and 15 January. BR8845-18-1-1-1 (SP21) could be considered as planted on 25 December and 15 January (Table 4).

For Haor region BRRI developed varieties BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan84, BRRI dhan88, BRRI dhan89, BRRI dhan28 (ck) and BRRI dhan29 (ck) were transplanted on 30 November, 10 December, 20 December, 30 December and 10 January. The grain yield of tested varieties produced different grain yields irrespective of transplanting time (Table 4). The highest yield was observed from BRRI dhan67 at 30 November to 30 December transplanting followed by BRRI dhan89. BRRI dhan74 produced the lowest yield among the tested varieties. In case of growth duration, higher growth duration was observed in early transplanting which was decreased in late transplanting in all varieties.

Two ALART, PQR lines such as BR8862-29-1-5-3, BR8995-2-5-5-2-1 and BRRI dhan50 (ck) were transplanted on 15 December, 30 December, 15 January and 30 January at BRRI farm, Gazipur. The grain yield of tested PQR lines produced statistically identical with check variety BRRI dhan50 irrespective of planting time (Table 5). The maturity of both PQR lines were 1-5 days delayed than check BRRI dhan50 from mid December to mid January.

One ALART, ZER lines was transplanted with checks IR99285-1-1-1-P2, BRRI dhan29 (ck) and BRRI dhan84 (ck) were planted on 15 December, 30 December, 15 January and 30 January at BRRI farm, Gazipur. There was no significant yield difference found among the tested entries over the checks (Table 5). Moreover, growth duration of tested entries was similar with BRRI dhan29 but two weeks longer than the check variety BRRI dhan84.

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

The experiment was conducted at BRRI farm, Gazipur during T. Aman 2019 and Boro 2019-20 to find out the effect of seedling age on tiller production and grain yield. Five T. Aman varieties viz BRRI dhan71, BRRI dhan72, BRRI dhan75, BRRI dhan87, BRRI hybrid dhan6 were planted with seedling age 15, 20, 25 and 30 days. Four Boro varieties, BRRI dhan84, BRRI dhan86, BRRI dhan88 and BRRI hybrid dhan5 were grown with seedling age 30, 35, 40, 45 and 50 days.

Table 4. Effect of planting time on grain yield and growth duration of advanced lines at BRRI farm Gazipur and varieties at Habiganj for Haor region in Boro 2019-20 season.

Varietiy/line	Grain yield (t ha-1)					Growth duration (day)				
	Advanced lines for Haor region in Gazipur									
	05 Dec	15 Dec	25 Dec	05 Jan	15 Jan	05 Dec	15 Dec	25 Dec	05 Jan	15 Jan
BRRI dhan29-SC3-P8 (Hbg)	5.56	5.92	5.54	4.92	7.81	155	143	134	131	130
BRRI dhan29-SC3-P11 (Hbg)	4.57	5.82	5.88	5.54	7.62	153	142	134	131	130
BR8845-18-1-1-1 (SP21)	5.55	5.74	5.87	5.21	6.15	153	142	134	131	130
BRRI dhan28(ck)	7.48	6.38	6.67	6.10	7.83	159	152	156	141	140
LSD (0.05)			0.648					0.654		
CV (%)			1.1					0.85		
	HYV for Haor region at Habiganj									
	30 Nov	10 Dec	20 Dec	30 Dec	10 Jan	30 Nov	10 Dec	20 Dec	30 Dec	10 Jan
BRRI dhan28	5.82	7.31	6.73	7.35	7.33	164	156	152	148	138
BRRI dhan29	6.78	6.45	7.98	7.77	6.73	180	170	168	163	153
BRRI dhan58	6.98	6.65	7.70	7.25	6.20	170	163	154	155	147
BRRI dhan67	8.79	8.09	8.29	8.95	6.86	167	159	150	149	147
BRRI dhan74	4.83	6.03	7.88	7.16	6.69	165	157	148	145	137
BRRI dhan84	6.80	6.80	6.89	6.19	5.93	163	156	148	146	138
BRRI dhan88	6.80	6.58	6.99	6.45	5.49	164	157	150	148	137
BRRI dhan89	7.09	7.30	7.63	7.90	8.47	174	168	166	158	151
LSD (0.05)			1.451					2.77		
CV (%)			12.6					1.1		

Table 5. Effect of planting time on grain yield and growth duration of ALART, PQR and ALART, ZER lines in Boro 2019-20 season at BRRI farm Gazipur.

Variety/line	Grain yield (t ha-1)				Growth Duration (day)			
	15 Dec	30 Dec	15 Jan	30 Jan	15 Dec	30 Dec	15 Jan	30 Jan
	ALART, PQR							
BR8862-29-1-5-3	5.16	5.41	5.50	4.86	161	158	157	151
BR8995-2-5-5-2-1	5.16	5.47	5.55	4.88	158	156	155	148
BRRI dhan50 (Ck)	4.93	5.30	5.34	4.76	156	155	153	149
LSD (0.05)		0.653				1.485		
CV (%)		7.3				o.6		
	ALART, ZER							
IR99285-1-1-1-P2	5.32	5.79	5.75	4.80	160	158	158	153
BRRI dhan29 (Ck)	5.87	6.39	6.46	5.39	162	158	156	149
BRRI dhan84 (Ck)	5.42	5.73	5.81	5.20	145	142	141	136
LSD (0.05)		0.717				2.672		
CV (%)		7.4				1.0		

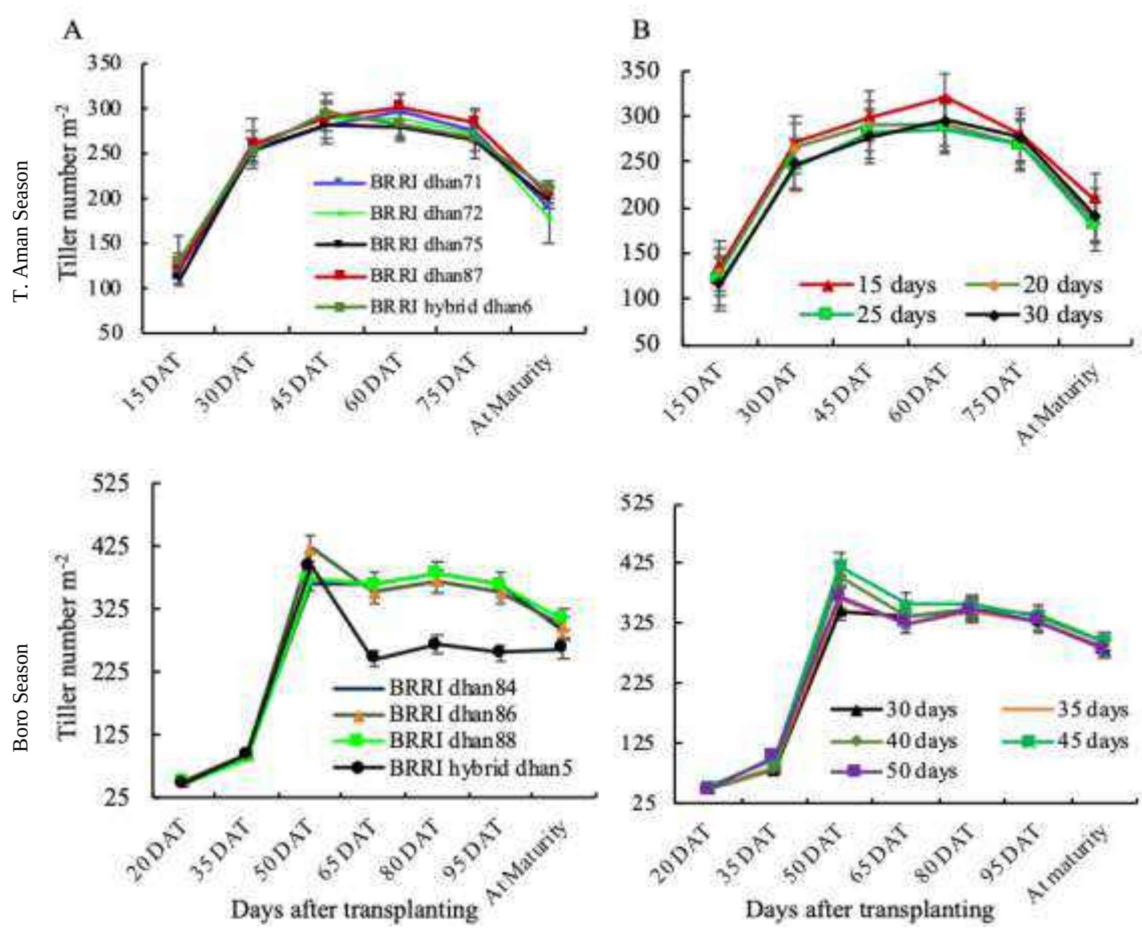


Fig. 1. Effect of seedling age on tillering number at different growth stages showing vertical bars represent SE value at the 5% level of significance.

In T. Aman, the youngest (15 day old) seedling produced the highest tillers among all varieties. Young seedling started quicker tiller formation compared to gradually older one might be for the longer adaptation time. The maximum tiller number was observed at 60 DAT for all the varieties and then it declines (Fig. 1). BRRI dhan87 produced the highest tiller number (302 m^{-2}) followed by statistically similar that of BRRI dhan71 (297 m^{-2}), BRRI dhan72 (290 m^{-2}) and BRRI hybrid dhan6 (283 m^{-2}) respectively. Transplanted with 25-day-old seedling produced the highest grain yield (5.09 t ha^{-1}) followed by statistically identical 20-day-old seedling (4.46 t ha^{-1}) and 30-day-old seedling (4.45 t ha^{-1}) respectively. Higher grain yield of BRRI dhan71 and BRRI dhan87 was mainly attributed due to higher grains $panicle^{-1}$ (Table 6).

In Boro season, 45-day-old seedling produced higher grain yield (7.09 t ha^{-1}) followed by that of 40 days (6.97 t ha^{-1}) and 30 and 35-day-old seedling (6.68 t ha^{-1}). BRRI dhan84, BRRI dhan86 and BRRI dhan88 produced statistically identical tiller pattern with an exception in BRRI hybrid dhan5 (Fig. 1). Maximum number of tillers were grown at 50 DAT for all varieties and then decline (Fig. 1). BRRI dhan84 and BRRI hybrid dhan5 produced the highest yield 8.44 and 8.01 t ha^{-1} respectively mainly attributed to higher dry matter production (Table 6). Among the varieties BRRI hybrid dhan5 showed significantly the highest straw yield (8.8 t ha^{-1}) and BRRI dhan84 showed the highest harvest index (0.58).

Table 7. Effect of seedling age of BRRI varieties on grain yield and yield components in T. Aman and Boro season 2019, Gazipur.

Treatment	Panicles m^{-2}	Grains $panicle^{-1}$	1000 GW (g)	GY ($t\ ha^{-1}$)	Harvest index
	T. Aman season				
BRRI dhan71	170	103	23.0	5.22	0.57
BRRI dhan72	146	99	26.4	4.58	0.46
BRRI dhan75	199	84	19.7	4.02	0.49
BRRI dhan87	175	96	22.0	4.95	0.47
BRRI hybrid dhan6	202	72	23.1	4.31	0.47
$LSD_{(0.05)}$ for variety	25.4	14.1	0.90	0.74	0.56
15 days	191	89	23.3	4.28	0.47
20 days	184	88	23.5	4.46	0.50
25 days	178	92	23.2	5.09	0.51
30 days	171	95	22.7	4.45	0.49
$LSD_{(0.05)}$ for seedling age	ns	ns	ns	0.45	ns
CV (%)	13.2	20.3	5.1	14.5	10.6
	Boro season				
BRRI dhan84	285	125	23.3	8.44	0.58
BRRI dhan86	290	82	22.1	4.66	0.38
BRRI dhan88	303	109	21.0	6.07	0.43
BRRI hybrid dhan5	253	130	24.3	8.01	0.47
$LSD_{(0.05)}$ for variety	7.23	10.3	1.82	0.78	0.66
30 days	282	111	23.0	6.68	0.47
35 days	281	108	22.6	6.67	0.46
40 days	283	115	22.4	6.97	0.49
45 days	285	112	22.7	7.09	0.46
50 days	283	113	22.2	6.48	0.45
$LSD_{(0.05)}$ seedling age	NS	NS	NS	NS	NS
CV (%)	3.3	12.0	4.2	11.3	10.6

FERTILIZER MANAGEMENT

Determination of economic Nitrogen rate for popular transplant Aus rice varieties

The experiment was conducted at BRRI farm, Gazipur during Aus season of 2019. Different 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 followed factorial RCB design with three replications. Twenty-days-old seedlings were transplanted on 30 April 2019 having 20 × 20 cm spacing with two seedlings per hill.

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 8). The highest grain yield of 5.52 t ha^{-1} was produced in BRRI dhan48 followed by BRRI dhan82 (4.52 t ha^{-1}) and BR26 (4.51 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. 2). Differentiating the quadratic equation of yield response with respect to applied N doses, the optimum N rate appeared as 88, 86 and 60 kg ha^{-1} for BR26, BRRI dhan48 and BRRI dhan82 respectively.

Table 8. Growth, yield and yield character of BR26, BRRI dhan48 and BRRI dhan82 as affected by different N rates during Aus 2019.

Variety	N rate (kg ha^{-1})	Panicle/m^2	Grain/Panicle	1000 GW (g)	GY (t ha^{-1})	Pl. ht. (cm)	LAI at booting	TDM at boot
	N_0	232	67	20.33	2.63	118.0	3.02	6.18
	N_{40}	244	80	20.38	3.26	120.5	3.03	7.65
BR26	N_{60}	257	91	20.16	4.22	119.8	3.04	9.43
	N_{80}	265	96	20.10	4.51	121.8	3.05	9.90
	N_{100}	252	89	19.98	4.10	121.7	3.04	9.36
	N_0	234	83	18.38	2.92	118.3	3.02	7.00
	N_{40}	243	88	22.08	3.69	120.4	3.03	8.45
BRRI dhan48	N_{60}	260	102	19.19	5.26	123.6	3.04	11.32
	N_{80}	270	106	19.17	5.57	125.4	3.06	11.97
	N_{100}	262	102	22.41	4.88	122.3	3.05	10.93
	N_0	239	77	21.86	3.09	118.4	3.02	7.45
	N_{40}	217	98	21.98	4.04	120.6	3.03	9.30
BRRI dhan82	N_{60}	249	94	22.14	4.26	123.1	3.04	9.72
	N_{80}	250	98	19.01	4.52	126.9	3.06	9.96
	N_{100}	202	83	20.87	3.33	122.9	3.04	7.79
LSD $_{(0.05)}$ for V		14.98	7.77	ns	0.49	1.46	ns	0.99
LSD $_{(0.05)}$ for N rate		19.33	10.03	ns	0.63	1.88	0.48	0.44
LSD $_{(0.05)}$ for V × N rate		ns	ns	ns	ns	ns	ns	ns
CV (%)		8.2	11.5	11.2	16.4	1.6	1.2	14.6

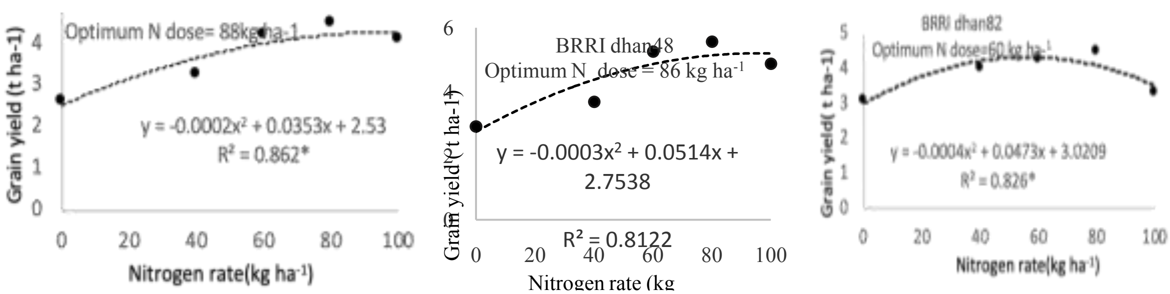


Fig. 2. Optimum N rate of BR6, BRRI dhan48 and BRRI dhan82.

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

BRRI dhan89 was mechanically transplanted to determine potassium (k) management at BRRI farm, Gazipur with treatments 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 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= BRRI recommended fertilizer (N-P-K-S-Zn 138-20-82-20-3.6 kg ha^{-1}). The initial soil status was: pH= 6.3, OM= 1.36, Total N= 0.13, P= 9.7 ppm, K= 0.16 meq/100 g soil.

Panicle per m^2 and grains per panicle were non-significant. The highest grain yield was observed in M_2 treatment (7.30 t ha^{-1}) (Table 9). So, it may me concluded that 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 apply with 3^{rd} top dress of urea.

Effect of nitrogen management at the reproductive phase of rice

An experiment was conducted in T. Aman 2019 at BRRI farm, Gazipur to find out the effect of urea top dress at reproductive stage. Soil test based fertilizer rate was N-P-K-S-Zn @ 69-10-41-16 kg ha^{-1}. BRRI dhan75 was tested under four N split treatments as, T_0=No fertilizer, T_1=23 kg ha^{-1} as basal + 23 kg ha^{-1} at 15 DAT + 23 kg ha^{-1} at BPI (BRRI recom. practice); T_2=29.5 kg ha^{-1} as basal + 29.5 kg ha^{-1} at 15 DAT + 10 kg ha^{-1} at 10 days after PI (DAPI); T_3=29.5 kg ha^{-1} as basal + 29.5 kg ha^{-1} at 15 DAT + 10 kg ha^{-1} at 20 days after PI (DAPI)/Booting and T_4 = 29.5 kg ha^{-1} as basal + 29.5 kg ha^{-1} at 15 DAT + 10 kg ha^{-1} at heading stage. Initial soil status of the experimental field was pH=6.5, Total N=0.13%, P=40.1 µg/g, K=0.146 me/100 g soil, S=14.06 µg/g and Zn=0.81 µg/g.

Among N management treatments BRRI recommended management (T_1) and 29.5 kg as basal + 29.5 kg at 15 DAT + 10 kg ha^{-1} at heading stage (T_4) produced the significantly highest grain yield (5.5 and 5.2 t ha^{-1}). The lowest grain yield was observed from T_0, T_2 and T_3 treatment (4.2, 4.62 and 4.95 t ha^{-1}) respectively. No significant difference was observed in grains $panicle^{-1}$, thousand grain weight (g), straw yield and harvest index. There was significant difference among different N management techniques in $panicle^{-2}$ and sterility (%). The highest sterility% was found in T_0 (42.2%) and the lowest sterility % was found in T_1 (26.3%), T_4 (32.8%), T_3 (36.7%) and T_2 (40.3%) respectively (Table 10).

Table 9. Growth and yield of mechanically transplanted rice with different fertilizer management compared with traditional transplanted rice.

Treatment	LAI at booting	CGR (g m-2 day) at MT	Panicle m^{-2}	Grains $panicle^{-1}$	1000 GW (g)	GY (t ha^{-1})
M_1	4.08	45.95	292	89	24.53	6.51
M_2	4.88	55.44	305	100	24.65	7.30
M_3	4.55	45.40	297	93	24.25	6.69
M_4	4.70	46.28	290	90	24.20	6.71
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	0.26
CV (%)	10.1	16.1	3.9	9.6	5.85	2.5

Table 10. Yield and yield components affected by different N management practices in BRRI dhan75 at BRRI farm, Gazipur.

Treatment	Panicle m^{-2}	Grain $panicle^{-1}$	1000 GW (g)	GY (t ha^{-1})	Sterility (%)	HI
T_0 = No fertilizer	223	86	21.6	4.2	42.2	0.42
T_1 = 23 kg ha^{-1} as basal + 23 kg ha^{-1} at 15 DAT + 23 kg ha^{-1} at BPI (BRRI recom. practice)	267	82	20.1	5.5	26.3	0.53
T_2 = 29.5 kg ha^{-1}as basal + 29.5 kg ha^{-1}at 15 DAT + 10 kg ha^{-1} at 10 days after PI (DAPI)	295	88	19.4	4.62	40.3	0.47
T_3 = 29.5 kg ha^{-1}as basal + 29.5 kg ha^{-1}at 15 DAT + 10 kg ha^{-1} at 20 days after PI (DAPI)	279	90	21	4.95	36.7	0.47
T_4 = 29.5 kg ha^{-1}as basal + 29.5 kg ha^{-1}at 15 DAT + 10 kg ha^{-1}	264	82	20.4	5.22	32.8	0.49
$LSD_{(0.05)}$	7.40	NS	NS	0.30	4.58	NS
CV (%)	1.5	20.5	5.7	3.2	6.9	8.9

Comparative performance of logo method and normal transplanting with different spacings

An experiment were conducted at BRRI farm, Gazipur during T. Aman 2019 to observe the grain yield of line spacing and logo method or, one line gap after few lines of transplanting. The transplanting methods were in main plots; L_1= Normal line transplanting, L_2= Transplanting with logo method after six lines; L_3=Transplanting with logo method after eight lines; L_4= Transplanting with logo method after ten lines. The spacings were in sub plots S_1=20 cm × 15 cm, S_2=15 cm × 15 cm with three replications.

The interaction effect of line and logo method with spacing and their individual effect was not significant (Table11). Line transplanting with logo method after ten lines with 20 cm × 15 cm spacing produced insignificant higher grain yield (4.53 t ha^{-1}). Other treatments produced similar grain yield ranging from 4.28 to 4.48 t ha^{-1}. Results shows that there is no significant effect of line and logo method with variable spacing.

Yield maximization of T. Aus rice through integrated crop management

To maximize the yield of potential BRRI dhan48, BRRI dhan82 and BRRI dhan85 this experiment was conducted at BRRI farm Gazipur during T. Aus season of 2019. The treatments were: M_1= BRRI recommended management (BRM) fertilizer N-P-K (69-10.4-41 kg ha^{-1} and 2 seedlings hill^{-1}) and M_2= Integrated crop management (ICM) 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). The experiment followed factorial RCB design with three replications. Twenty-day-old seedlings were transplanted on 6 May 2019 with 20 × 20 cm spacing. Initial soil status of the experimental field was pH=6.5, N= 0.13%, P=8.89 ppm and K=0.28 me/100 g, S = 32.1 ppm, Zn = 4.1 ppm.

Table 11. Effect of line and logo method and spacing on grain yield of BRRI dhan71.

Transplant method	Spacing	Panicle m^{-2}	Grain panicle^{-1}	1000 GW (g)	GY (t ha^{-1})
L_1	S_1	126	119	23.63	4.45
L_1	S_2	122	116	23.08	4.41
L_2	S_1	124	121	23.22	4.45
L_2	S_2	139	111	23.04	4.42
L_3	S_1	111	108	23.30	4.28
L_3	S_2	123	113	23.10	4.43
L_4	S_1	127	127	23.38	4.53
L_4	S_2	123	123	23.16	4.48
LSD (0.05)		ns	ns	ns	ns
CV (%)		13.2	10.4	4.0	8.8

Table 12. Yield and yield components of BRRI dhan48, BRRI dhan82 and BRRI dhan85 as affected by integrated crop management at BRRI farm, Gazipur.

Variety	Crop management	Panicle m^{-2}	Grain panicle^{-1}	1000 GW (g)	Grain yield (t ha^{-1})	Sterility (%)	Harvest Index
BRRI dhan48	RDF	205	88	18.6	3.55	30.9	0.52
	ICM	232	104	19.0	4.53	28.6	0.56
BRRI dhan82	RDF	199	86	18.1	3.10	33.4	0.48
	ICM	202	92	18.4	3.46	30.3	0.53
BRRI dhan85	RDF	210	98	18.2	3.91	30.1	0.49
	ICM	227	104	18.7	4.43	34.1	0.54
LSD $_{(0.05)}$ for variety (V)		12.17	NS	NS	0.44	NS	NS
LSD $_{(0.05)}$ for crop management		9.93	9.34	NS	0.36	NS	NS
LSD $_{(0.05)}$ for V × CM		NS	NS	NS	NS	NS	NS
CV (%)		4.5	9.3	3.3	9.1	29.6	9.7

Interaction effect of variety and crop management was not significant in grain yield and yield components (P>0.05) but individual effect of variety and nutrient management significantly varied. Higher grain yield, 4.53 and 4.43 t ha^{-1} was given by BRRI dhan48 and BRRI dhan85, respectively with ICM (N-P-K; 80-10.4-49 kg ha^{-1} and four seedlings $hill^{-1}$). BRRI dhan82 produced the lowest yield (3.1- 3.46 t ha^{-1}) with all crop management practices (Table 12). Higher grain yield of ICM was mainly attributed to higher grains $panicle^{-1}$ and the poor yield resulted from higher sterility % of all varieties due to lodging before maturity.

WEED MANAGEMENT

Screening of rice varieties for weed competitiveness in T. Aman and Boro season

The experiment was conducted at two sites at BRRI farm, Gazipur and farmer's field in Kapasia, Gazipur to determine the weed competitive ability of most popularly grown varieties in T. Aman season in 2019 and Boro seasons 2020. During Boro season 14 rice varieties and in T. Aman season 11 rice varieties were used and compared with weedy condition which was naturally weedy throughout the season and weed free condition which was weed-free throughout the season. The results of BRRI farm, Gazipur experiment was analyzed and presented here briefly.

In T.Aman season, BR23 was the most promising for weed competitiveness because of less weed number and biomass in different days after transplanting. BR23 had the ability to suppress weed in initial stage may be due to initial faster plant growth. Grain yield of BR23 in weedy and weed free plots were, 4.38 and 5.28 t ha^{-1} respectively (Table 13). The other varieties BRRI dhan39 and BRRI hybrid dhan6 showed some extent weed competences based on weed population, weed dry matter, plant height, initial tillering ability and dry matter of crops.

In Boro season, BR17 seems most promising for weed competitiveness, as the lowest weed number and weed dry matter weight found in this variety compared to others. BR17 has the ability to suppress weed at pre-flowering stage and dead-dried weeds were found in BR17 plots (Table 13). Grain yield of BR17 was 3.64 and 5.17 t ha^{-1} in weedy and un-weeded plot respectively (Table 19). Grain yield of BR17 in weedy and weed free plots differed about 1.50 t ha^{-1}. Among the other varieties BRRI dhan45 and BRRI hybrid dhan5, hybrid mollica and SL8 showed to some extent weed competences based on weed population, weed dry matter weight, plant height, initial tillering ability and dry matter weight of crops.

BRRI's Agronomy Division Development and Research Strengthening Programme:

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 crucial issue. It is difficult to maintain soil health due to intensive land use. Considering the above facts, the present study was undertaken in farmers' field at Alimganj, Rajshahi and Amtoli, Borguna, from Kharip I with the following objectives to:

- Improve the soil health.
- Increase the cropping intensity and productivity

Rice varieties used for T. Aman season were:

V_1=BR23	V_4=BRRI dhan49	V_7=BRRI dhan70	V_{10}=BRRI dhan80
V_2=BRRI dhan34	V_5=BRRI dhan52	V_8=BRRI dhan71	V_{11}=BRRI hybrid dhan6
V_3=BRRI dhan39	V_6=BRRI dhan66	V_9=BRRI dhan72	

Rice varieties used for Boro season were:

V_1=BRRI dhan17	V_5=BRRI dhan50	V_9=BRRI dhan84	V_{13}=SL-8H
V_2=BRRI dhan28	V_6=BRRI dhan58	V_{10}=BRRI dhan86	V_{14}=Mollica
V_3=BRRI dhan29	V_7=BRRI dhan67	V_{11}=BRRI hybrid dhan5	
V_4=BRRI dhan45	V_8=BRRI dhan81	V_{12}=Jolok	

Table 13. Weed occurrence in weedy plot and grain yield in weedy and weed free plot of T. Aman 2019 and Boro 2019-20 in BRRI, Gazipur.

Variety	Weed infestation						Grain yield ($t\ ha^{-1}$)		
	35 DAT		50 DAT		75 DAT				
	Weed no. m^{-2}	Weed wt. ($g\ m^{-2}$)	Weed no. m^{-2}	Weed wt. ($g\ m^{-2}$)	Weed no. m^{-2}	Weed wt. ($g\ m^{-2}$)	Un weeded	Weed free	Yield difference
				T. Aman					
V_1	26	70.16	21	44.25	66	31.69	4.38	5.28	0.90
V_2	64	116.95	74	117.38	65	84.44	3.22	4.86	1.64
V_3	49	102.33	47	104.70	48	72.38	4.25	5.61	1.36
V_4	74	159.63	33	394.86	31	355.56	3.20	5.66	2.45
V_5	54	186.38	77	166.57	85	189.45	2.39	5.28	2.89
V_6	69	141.01	56	144.44	33	175.76	2.63	5.43	2.80
V_7	97	136.18	73	413.03	87	139.44	2.63	5.42	2.79
V_8	102	145.72	54	139.24	93	248.09	2.78	6.18	3.41
V_9	86	157.14	73	458.19	84	181.69	3.22	5.76	2.53
V_{10}	75	141.48	78	210.21	78	158.85	2.42	5.66	3.24
V_{11}	60	128.67	41	142.19	59	92.74	4.45	6.18	1.73
				Boro					
V_1	56	13.07	47	20.90	13	9.68	3.64	5.17	1.53
V_2	46	21.43	54	32.33	64	15.31	3.67	6.56	2.89
V_3	47	18.80	52	34.22	54	18.93	4.26	6.83	2.57
V_4	43	20.25	56	22.81	51	17.88	3.69	6.33	2.64
V_5	61	27.33	36	27.60	44	16.32	3.72	6.30	2.59
V_6	50	20.97	38	30.31	50	20.04	3.13	6.08	2.95
V_7	76	23.21	47	34.35	44	22.35	3.83	6.28	2.45
V_8	44	14.04	51	29.32	40	19.06	2.50	6.52	4.01
V_9	60	23.40	47	29.64	31	17.92	4.22	6.82	2.61
V_{10}	36	18.37	47	27.38	54	18.56	3.78	7.30	3.52
V_{11}	47	18.53	50	28.90	50	19.74	4.34	7.22	2.88
V_{12}	53	19.61	42	30.44	44	19.89	4.43	6.52	2.09
V_{13}	56	18.07	54	26.86	58	22.35	2.80	6.59	3.79
V_{14}	49	18.80	49	22.93	51	21.83	3.77	6.49	2.72

Cropping pattern to 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

Incorporation of mungbean stubble with soil before T. Aus

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

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 was not satisfactory due to poor management in rice. Heavy rainfall during T. Aman harvest delayed potato sowing and heavy rainfall after sowing of potato hampered the crop growth of potato. But the growth and yield of mungbean was satisfactory (Table 14).

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, 4 crops systems obtained 17.45 t ha^{-1} while 11.47 t ha^{-1} in farmers' practice in that particular year. Normally, farmers are growing only Aus and Aman rice. Sunflower cultivation was imposed by another project which was not regular practice of that area.

Table 14. Yield of different crops in four crops systems in different locations, 2019-20.

Crops	Field duration	Variety	Yield ($t\ ha^{-1}$)	Remarks
		Alimganj, 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 2019 to 22 Feb 2020	Cardinal	22.45	Rat damage
Mungbean	25 Feb 2020 (Sowing)	BARI mung6	-	Poor germination
		Amtoli		
T. Aus	15 May 2019 to 10 August 19	BRRI dhan48	4.43	-
T. Aman	15 August to 15 Nov 2019	BRRI dhan56	3.75	Damaged by Bulbul
Potato	1 Dec 2019 to 16 Feb 2020	Cardinal	6.75	Late sowing & submergence
Mungbean	25 Feb to 21 & 30 Apr 2020	BARI mung6	1.15	-

Table 15. Productivity of different crops in 4 crops Systems in different locations, 2019-20.

Alimgonj, Rajshahi

Cropping pattern	1st crop	2nd crop	3rd crop	4th crop	REY/productivity
4 crops systems	4.25	4.75	22.45	-	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	17.45
Farmers' practice	3.25	4.15	2.40	-	11.47

(6.75 t/ha potato = 6.75 t/ha rice, 1.15 t/ha Mungbean = 3.45 t/ha rice, 1.5 t/ha Sunflower = 4.5 t/ha rice; Rice = Tk 15/kg, potato = Tk 15/kg, Mungbean = Tk 45/kg, Sunflower = Tk 45/kg)

Table 16. Economic analysis of four crops compared to farmers' practice, 2019-20

Alimgonj, Rajshahi

Crops	Yield ($t\ ha^{-1}$)	Input cost (Tk)	Gross return (Tk)	Net profit (Tk)	REY	Remarks
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	-1600	-	Damaged due to poor germin. & 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

Crops	Yield ($t\ ha^{-1}$)	Total input cost (Tk)	Gross return (Tk)	Net profit (Tk)	REY	Remarks
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	3.04	
Total	-	22,760	38,185	15,425	17.45	
Control						
T. Aus	4.00	5,500	9,000	3,500	4.00	Gota IRRI
T. Aman	4.50	5,800	10,750	5,350	4.50	BR23
Sunflower	1.50	5,600	9.000	3,400	3.97	Hysun (hybrid)
Total	-	16,900	28,750	11,850	11.47	

(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

Soil chemical properties

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 & Zn with few exceptions (Table 17). Textural class of soil of each location was determined; Alimganj soil was loam and Amtoli was silt. Other physical and biological properties were not yet determined.

Thus we can conclude that

Four crops system is possible and profitable in stress prone areas of Alimganj (drought) and Amtoli (salinity) without losing the soil health/ fertility if proper agronomic practices are maintained. The experiment should be repeated to confirm the results.

Table 17. Initial Soil status of each location in four crops system.

	pH	OM	Total N	K (meq/ 100 g)	S (ppm)	Zn (ppm)
			Alimgonj			
T. Aus	7.5	1.89	0.11	0.11	19.8	1.48
T. Aman	7.8	1.61	0.09	0.13	29.2	1.94
Potato	7.6	1.75	0.10	0.15	30.2	3.10
Mungbean	6.9	1.45	0.08	0.17		
			Amtoli			
T. Aus	5.1	1.91	0.10	0.21	17.5	1.78
T. Aman	5.5	1.98	0.11	0.25	20.8	1.88
Potato	5.7	1.85	0.11	0.24	22.1	1.87
Mungbean	5.8	1.75	0.12	0.22		

Soil Science Division

SUMMARY

BR (Bio)11447-3-10-7-1, BR (Bio) 11447-1-28-14-3 and IR 99285-1-1-1-P2 might be considered as high yielding-Nitrogen efficient Favourable Boro rice (FBR) and zinc enriched rice (ZER) lines respectively as it had greater potential to utilize native soil nitrogen (N). Application of urea-plus zeolite may increase rice grain yield and N use efficiency over prilled urea and urea-hydroxyapatite (HA) nanohybrids, however it requires further verification in field conditions. The calculated economic N doses of BRRI dhan87 and BRRI dhan89 was 83 and 154 kg ha^{-1} respectively. Among the varieties tested, BRRI dhan49 and BRRI dhan89 was more P efficient compared to BRRI dhan87 and BRRI dhan92. After 4th crop cycle, it was revealed that AEZ based or soil test based (STB) chemical fertilizers seemed sufficient to obtain potential yield of each crop in two four crops patterns (Cropping pattern,CP-1: Mustard-Boro-T. Aus-T. Aman; CP-2:Mustard-Mungbean-T. Aus-T. Aman). Considering rice equivalent yield (REY) and economics, CP-1 performed better than CP-2. A combination of 50 kg K and 50 kg N for BRRI dhan72 and 100 kg K and 120 kg N for BRRI dhan74 cultivation was found to be adequate for desired yield in AEZ28. Result of a pot experiment showed that application of Cu, Ni, Si and Se along with full dose of chemical fertilizer increased grain weight of rice. Unpuddled rice cultivation method in conservation agriculture (CA) required 25% more fertilizer than recommended fertilizer dose to obtain desirable grain yield.

Estimated soil critical limits of P, K, S and Zn for rice were 8.7 mg kg^{-1}, 0.09 meq 100 g soil^{-1}, 16.1 mg kg^{-1} and 0.70 mg kg^{-1}, respectively. Omission of N, P, and K decreased rice grain yield compared to complete fertilizer treatment. Organic amendments on Integrated Plant Nutrition System (IPNS) basis produced higher grain yield, however it is statistically identical to that with full dose of chemical fertilizer application. Increasing K rate from 40 to 80 (kg ha^{-1}) had insignificant impact on rice grain yield. The treatment with STB dose and 50% STB + mixed manure (MM) fertilization produced significantly higher grain yield of rice than farmers' practice. The cumulative yield of triple rice cropping was always higher than double rice cropping pattern. Triple rice cropping in continuous wetland condition may remove annually 287, 57, 280 and 25 kg ha^{-1} of N, P, K, and S respectively, by the crops. Application of 0.5 t ha^{-1} vermicompost (VC) or poultry manure (PM) with full doses of chemical fertilizer produced potential grain yield and emitted lower amount of CH_4 in rice cultivation. Deep placement of prilled urea (PU) by applicator had no significant effect on recovery efficiency of N (RE_N) over PU broadcasting treatment in T. Aman season. Alternate wetting and drying (AWD) irrigation significantly reduced cumulative CH_4 emission compared to continuous standing water (CSW) irrigation regime. The industrially polluted soils of Gazipur and Sripur contained high organic matter and high Fe which induced Fe toxicity in rice. There was no or little effect of added organic matter, plant growth promoting bacteria (PGPB) inoculum and biochar on rice yield. Application of bio-organic fertilizer (1-2 t ha^{-1}) along with 30% reduced urea and 100% removal of TSP fertilizer increased or produced similar grain yield at different locations including saline soil (4.59-7.66 dS/m). Soil microbial populations such as total bacteria, fungus, actinomycetes, free living N_2 fixing bacteria, rhizobium, and phosphate solubilizing bacteria from AEZ19, AEZ8 and AEZ21 were low in number compared to any healthy agricultural soil. Among three AEZs soil, the average populations were low in AEZ8.

SOIL FERTILITY AND PLANT NUTRITION

Determining N requirement of ALART materials. Before releasing a variety, the N requirements of ALART materials need to be adjusted as N is the most limiting nutrient for rice production. Separate field trials were conducted for premium quality rice (PQR), Zn enriched rice (ZER) and favourable Boro rice (FBR) (biotechnology) genotypes at BRRI HQ farm, Gazipur (AEZ 28) during T. Aman and Boro seasons of 2019-20. The trials were set up following split-plot design with three replications, where fertilizer doses were assigned in main-plot and rice genotypes in sub-plot. Two PQR lines: BR 8862-29-1-5-1-3 and BR 8995-2-5-5-2-1, one ZER line: IR 99285-1-1-1-P2 and two FBR genotypes:

BR (Bio) 11447-1-28-14-3 and BR (Bio) 11447-3-10-7-1 were evaluated. Six urea-N doses (kg ha^{-1}): N_0, N_{40}, N_{80}, N_{120}, N_{160} and N_{200} with standard doses of P, K, S were applied for each experiment. Quadratic regression model was used to determine optimum N requirement. Insignificant grain yield was obtained at 160 kg N ha^{-1} in two advanced PQR lines BR 8862-29-1-5-1-3 (5.52 t ha^{-1}) and BR 8995-2-5-5-2-1 (5.51 t ha^{-1}) with check variety BRRI dhan50 (5.23 t ha^{-1}). The calculated optimum N doses for advanced lines BR 8862-29-1-5-1-3, BR 8995-2-5-5-2-1 and the check variety BRRI dhan50 were 164, 167 and 165 kg ha^{-1} respectively, which proved that N use efficiency of the proposed PQR lines were similar to the check variety. At 160 kg N ha^{-1}, significantly higher grain yield was obtained in the advanced ZER line IR 99285-1-1-1-P2 (7.26 t ha^{-1}) compared to check varieties BRRI dhan29 (6.69 t ha^{-1}) and BRRI dhan84 (6.24 t ha^{-1}). The additional 0.5-1.2 t ha^{-1} of grain yield obtained with that N dose in IR 99285-1-1-1-P2 line compared to the check varieties directed it as N efficient ZER line. Among the FBR genotypes, significantly higher grain yields of 7.84 t ha^{-1} and 6.81 t ha^{-1} were obtained in BR (Bio) 11447-3-10-7-1 and BR (Bio) 11447-1-28-14-3 genotypes, respectively, compared to check variety BRRI dhan28 (6.06 t ha^{-1}) at 120 kg ha^{-1} N. The calculated optimum N dose for FBR lines BR (Bio) 11447-3-10-7-1, BR (Bio) 11447-1-28-14-3 and the check variety BRRI dhan28 was 133, 128 and 135 kg ha^{-1} respectively, which implied N efficient characteristics to some extent.

Increasing N use efficiency and determining nutrient requirements of MV rice. A pot experiment was conducted in Soil Science glasshouse, BRRI, to evaluate rice grain yield and N use efficiency of typically synthesized urea-HA (hydroxyapatite) nanohybrid and urea plus purified natural zeolite (71% SiO_2) over prilled urea using terrace paddy soil of BRRI, Gazipur during Boro season, 2020. Urea-HA nanohybrid was synthesized according to the method of Kottegoda *et al*. (2017). Transplanted rice (BRRI dhan89) was grown in the glasshouse under continuous flooding for 118 days. Five treatments were tested viz PKSZn, Urea-N_{120} PKSZn, Nano fertilizer-N_{120} PKSZn, Nano fertilizer-N_{60} PKSZn and Urea-N_{120} PKSZn + purified natural zeolite (71% SiO_2) @ 2.5 t ha^{-1}.

Biomass yield and N use efficiency. Among the yield contributing parameters only the grain and straw weights (yields), hence total yield per pot significantly ($p<0.05$) varied among the five treatments (Table 1). Agronomic efficiency (AE_N) (kg grain kg^{-1} N applied) was calculated only from T_5 (16), and no additional benefit in grain yield was obtained from urea and urea-HA nanohybrids applied pots over N unfertilized pot. Therefore, application of urea-plus zeolite may increase rice grain yield and N use efficiency over prilled urea and urea-HA nanohybrids but it requires further verification by using more paddy soils and field trials.

Table 1. Yield attributes and agronomic efficiency (AE_N) of the studied glasshouse rice during Boro season 2020.

Parameter	Treatment				
	PKSZn	Urea N_{120}-PKSZn	Nano fert. N_{120}-PKSZn	Nano fert. N_{60}-PKSZn	Urea N_{120}-PKSZn + Zeolite (2.5 t ha^{-1})
Plant height (cm)	90	90	87	91	95
Tiller no. (pot^{-1})	18	19	21	19	20
Panicle no. (pot^{-1})	18	18	18	19	20
Grain yield (t ha^{-1})*	8.10ab	7.33b	8.23ab	7.93ab	10.00a
Straw yield (t ha^{-1})*	8.38c	8.53abc	9.50ab	8.38bc	9.64a
AE_N			1		16

*Different lower-case letters within the row denotes significant differences between the treatments according to Duncan's Multiple Range Test.

Optimum nitrogen requirement for modern varieties. The optimum N requirement of BRRI dhan87 and BRRI dhan89 was determined. The experiments were laid out in an RCB design with three replications. The applied N doses (kg ha^{-1}) for T. Aman was 0, 30, 60, 90, 120 and 150 and Boro was 0, 40, 80, 120, 160, 200 respectively, along with flat doses of P, K, S fertilizer. The estimated N and grain yield response function were derived from quadratic regression analysis. The grain yield of BRRI dhan87 increased with increased N rates up to 90 kg ha^{-1}. The calculated optimum and economic N doses of BRRI dhan87 were 84 and 83 kg ha^{-1} respectively. The grain yield of BRRI dhan89 increased with the increased N rates up to 160 kg ha^{-1}. The calculated optimum and economic N doses of BRRI dhan89 were 155 and 154 kg ha^{-1} respectively.

Performance of rice varieties under P deficit condition. An experiment was conducted at BRRI farm, Gazipur to determine the performance of MV rice under different soil P levels. Soil available P level was grouped into four levels (1.70-2.30, 2.31-2.90, 2.91-3.50 and 3.51-4.10 mg kg^{-1}) where each level had three plots considered as three replications. Each plot received NKS as per recommended fertilizer doses. Main plots were considered as soil P levels and in the sub-plots P was applied @ 0 and 12 kg ha^{-1} in wet season and 0 and 20 kg ha^{-1} in dry season respectively. Study result proved that, under both inherent soil P and applied P conditions, BRRI dhan49 performed better than BRRI dhan87 in T. Aman season. In Boro season, BRRI dhan89 showed better result than BRRI dhan92.

Nutrient requirement for aromatic rice varieties. Field experiment was conducted to develop Integrated Nutrient Management (INM) and Integrated Plant Nutrition System (IPNS) based fertilizer management package for fine aromatic T. Aman rice and to maintain the grain quality. Eight different fertilizer treatments combinations viz control, STB fertilizer, cowdung (CD) @ 1 t ha^{-1}+ IPNS, CD @ 2 t ha^{-1}+IPNS, CD @ 3 t ha^{-1}+IPNS, CD @ 1 t ha^{-1}+ 75% STB, CD @ 2 t ha^{-1}+50% STB, CD @ 2 t ha^{-1}+ 50% STB, and CD @ 3 t ha^{-1}+ 25% STB were assigned in split plot design with three replications. Results showed that, BRRI dhan80 produced 4.41 t ha^{-1} grain yield in CD @ 2 t ha^{-1}+ IPNS which was statistically similar to all other treatments except control. However, in the same treatment, BRRI dhan34 produced significantly higher grain yield (3.89 t tha^{-1}), though it was statistically similar to application of CD @ 2 t ha^{-1} + 50% STB. Kataribhog produced 3.12 t tha^{-1} and 3.11 t tha^{-1} in CD @ 2 t ha^{-1}+ 50% STB and CD @ 3 t ha^{-1} + 25% STB respectively. However, it was similar to application of 1-2 t CD ha^{-1} + IPNS treatment.

Nutrient management for growing four crops in a year. Experiment has been initiated in T. Aus 2016 to grow four crops in a year for sustainable soil fertility status as well as increasing productivity. Three fertilizer treatments viz, soil test based (STB) fertilizer (T_1), crop residue (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 three replications. First crop (Mungbean) was incorporated in T_2 treatment. After two crop cycle, T_1 and T_2 treatments produced similar yield in each crop. In the 3rd year and 3rd crop cycle, both cropping patterns showed their potential yield with STB chemical fertilizer application (T_1) as well as with crop residue incorporation (T_2). After 4th crop cycles, it is revealed that STB chemical fertilizers seemed sufficient to obtain potential yield of each crop under both the patterns. In all cases, incorporation of crop residue is expected to have some positive impact on yield and on soil fertility than chemical fertilizer alone (Table 2). Considering rice equivalent yield (REY) and economics, CP-1 (Mustard-Boro-T. Aus-T. Aman) performed better than CP-2 (Mustard-Mungbean-T. Aus-T. Aman) (Table 3). However, it requires long-term evaluation to observe the sustainable yield trends and soil fertility status.

Table 2. Grain yield (t ha^{-1}) of T. Aus (BRRI dhan65), T. Aman (BRRI dhan62), Mustard (BARI sharisa14), Boro (BRRI dhan28) and Mungbean (BARI Mung-6) during 2019-20 (means ± SE).

Treatment	T. Aus 2019		T. Aman 2019		Mustard 2019-20		Boro 2020	Mung 2020
	CP-1	CP-2	CP-1	CP-2	CP-1	CP-2	CP-1	CP-2
T_1: STB fertilizer dose*	3.32 ±0.06a	3.45 ±0.05a	3.13 ±0.03a	3.24 ±0.04a	0.53 ±0.105a	0.89 ±0.05a	4.88 ±0.29a	0.48 ±0.05
T_2: Crop residues (CR) + T_1	3.22 ±0.03a	3.36 ±0.03a	3.26 ±0.05a	3.32 ±0.05a	0.76 ±0.003a	0.99 ±0.03a	5.39 ±0.11a	0.59 ±0.02
T_3: Native nutrient	2.10 ±0.07b	2.15 ±0.06b	1.53 ±0.03b	1.64 ±0.06b	0.02 ±0.000b	0.24 ±0.05b	1.82 ±0.29b	0.32 ±0.03

*Different lower case letters within the column denote significant differences ($p<0.05$) of grain yields between the treatments according to DMR- Post-Hoc Test. CP-1= Mustard-Boro-T. Aus-T. Aman cropping pattern and CP-2 =Mustard-Mungbean-T. Aus-T. Aman cropping pattern.

Table 3. Rice equivalent yield (t ha^{-1}) of two cropping patterns, estimated during 2019-20.

Treatment	Cropping pattern-1					Cropping pattern-2				
	T. Aus 2019	T. Aman 2019	Mustard 2020*	Boro 2020	Tot.	T. Aus 2019	T. Aman 2019	Mustard 2020*	Mung 2020*	Total
STB fertilizer dose	3.3	3.1	1.5	4.9	12.8	3.4	3.2	2.5	1.7	11
Crop residues (CR) + T_1	3.2	3.3	2.1	5.4	14.0	3.4	3.3	2.8	2.1	12
Native nutrient	2.1	1.5	0.1	1.8	5.5	2.2	1.6	0.7	1.1	6

*To calculate REY it was assumed that prices of mustard, mungbean and rice were 50, 65 and 18 Tk. kg^{-1}, respectively.

Influence of N and K rates on MV rice. The objectives of the study were to find out suitable N and K ratio for MV rice cultivation and to study their dynamics in soil-and plant systems. Six years' study from T. Aman 2014 to Boro 2020 was conducted at BRRI HQ farm, Gazipur (AEZ 28) following split-plot design with three replications. The doses of K were assigned in the main plots and that of N in the subplots. Phosphorus and S was applied as blanket dose. In T. Aman season, K was applied @ 0, 50, 100, 150 and 200 kg ha^{-1} and N @ 0, 50, 75 and 100 kg ha^{-1}, respectively. However, in the Boro season, K doses remained same, but N was applied @ 0, 100, 120 and 140 kg ha^{-1}. During the first three years, the test varieties were BRRI dhan49 in T. Aman and BRRI dhan29 in Boro season. However, from the 2017 onward, BRRI dhan72 and BRRI dhan74 were selected for T. Aman and Boro seasons, respectively.

Grain and straw yields. Interaction effect of K and N on grain yields was significant in both the cropping seasons. It was proved that increasing N significantly decreased grain yield in K deficient condition. In N deficient condition, K rates were not responsible for increased grain yield. In T. Aman season, application of N @ 50 kg ha^{-1} with 50 kg K ha^{-1} produced 4.47 t ha^{-1} grain yield of BRRI dhan72, which was statistically identical to the highest grain yield of 4.53 t ha^{-1} achieved with a combination of 75 kg N and 100 kg K ha^{-1}. It proved that 50 kg K and 50 kg N combination is suitable to get optimum yield of BRRI dhan72. In Boro season, application of N @ 120 kg ha^{-1} with 100 kg K ha^{-1} produced the highest grain yield of 6.17 t ha^{-1}, which was statistically identical to grain yield (6.14 t ha^{-1}) achieved with a combination of 140 kg N and 100 kg K ha^{-1}. Thus, 100 kg K and 120 kg N combination was suitable to get optimum yield of BRRI dhan74 in Gazipur soil. Both increasing N and K rates gradually increased straw yield of BRRI dhan74.

Effect of micro- and beneficial nutrients on growth and yield of rice. The study was undertaken with the objectives to determine the effect of micronutrients and beneficial nutrients on growth and yield of rice and to observe the interactions among the applied nutrients. A pot experiment was set up in the glasshouse of Soil Science Division, BRRI, Gazipur. The study was laid out in a completely randomized block design with three replications. Approximately, 14 kg of air-dried sandy loam soil was washed with distilled water before adding to each plastic pot. Two seedlings of BRRI dhan87 were transplanted to each pot. There were five treatments as follows: 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 treatments received a blanket dose of chemical fertilizer i.e. N-P-K-S-Zn @ 120-15-60-10-1.5 kg ha^{-1}. Application of Cu-Ni-Se-Si @ 1%-0.2%-10ppm-2% as foliar spray were done according to treatments.

Growth and yield contributing parameters. Plant height, panicle per hill and panicle length did not differ significantly with the applied treatments. However, the filled and unfilled grains per panicle were significantly influenced with the imposed treatments. The maximum number of filled grains per panicle (137) and grain weight (28.79 g per pot) was obtained in T_2 where, Cu, Ni, Si and Se were sprayed in combination with recommended chemical fertilizer. Application of Cu and Si along with recommended fertilizer significantly reduced grain weight to 18.48 g per pot, the lowest among the treatments.

Nutrient management under conservation agriculture (CA) in double rice cropping system. The study was initiated at Paba, Rajshahi, in Boro 2018-19 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 puddled) 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. Interaction effect was significantly exhibited by crop establishment methods and fertilizer doses for grain yield (Table 4). In Boro 2018-19, puddled and unpuddled rice cultivation produced similar amount of grain yield at each level of fertilizer application. Recommended (100% RD) fertilizer was enough to produce the highest grain yield in puddled rice, while 125% of RD was required for the highest yield under unpuddled condition. In T. Aman 2019, puddled and unpuddled rice cultivations produced similar amount of grain at 100% RD fertilizer application. However, 75% of RD produced statistically identical grain yield in puddled rice, whereas reduced fertilizer doses under unpuddled condition significantly reduced the grain yield of BRRI dhan75.

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 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 STB doses of N, P, K, S, and Zn were 140-12-80-5-2 kg ha^{-1} and 100-10-80-5-2 kg ha^{-1} for Boro and T. Aman respectively.

Grain and straw yield. In the T. Aman and Boro seasons, omission of N, P, and K decreased rice grain yield compared to complete fertilizer treatment (Table 5) and straw yield was higher in all organic + IPNS treatments. In T. Aman season, among the applied organic materials, CD + IPNS (5.25 t ha^{-1}) and VC + IPNS (5.20 t ha^{-1}) treated plots produced higher grain yield. However, yield differences among the organic + IPNS treated plots, complete chemical fertilizer, Zn and S omitted plots were statistically similar.

Table 4. Interaction effect of crop establishment method and fertilizer rates on grain yield (t ha^{-1}) at Paba, Rajshahi in 2018-19.

Fertilizer dose	Crop establishment method			
	Boro 2018-19		T. Aman 2019	
	Unpuddled	Puddled	Unpuddled	Puddled
125% of RD	5.70 aA	5.02 aA	4.55 bB	4.93 aA
100% RD	4.62 bA	5.00 aA	4.82 aA	4.93 aA
75% of RD	4.07 cA	4.46 bA	4.01 cB	4.71 aA
50% of RD	3.70 dA	3.99 cA	3.70 dB	4.34 bA
CV (%)	5.97		4.99	

Table 5. Effect of organic and inorganic amendments on rice grain and straw yield (t ha^{-1}) of BRRI dhan87 (T. Aman) and BRRI dhan89 (Boro) at BRRI HQ, Gazipur in 2019-2020.

Treatment	T. Aman		Boro	
	Grain	Straw	Grain	Straw
T_1 = NPKSZn@100/140-10/12-80-5-2 kg ha^{-1}	4.91	5.25	6.15	5.08
T_2 = NPSZn (-K)	3.65	4.82	3.62	1.30
T_3 = NKSZn (-P)	3.80	4.79	2.35	3.62
T_4 = PKSZn (-N)	3.92	4.58	2.53	2.20
T_5 = CD (3 t ha^{-1}) + IPNS	5.25	6.30	5.96	1.61
T_6 = NPKS (-Zn)	5.00	6.21	5.69	5.00
T_7 = NPKZn (-S)	4.90	5.72	5.78	4.96
T_8 = PM (2 t ha^{-1}) + IPNS	5.16	6.21	6.20	5.04
T_9 = NPKSZn @100/140-10/12-60-5-2 kgha^{-1}	4.87	5.80	5.98	5.32
T_{10} = VC (2 t ha^{-1}) + IPNS	5.20	6.31	6.00	4.80
T_{11} = NPKSZn@100/140-10/12-40-5-3 kgha^{-1}	4.53	5.72	5.64	5.03
T_{12} = Control (native nutrients)	3.46	4.57	1.49	4.73
$LSD_{0.05}$	0.52	0.85	0.71	0.54
CV (%)	4.58	6.27	5.95	5.38

Moreover, there was no significant yield difference found between the two K doses (40 and 80 kg ha^{-1}) of complete fertilizer treatment. In the Boro season, the complete fertilizer treatment produced 6.15 t ha^{-1} grain yield, which decreased due to omission of N, P and K by 3.62, 3.8, and 2.53 t ha^{-1} respectively. The highest grain yield (6.20 tha^{-1}) was obtained from PM + IPNS, which was statistically identical to all other organic + IPNS and complete chemical fertilizer treatments including Zn and S omitted plots. Alike T. Aman, there was no significant yield impact in Boro due to application of two K doses (40 and 80 kg ha^{-1}) in complete fertilizer treatment.

Intensive wetland rice cropping and grain yield. The experiment was designed with the objectives to harvest three rice crops in a year and to evaluate the consequences of intensive cropping on soil fertility over time. The experiment was initiated in 1971 in a permanent layout with NPK fertilizer application. After several modifications of treatments in 1982, 1984 and 1991, six treatments viz control, reverse control (NPKSZnCu), NPK, NPKS, NPKSZn and NPKSZnCu were imposed in 2000. The tested varieties in T. Aus, T. Aman and Boro seasons were BRRI dhan48, BRRI dhan46 and BRRI dhan50 respectively. The NPK doses used were 140-25-80, 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 Boro season only.

Rice production trend and annual nutrient removal. Annual rice production in control plot decreased because of continuous rice cultivation without fertilizer application. However, grain yield in this treatment showed somewhat increasing trend during 2008-2019. Moreover, from 2001, the reverse control treatment produced grain yield almost similar to the complete fertilizer treatment (Fig. 1). In 2019, annual rice production in control plot was 6.23 t ha^{1}. However, its reversed management (addition of NPKSZnCu fertilizer) resulted in 12.76 t ha^{-1}yr^{-1} grain production, which was close to complete fertilizer treatment (13.43 t ha^{-1}yr^{-1}). Results also indicated that additional use of Zn and Cu once in a year with NPKS increased annual grain yield by more than 0.5 t ha^{-1} than NPKS alone. The highest N (286.62 kg ha^{-1} yr^{-1}), K (280.39 kg ha^{-1} yr^{-1}) and S (24.90 kg ha^{-1} yr^{-1}) removal was found with NPKSZnCu treatment. However, the highest P (56.74 kg ha^{-1} yr^{-1}) uptake was found with NPKSZn treatment.

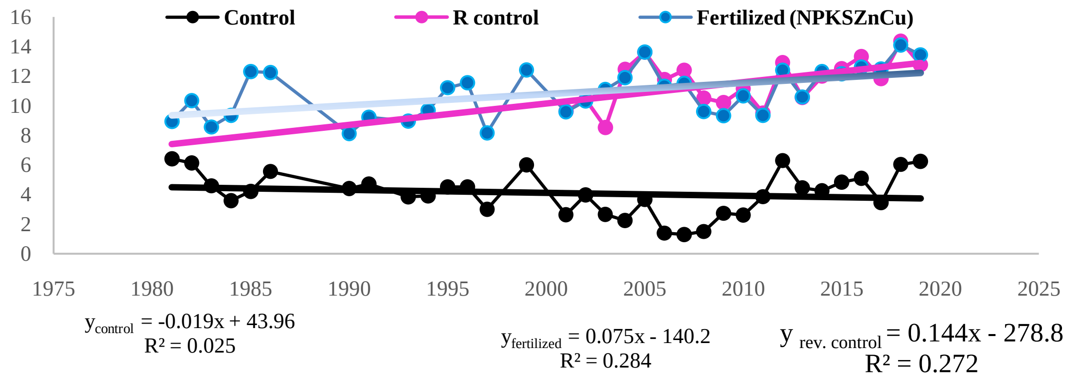


Fig. 1. Annual rice production trend under intensive wetland conditions in BRRI-Gazipur during 1981-2019.

Determining critical limit (CL) of soil nutrients. The study was conducted with the objective to determine the critical limit of soil P, K, S and Zn for rice cultivation. Based on land type and soil texture, soils were collected from intensively cropped areas of 3 AEZs (viz, 18, 19 and 20). Soil samples were analyzed and selected for low, medium and highly fertile soils. Pot experiment was conducted for each nutrient (with and without respective nutrients) following completely randomized design (CRD) 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 and the soil nutrient concentration on the X axis for each crop per nutrient following Cate and Nelson method (1965). The study result showed 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^{-1}, 16.1 mg kg^{-1} and 0.70 mg kg^{-1}, respectively (Fig. 2).

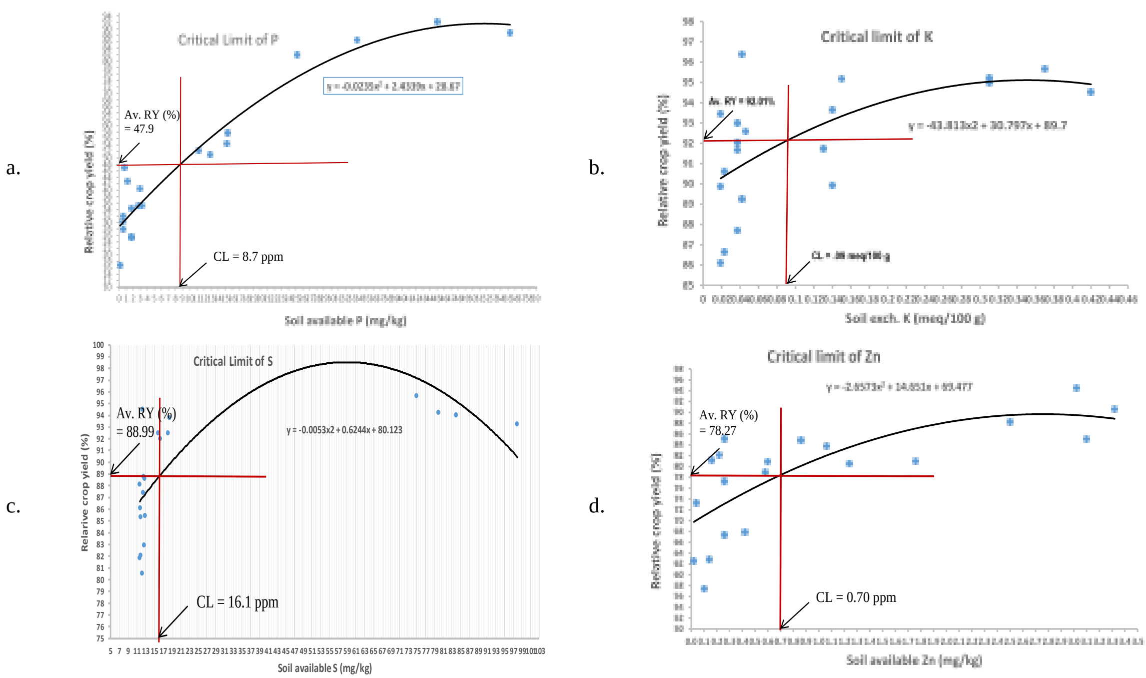


Fig. 2. Critical limits of a) P, b) K, c) S, d) Zn in the soils of three AEZs.

Integrated nutrient management for double and triple rice cropping. The experiment was initiated in Boro 2008-09 at BRRI HQ, farm 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 variety. Fertilizer treatments used were: control, STB dose (NPKS @ 160-25-60-20 kg ha^{-1} for Boro, 70-12-48-10 kg ha^{-1} for T. Aus and 84-15-54-14 kg ha^{-1} for T. Aman), STB (50%) + Mixed manure (MM) (CD @ 2 t ha^{-1} + ash @ 1 t ha^{-1} (oven dried), farmers' practice (FP) (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). The experiment was laid out in RCB design with three replications.

Grain yield. The study result of Boro 2018-19 showed that under double rice cropping pattern, 50% STB + MM fertilizer produced significantly higher grain yield than 100% STB fertilizer, but in the same cropping pattern, the treatments produced statistically similar grain yield in T. Aman 2019. In the same year under triple rice cropping pattern, 100% STB and 50% STB + MM fertilizer produced statistically similar 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 (FP) and native nutrient except T. Aus 2019. Cumulative yield of triple rice cropping was always higher than double rice cropping pattern irrespective of treatment (Table 6).

Performance of vermicompost (VC) and poultry manure (PM) on rice yield and environment. The study was undertaken to find out the effect of PM and VC with chemical fertilizers on yield and yield attributes and nutrient uptakes of T. Aman and Boro rice and its impacts upon soil nutrient status. The experiment was conducted at BRRI HQ, farm Gazipur since Boro 2015. Initial soil (0-15 cm depth) properties were as follows: clay loam texture; pH 6.78; 12.3 g kg^{-1} organic C; 1.3 g kg^{-1} total N, 1.8 mg kg^{-1} available P and 50 mg kg^{-1} soil exchangeable K. The VC contained 50% moisture content (MC), 2.0% total N, 0.52% P, 0.42% K and 0.3% S. While, the PM contained 50% MC, 1.9% total N, 0.56% P, 0.75% K and 1.1% S. Both PM and VC were used with full doses of chemical fertilizer @ 0.5, 1.0, 1.5, 2.0 and 2 t ha^{-1} on the basis of IPNS and compared with control. Each treatment was assigned in 4 m x 5m sized plot and replicated three times in a RCB design. Seedlings of BRRI dhan29 and of BRRI dhan49 were transplanted at 20 cm x 20 cm spacing in Boro and T. Aman seasons. Chemical fertilizers (N-P-K-S-Zn @ 138-10-80-5-5kg ha^{-1}) were applied one day before rice transplanting.

Table 6. Grain yield (t ha^{-1}) of double and triple rice cropping pattern under continuous wetland condition, BRRI farm, Gazipur 2019-2020.

Treatment	Double rice cropping			
	Boro 2018-19 (BRRI dhan58)	Fallow	T. Aman 2019 (BRRI dhan49)	Annual yield (t ha^{-1})
Native nutrient	1.64d	-	2.28c	3.92
STB (100%)	4.97b	-	4.03a	9.00
STB (50%)+MM	5.92a	-	4.25a	10.17
FP	3.53c	-	2.93b	6.46
CV (%)	4.76	-	3.71	
	Triple rice cropping			
	Boro 2018-19 (BRRI dhan74)	T. Aus 2019 (BRRI dhan48)	T. Aman 2019 (BRRI dhan46)	Annual yield (t ha^{-1})
Native nutrient	1.49c	2.17b	2.42c	6.08
STB (100%)	5.45a	4.36a	4.24a	14.05
STB(50%)+MM	5.85a	4.80a	4.15ab	14.80
FP	3.72b	4.18a	2.82b	10.72
CV (%)	5.28	11.68	5.41	

Rice productivity and methane emission. Integrated use of OM (either PM or VC) and chemical fertilizer significantly stimulated rice yield in both the seasons during the year 2019-20. The selected VC contained N-P-K@ 2-5.0-4.2 g kg^{-1} and application of 2 t ha^{-1} of VC approximately supplied N-P-K@ 40-10-8.2 kg ha^{-1} respectively. These nutrients are helpful to reduce chemical fertilizer requirement. In the IPNS treatment, application of either VC or PM @ 0.5 t ha^{-1} provided identical grain yield with application of 2 t ha^{-1} of VC or PM during T. Aman and Boro seasons. Application of OM may stimulate CH_4 emission in rice cultivation. To check this hypothesis CH_4 emission was measured in this study. The range of total CH_4 flux were 102- 402 kg ha^{-1} and 240-578 kg ha^{-1} under different VC treatment with full dose of chemical fertilizer during T. Aman and Boro season respectively. Among the treatments VC @ 0.5 t ha^{-1} + full dose of chemical fertilizer showed significantly lower total seasonal CH_4 flux and yield scale CH_4 emission than that of other treatments. In conclusion, application of 0.5 t ha^{-1} VC or PM with full doses of chemical fertilizer produced potential grain yield and emitted lower amount of CH_4 in rice cultivation.

SOIL AND ENVIRONMENTAL PROBLEMS

Suitable and profitable nutrient management for rice in coastal saline soils. Experiments were conducted at farmer's field under coastal saline soils of Dacope and Amtoli to find out a suitable and economic tool of fertilizer recommendation for rice cultivation. Three fertilizer recommendation tools e.g., Fertilizer Recommendation Guide (FRG) 2012 (AEZ basis), rice crop manager (RCM) and farmer's practice (FP) were evaluated with test rice being BRRI dhan67 in Boro 2018-19 season.

Crop growth and yield. There was no significant effect of fertilizer packages on tiller and panicle number during the reporting period in both the locations. However, RCM based fertilization was the best regarding rice grain yield at Dacope, Khulna. Nevertheless, AEZ and RCM treatments performed identically at Amtoli site. The FP fertilization produced significantly the lowest rice grain yield compared to other two treatments in both the locations.

Effect of biochar on rice yield in charland. The study was conducted at BRRI RS, Sirajganj with the objective to improve rice yield by application of biochar. Four treatments (control, recommended fertilizer (RF), RF + biochar @ 2 t ha^{-1}, and RF + biochar @ 4 t ha^{-1}) were laid out in RCB design with three replications. The biochar was produced from rice husks (unfilled grain). The recommended doses of N, P, K and S were 100-15-40-10 kg ha^{-1} in T. Aman and 138-21-75-18 kg ha^{-1} in Boro season respectively. Biochar was applied at the time of final land preparation.

Rice growth and grain yield. Combined application of chemical fertilizer and biochar showed positive impact on growth and yield of rice in T. Aman season. In this season, among the two rates of biochar, application of biochar @ 4 t ha^{-1} with recommended fertilizer dose obtained 1.4 t ha^{-1} yield benefit over chemical fertilizer in BRRI dhan87. However, the effect of Biochar was not significant in Boro season over chemical fertilizer. Therefore, further investigations are required to get more clear messages on biochar.

Greenhouse gas emissions from rice field. Field experiment was conducted at BRRI HQ farm, Gazipur to study the effects of N placement and its sources on rice yield, nitrogen use efficiency (NUE) and emissions of CH_4 gas under continuous standing water (CSW) and alternate wetting and drying (AWD) irrigation regimes. Eight treatments were tested with different N containing organic amendments (OA) on IPNS basis. Prilled urea (PU) was applied as broadcast in three equal splits in Boro season and two splits in T. Aman season at 7-10 DAT, while urea briquettes (UB) were applied as a single application during first top dressing (TD) of PU. In the IPNS treatments, poultry litter (PL) and vermicompost (VC) was applied before transplanting. Floodwater samples were collected every day at 8:00 AM before one day of fertilizer application and continued for seven days after each TD of PU to measure floodwater NH_4^+-N colorimetrically using spectrophotometer at 420 nm. The concentration of CH_4 flux in the collected samples were measured using a gas chromatograph (Shimadzu GC-2014, Japan) equipped with a flame ionization detector (FID) and electron capture detector (ECD).

Rice yield, total N uptake and (RE_N). Irrespective of water management, deep placed UB significantly increased grain yield compared to broadcast PU at similar N rate in T. Aman while, it showed similar yield in Boro season. UB+IPNS with PL showed higher rice yield compared to broadcasted PU under both irrigation regimes in T. Aman season. While in Boro season, there was no significant variations were observed in rice yield between IPNS and PU treatments. However, grain yield in deep placed PU by applicator showed insignificant variation with that in broadcasted PU under both irrigation regimes and both the seasons. Unlike grain yield, N recovery efficiency (RE_N) was higher in deep placed UB than that in broadcasted PU at similar rate in T. Aman season. Deep placement of PU by applicator had no significant effect on RE_N over PU broadcasting treatment in T. Aman season.

Methane emissions. Cumulative CH_4 emission was measured from control, UB, PU and PU+IPNS with PL treatments under AWD and CSW conditions during T. Aman season (Fig. 3). Control treatments produced significantly lower seasonal CH_4 emission compared to the other treatments. Deep placement of UB and IPNS based OA showed similar CH_4 emission in both AWD and CSW conditions. IPNS based OA showed higher seasonal CH_4 emission compared to broadcast PU under both the water regimes. On the other hand, AWD irrigation significantly reduced cumulative CH_4 emission compared to CSW irrigation regime in any treatment during T. Aman season.

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. Moreover, soils of Mirzapur and Pirojali remain under contaminated water for 5-7 months in a year. A benchmark survey was done with 30 rice soil samples (0-15 cm depth) of that area and found that the soils of Sripur, Pirojali and Mirzapur contained high levels of organic matter (>2.5%), Fe (87 to 580 ppm), Mn (7 to150 ppm), Cu (1 to 7 ppm), and Zn (3 to 65 ppm). Soils of Mirzapur and Pirujali were acidic in nature and pH ranged from 4.95 to 5.88 and 4.42 to 6.0 respectively. Three field experiments were conducted in farmers' field in Boro 2019-20 at each of Mirzapur, Pirujali and Sripur to ameliorate such soil with different amendments for rice productivity. Five treatments were used as follows: mixed PGPB inoculum + chemical fertilizer (CF), biochar 2 t ha^{-1} + CF, vermicompost 3 t ha^{-1} + IPNS, CF and control. Chemical fertilizer dose was N-P-K-S kg ha^{-1} @100-20-80-10 and treatments were laid out in RCB design with three replications.

Effect of amendments on rice grain yield. There was no significant positive effect found on grain yield of rice due to application of biochar, vermicompost and PGPB inoculum over chemical fertilizer in the soils of Sripur, and Pirujali. However, significant negative effect of vermicompost was found in Mirzapur site. The studied soils contained high organic matter and after 45 days of transplanting severe Fe toxicity appeared in rice plant. The higher the organic

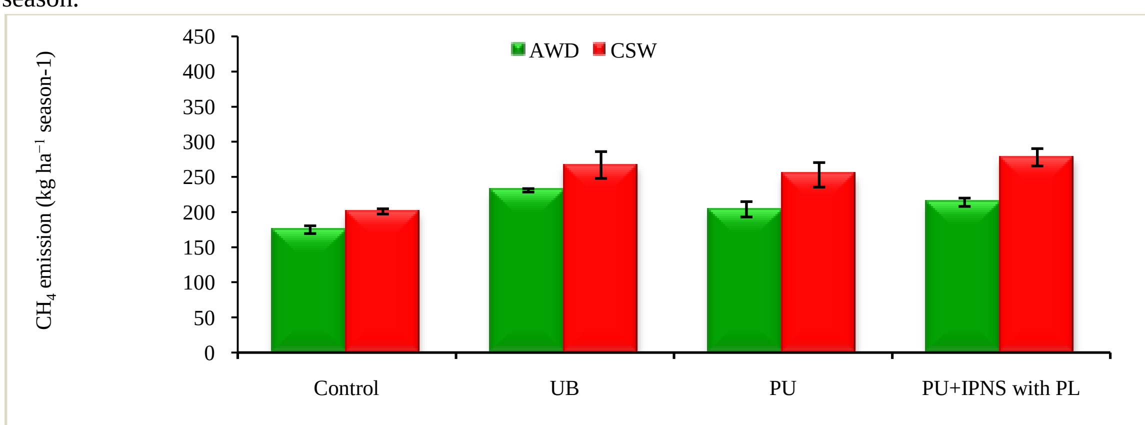


Fig. 3. Effect of water regime and fertilizer management on cumulative CH_4 emission from rice field during T. Aman 2019 at BRRI farm, Gazipur.

matter of the soils, the more amorphous and crystalline Fe^{3+} compounds were used as electron acceptors and the more intensive was the accumulation of Fe^{2+} in flooded soil which might be the possible cause of Fe toxicity in such soils. There was a positive relationship (r = 0.80) found between soil organic matter and Fe content of the study areas (Fig. 4).

SOIL MICROBIOLOGY AND BIOFERTILIZER

Field evaluation of BRRI bio-organic fertilizer. BRRI bio-organic fertilizer was developed to reduce synthetic N and P fertilizer use in rice cultivation and improve soil health. To evaluate its field performance, two field experiments were conducted at each farm of BRRI HQ and BRRI RS, Cumilla in both the season of T. Aman 2019, and Boro 2019-20. Bio-organic fertilizer (BoF) was used at 2 t ha^{-1}. The treatment combinations for BRRI HQ, Gazipur was NPKS (100%), BoF + 70% (N) +100% (KS), BoF +100% NPKS and fertilizer control. At BRRI RS, Cumilla, treatments were as; BoF, NPKS (100%), BoF + N (70%) + KS (100%), N (70%) + PKS (100%), NPKZnS (100%) and control. Recommendation rates of chemical fertilizers for T. Aman and Boro were (N-P-K-S) kg ha^{-1}@ 67-10-41-10 and 140-20-80-10, respectively. BRRI dhan87 in T. Aman and BRRI dhan89 was grown in Boro season. In addition, two farmer's field demonstrations were conducted in saline soil.

Effect of bio-organic fertilizer on grain yield. Bio-organic fertilizer (BoF_1@ 2t ha^{-1}) has potential to supplement 30% N and 100% P requirement for HYV rice at Gazipur and Cumilla soil without sacrificing yield. In T. Aman, application of bio-organic fertilizer with 100% NKS produced the highest grain yield of 5.3 t ha^{-1} and it was statistically similar with 100% NPKS and 30% reduced N with 100% KS treatment. However, in Boro, the highest grain obtained (7.3 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 obtained in control treatment. In Cumilla, bio-organic fertilizer with 30% reduced N and 100% omission of TSP produced statistically similar grain yield (5.22 t ha^{-1}) with full dose of chemical NPK fertilizer and reduced chemical fertilizer in T. Aman season. However, in Boro season, the highest grain yield (7.41 t ha^{-1}) was obtained from BoF with 30% reduced N and 100% omission of TSP treatment and it was statistically similar to other chemical fertilizer treatments. Bio-organic fertilizer is capable to improve rice yield in saline soil where irrigation (water salinity varied from 0.65-2.53 dS/m with the corresponding soil salinity ranged from 4.59-7.66 dS/m). In Amtali, Barguna site, application of bio-organic fertilizer 2 t ha^{-1} (dry weight basis) along with 30% reduced urea and 100% removal of TSP fertilizer increased rice yield about 1.56 t ha^{-1} (28.3%) compared to full chemical fertilizer. Whereas, in Dacope, Khulna site, bio-organic fertilizer increased 0.5 t/ha (9.6%) yield compared to balanced chemical fertilizer of BRRI dhan67.

Microbial characterization of different AEZs soil. Soil biology dictates soil health. The study was initiated in the year of 2019 with the objective to determine the microbial properties of different AEZ soils of Bangladesh. Soil sample collection was started after harvest of Boro rice in 2019-20. A total of 40 soil samples were collected (0-20 cm) from each AEZ using GPS and analyzed for total and beneficial bacteria, fungus and actinomycetes.

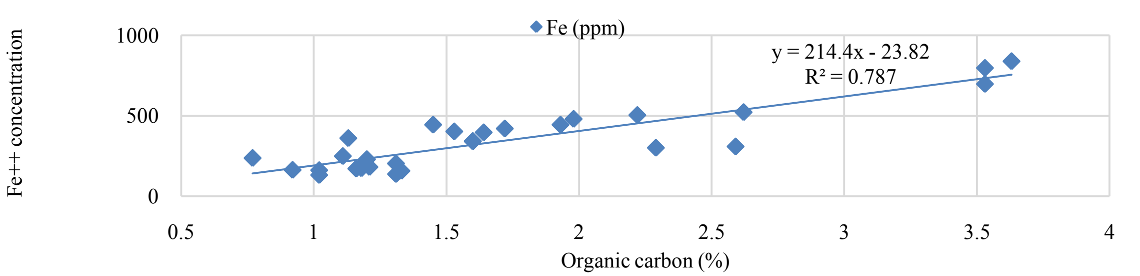


Fig. 4. Relationship between soil organic matter and soil Fe^{++} content at Sripur soil.

Microbial populations were determined using spread plate count technique with specific growth media. In the first phase, soil samples were collected from AEZ19, AEZ8 and AEZ21.

Total and beneficial microbial population. In general, microbial populations were lower compared to any other healthy agricultural soil. Among the tested three AEZs soils, comparatively higher number of microbial population were found in AEZ19 and lower in the AEZ8 soil. In AEZ19, soil samples were collected from Burichang and Debidwar union of Cumilla district. In this AEZ, average population (log_{10} cfu g^{-1} soil) of total bacteria, fungus, actinomycetes, free living N_2 fixing bacteria, rhizobium and phosphate solubilizing bacteria (PSB) were 5.8, 4.3, 3.5, 5.8, 5.4 and 5.0 respectively. Samples of AEZ21 and AEZ8 were collected from Kishoreganj district. In the AEZ21 (Karimganj, Sutarpara union), the average population (log_{10} cfu g^{-1} soil) of total bacteria, fungus, actinomycetes, free living N_2 fixing bacteria, rhizobium, and PSB were 5.8, 3.7, 3.4, 5.8, 5.8 and 5.6 respectively. In the AEZ8 (Bazitpur, Uttar Pirijpur union), average population (log_{10} cfu g^{-1} soil) of total bacteria, fungus, actinomycetes, free living N_2 fixing bacteria, rhizobium, and PSB were 5.3, 3.9, 3.4, 4.7, 4.7 and 5.3 respectively (Fig. 5).

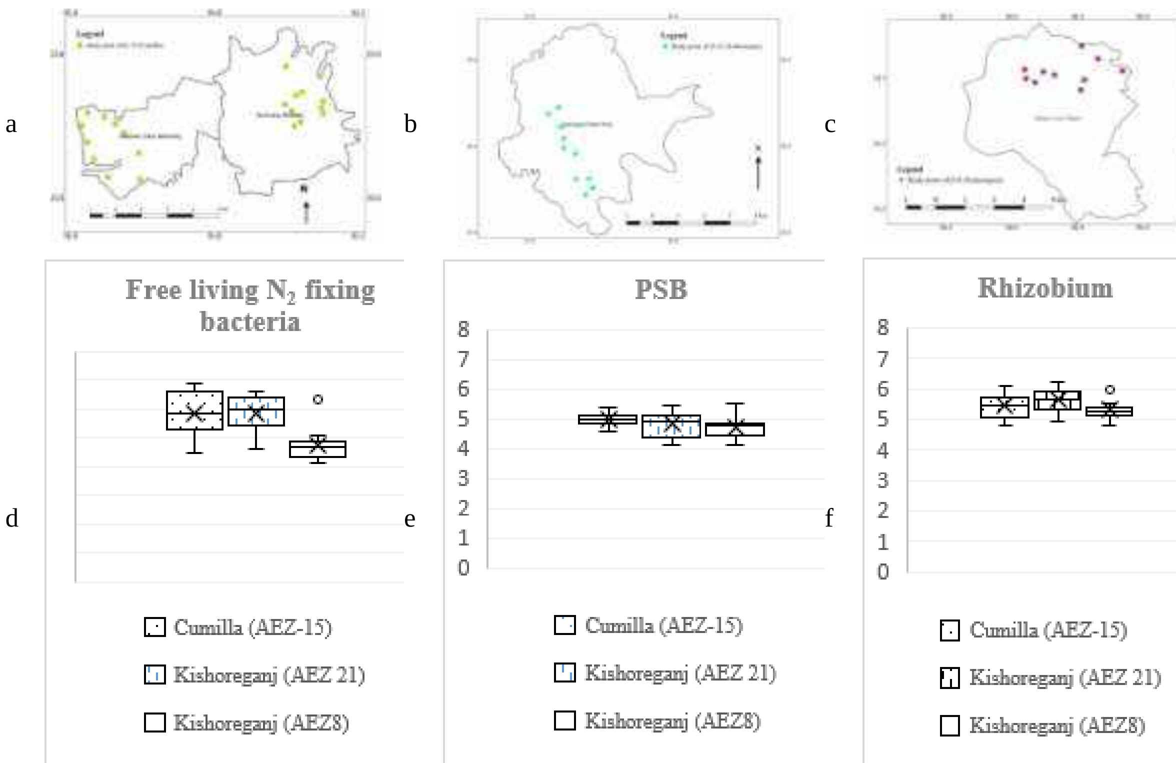


Fig. 5. Location map of AEZs originates from GPS information (a-c), and beneficial bacteria population (d-f). a) study points of AEZ19 (Burichang and Debidwar, Cumilla), b) study points of AEZ21(Sutar Para, Kishoreganj), c) Study points of AEZ8 (Bazitpur, Kishoreganj), d) Population of free living N_2 fixing bacteria, e) population of phosphate solubilizing bacteria, f) population of rhizobium. The line that divides in the box represents the median of the data. The end of the box shows the upper and lower quartiles. (n=20 for each AEZ).

Irrigation and Water Management Division

SUMMARY

Soil textural classes were mostly clay, loam to silty loam, mostly loam (average bulk density from 1.30 to 1.46 gm/cc) for BRRI RS, Kushtia farm, BRRI RS, Sirajganj farm and BRRI RS, Rangpur farm respectively. An automated irrigation system containing a base station, field tubes with transmitting section and an internet modem to transmit data to severe was installed in BRRI HQ, Gazipur farm for field validation in collaboration with CSE department of United International University. Hill area water resources assessment study revealed that cross dam or rubber dam along with a pipe distribution system could increase cultivable land coverage in valley area. Any significant drought event did not occur in the reported year that could be forecasted. Considerable amount of fresh water could be stored in canal networks and used for Boro rice and non-rice cultivation within Polder 30 and Polder 31 if a certain percentage of poor and bad canals would be reconstructed. A groundwater level depletion analysis in northwest region of Bangladesh showed that 40-100% Boro rice area should be irrigated according to actual water requirement to balance groundwater mining. Eighty-two hectares of fallow land were brought under Boro rice cultivation in Barishal region by using fresh water from nearby canal, 286 farmers involved in producing 500 tons rice with the support of 20 LLPs and flexible water distribution pipes. Solar irrigation system evaluation reported that the highest discharge (232 m^3/day) was found for Sadar and Nazirpur upazilas of Pirojpur district in March and the lowest discharge (171 m^3/day) was found in May at Bakerganj upazila of Barishal district. In T. Aman season, BRRI dhan87 produced the highest grain yield (5.4 t ha^{-1}) in Dacope, Khulna and BRRI dhan76 produced the highest grain yield (5.6 t ha^{-1}) in Amtali, Barguna. In Boro season, rice yield did not vary with water management practices, but varied with rice variety and location. In T. Aus season, BRRI dhan48 performed the best in Dacope, Khulna (4.16 t ha^{-1}) and Amtali, Barguna (4.11 t ha^{-1}). The best planting window for T. Aus was found 10 April to 30 April in coastal areas. Heavy rainfall event in every 1.5 to 2 years might cause problem for non-rice crops but could enhance rice cultivation in coastal areas. The best water efficient cropping pattern was Lentil-T. Aus-T. Aman (water productivity 3.5 kg/m^3) followed by Potato-Boro-T. Aman (3.3 kg/m^3) for the northwest hydrological region.

WATER USE EFFICIENCY IMPROVEMENT IN IRRIGATED AGRICULTURE

Determination of physical and hydraulic properties in different soil types

The study was conducted in BRRI RS, Kushtia, Rangpur and Sirajganj. Soil samples were collected from different soil profiles at 0-15, 15-30, 30-45, 45-60 cm using standard protocols. Eighty, 24 and 62 samples were collected from BRRI RS, Kushtia, BRRI RS, Rangpur and BRRI RS, Sirajganj respectively. GPS coordinates were recorded for all soil sample collection points. The soil textural class information along with sand, silt and clay percentages were presented in Table 1, 2, and 3 for Kushtia farm, Sirajganj farm and Rangpur farm, respectively. Irrespective of depths, the general textural class of Kushtia farm was clay, when it was loam to silty loam in Sirajganj farm and mostly loam in Rangpur farm. The average soil bulk density considering all depths, Kushtia farm had a bulk density of 1.46 gm/cc, Sirajganj farm had bulk density of 1.33 gm/cc and Rangpur farm had bulk density of 1.30 gm/cc. Figure 1 presents the soil water release curves of all depths in each sampling points. The infiltration experiments both in Kushtia farm and Sirajganj farm showed (Fig. 2) that final infiltration rate was higher in Kushtia farm and it was 24 mm/hr. On the other way, Sirajganj farm infiltration rate was comparatively low (2 mm/hr). However, the final or constant infiltration rates were calculated from field observed data and did not fitted with any infiltration equation.

Development of automated alternate wetting and drying irrigation system for rice production

The study is currently ongoing in collaboration with Department of Computer Science and Engineering, United International University (UIU), Bangladesh. A sensor-based technique has been adopted for applying water efficiently and properly in AWD irrigation system. The Arduino pro mini and Arduino UNO as processing power, sonar sensor for measuring the water level and RF module for communication between field monitoring device and the base station (pump turning on/off) are the components of the automated irrigation system (Figs. 3a and 3b). Figure 4 is a design model of the total implementing device. In Boro 2019-20 season, the automated system containing a base station, field tubes with transmitting section to base station and an internet modem to transmit data to server was installed in BRRI HQ, Gazipur farm. The base station with internet modem was setup in the pump house near the IWM research field. Four field tubes (i.e. AWD perforated pvc pipe) were setup in four plots after transplanting. The transmitter module was placed on top of each field tube. A monitoring app (Fig. 5) was developed by CSE department, United International University (UIU) to get update about the water level in the field tubes remotely. A small solar panel would be connected instead of rechargeable batteries to supply power so that the whole unit could be placed with a clamp on top of the field tube. The modification of the system and testing has been in progress in CSE department lab.

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

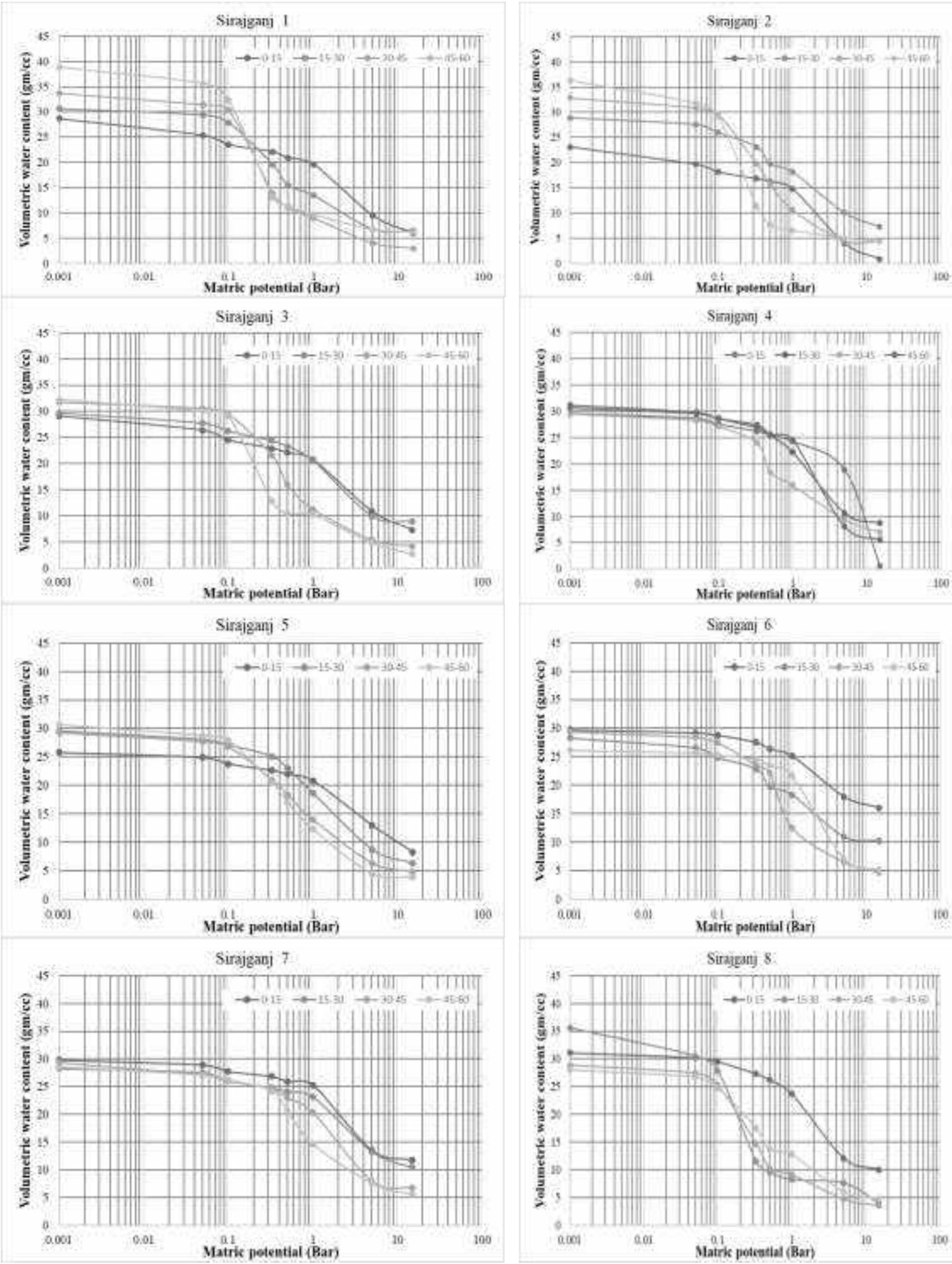
Longitude	Latitude	Depth (cm)	Bulk density (gm/cc)	Sand%	Silt%	Clay%	Textural class
23°54´51″N	89°05´56″E	0-15	1.60	22	16	62	CLAY
		15-30	1.47	22	25	53	CLAY
		30-45	1.44	21	25	54	CLAY
		45-60	1.52	18	42	40	SILT CLAY
23°54´50″N	89°05´57″E	0-15	1.54	24	16	60	CLAY
		15-30	1.59	22	23	55	CLAY
		30-45	1.59	22	29	49	CLAY
		45-60	1.45	21	39	40	CLAY
23°54´50″N	89°05´58″E	0-15	1.62	24	14	62	CLAY
		15-30	1.47	23	21	56	CLAY
		30-45	1.51	22	34	44	CLAY
		45-60	1.46	22	32	46	CLAY
23°54´50″N	89°05´60″E	0-15	1.45	22	16	62	CLAY
		15-30	1.48	21	19	60	CLAY
		30-45	1.46	24	38	38	CLAY LOAM
		45-60	1.49	22	43	35	CLAY LOAM
23°54´49″N	89°05´59″E	0-15	1.52	23	17	60	CLAY
		15-30	1.53	20	26	54	CLAY
		30-45	1.53	23	49	28	CLAY LOAM
		45-60	1.36	18	40	42	SILTY CLAY
23°54´49″N	89°05´58″E	0-15	1.30	21	21	58	CLAY
		15-30	1.29	22	24	54	CLAY
		30-45	1.23	22	46	32	CLAY LOAM
		45-60	1.44	21	35	44	CLAY
23°54´49″N	89°05´57″E	0-15	1.42	25	21	54	CLAY
		15-30	1.40	22	26	52	CLAY
		30-45	1.43	24	32	44	CLAY
		45-60	1.41	21	18	61	CLAY
23°54´48″N	89°05´56″E	0-15	1.31	24	36	40	CLAY
		15-30	1.39	22	22	56	CLAY
		30-45	1.36	22	32	46	CLAY
		45-60	1.25	23	43	34	CLAY LOAM
23°54´47″N	89°05´57″E	0-15	1.35	24	27	49	CLAY
		15-30	1.34	24	34	42	CLAY
		30-45	1.30	20	39	41	CLAY
		45-60	1.40	21	39	40	CLAY
23°54´47″N	89°05´57″E	0-15	1.55	22	29	49	CLAY
		15-30	1.39	20	36	44	CLAY
		30-45	1.35	26	40	34	CLAY LOAM
		45-60	1.27	24	50	26	SILT LOAM

Table 2. The soil texture of BRRI RS, Sirajganj.

Longitude	Latitude	Depth (cm)	Bilk density (gm/cc)	Sand%	Silt%	Clay%	Textural class
24°24.172'	89°38.706'	0-15	1.13	32	48	20	LOAM
		15-30	1.49	36	44	20	LOAM
		30-45	1.41	38	57	5	SILT LOAM
		45-60	1.38	38	58	4	SILT LOAM
24°24.177'	89°38.714'	0-15	1.18	34	44	23	LOAM
		15-30	1.43	35	42	23	LOAM
		30-45	1.41	33	56	11	SILT LOAM
		45-60	1.34	31	59	11	SILT LOAM
24°24.169'	89°38.707'	0-15	1.13	31	45	25	LOAM
		15-30	1.45	28	50	23	LOAM
		30-45	1.37	28	58	15	SILT LOAM
		45-60	1.28	29	59	13	SILT LOAM
24°24.174'	89°38.696'	0-15	1.29	29	41	31	CLAY LOAM
		15-30	1.44	24	58	19	SILT LOAM
		30-45	1.34	31	57	12	SILT LOAM
		45-60	1.36	21	59	20	SILT LOAM
24°24.213'	89°38.701'	0-15	1.13	32	42	26	LOAM
		15-30	1.44	23	64	13	SILT LOAM
		30-45	1.31	38	53	9	SILT LOAM
		45-60	1.33	36	56	8	SILT LOAM
24°24.246'	89°38.709'	0-15	1.37	25	34	41	CLAY
		15-30	1.43	22	47	31	CLAY LOAM
		30-45	1.29	28	59	13	SILT LOAM
		45-60	1.24	23	64	13	SILT LOAM
24°24.239'	89°38.723'	0-15	1.32	32	39	29	CLAY LOAM
		15-30	1.34	23	49	28	CLAY LOAM
		30-45	1.26	22	50	28	CLAY LOAM
		45-60	1.30	24	60	16	SILT LOAM
24°24.214'	89°38.763'	0-15	1.32	35	48	17	LOAM
		15-30	1.43	33	45	22	LOAM
		30-45	1.22	48	47	5	SANDY LOAM
		45-60	1.27	30	62	8	SILT LOAM

Table 3. The soil texture of BRRI RS, Rangpur.

Longitude	Latitude	Depth (cm)	Bulk density (gm/cc)	Sand%	Silt%	Clay%	Textural class
25°41´42″N	89°16´03″E	0-15	1.56	50	40	10	LOAM
		15-30	1.39	36	44	20	LOAM
		30-45	1.25	33	49	18	LOAM
		45-60	1.30	31	49	20	LOAM
25°41´42″N	89°16´03″E	0-15	1.23	34	52	14	SILT LOAM
		15-30	1.32	32	48	20	LOAM
		30-45	1.30	36	47	17	LOAM
		45-60	1.43	32	48	20	LOAM
25°41´42″N	89°16´02″E	0-15	1.22	46	40	14	LOAM
		15-30	1.14	58	30	12	SANDY LOAM
		30-45	1.27	33	48	19	LOAM
		45-60	1.20	34	48	18	LOAM


Sirajganj 1
Sirajganj 2
Sirajganj 3
Sirajganj 4
Sirajganj 5
Sirajganj 6
Sirajganj 7
Sirajganj 8
0-15
15-30
30-45
45-60
Volumetric water content (gm/cc)
Matric potential (Bar)
0.001
0.01
0.1
1
10
100

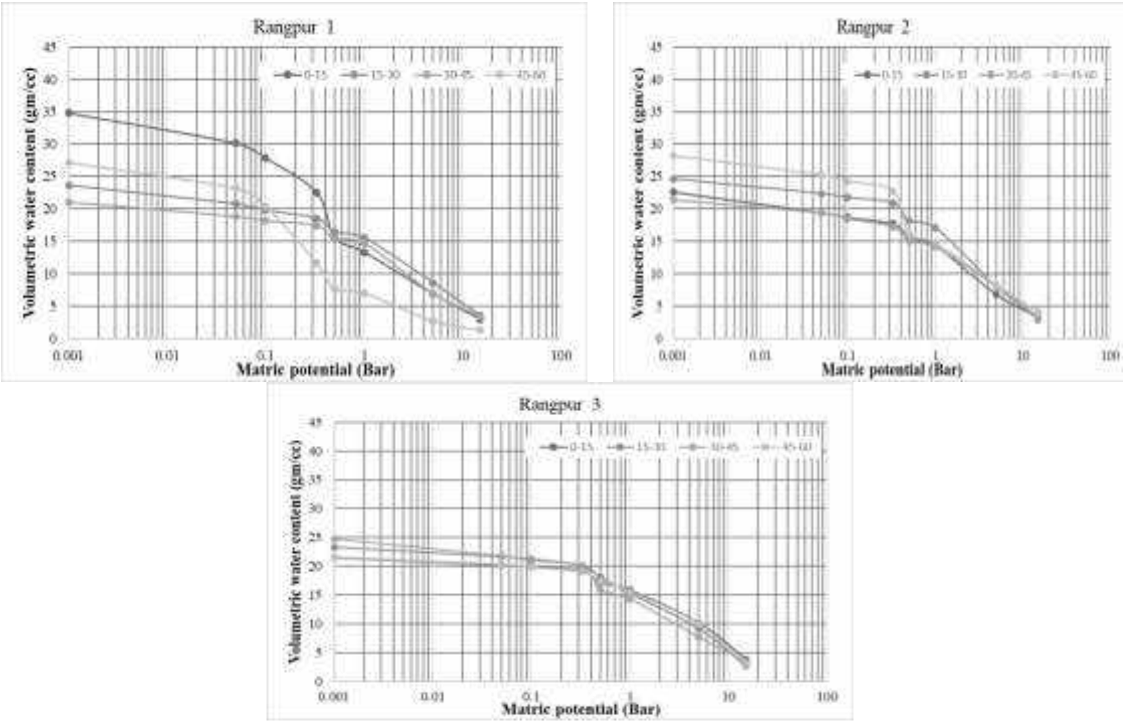


Fig. 1. Soil moisture characteristics curve of different soil depth in different locations.

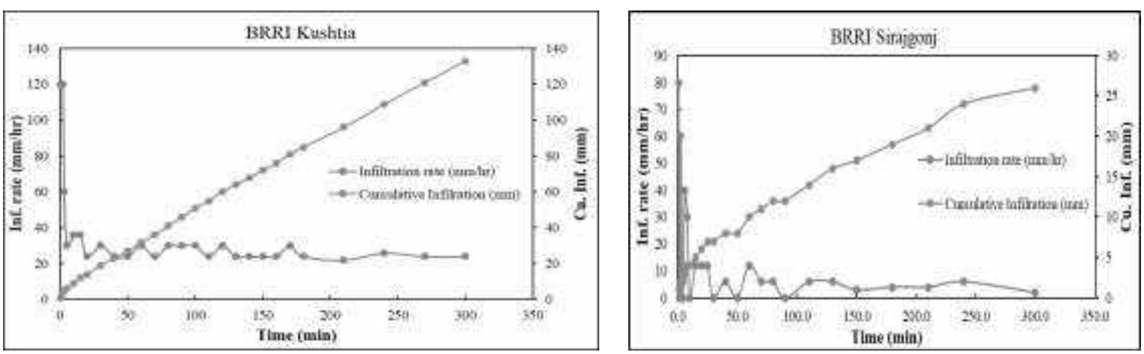


Fig. 2. Infiltration rate and cumulative infiltration in different locations.

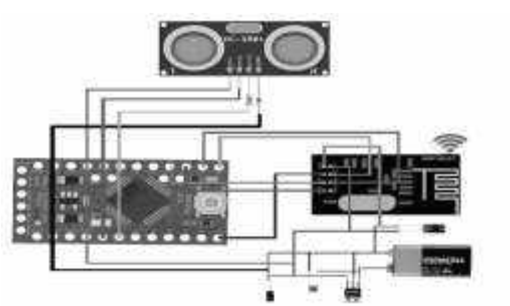


Fig. 3. (a) Transmitter section

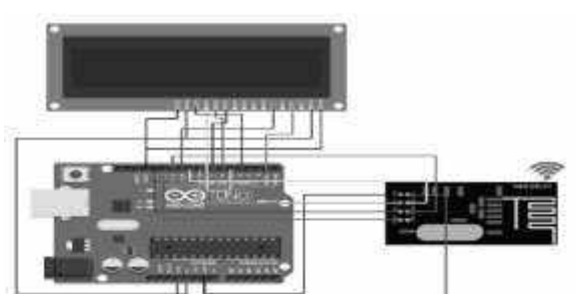


Fig. 3. (b) Receiving section (Base station).

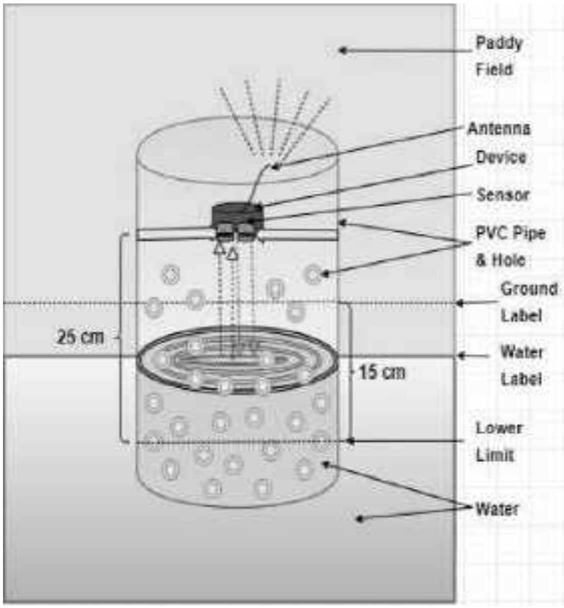


Fig. 4. Field monitoring device prototype.

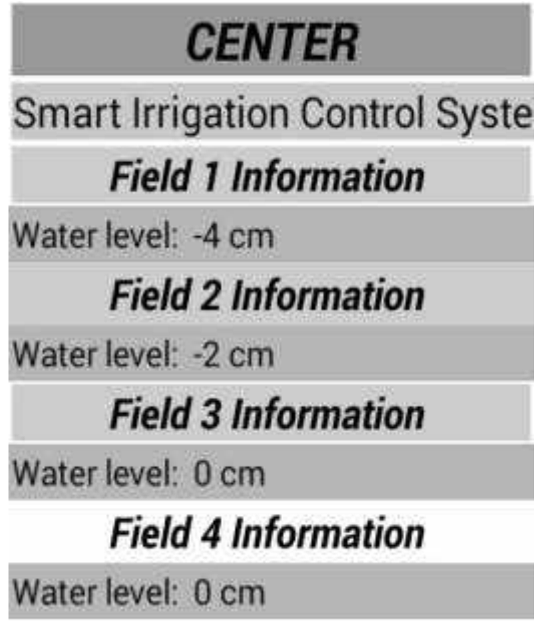


Fig. 5. Screenshot of monitoring App.

Problem and potentials for crop productivity improvement through water management in hilly areas

In 2019-20, the study was conducted in Rajastali upazila of Rangamati district. A field visit and detailed survey was conducted in that region. Five locations, based on water resources availability sources for irrigation purpose, were physically assessed extensively. The water sources are basically small hill creeks, locally known as ‘Chara’. As mentioned earlier, Pine Chora-1, Pine Chora-2, Boga Chora, Kudum Chara and Bangalhalia Chora were visited. It was found from physical assessment and group discussion that the main source of irrigation water used in agriculture section was the small hill creeks or fountains. These water spots are locally known as ‘Jiri’ or ‘Chora’. Usually the water was conserved in the canal by constructing cross dams and applied to the agricultural field through gravity channel. If a pipe distribution networking could be built in each command area of a water source, it might increase the potential utilization of water sources in agriculture. The study in the respected area revealed that if cross dams across the creeks and fountains along with a proper water distribution system (pipe distribution networks) in the command area could possibly increase the agricultural land area coverage to 50 hectares (Table 4).

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

Grain yields were statistically significant by genotype and water stress during Boro season 2019-20 (Table 5). There were two ALARTs named, BR (Bio) 11447-1-28-14-3 and BR (Bio) 11447-3-10-7-1 along with standard and susceptible check BRRI dhan28 supplied from Biotechnology Division. ALART BR (Bio) 11447-1-28-14-3 and BR (Bio) 11447-3-10-7-1 has the water stress tolerance capacity of -10 kPa and -30 kPa respectively. ALART BR (Bio) 11447-3-10-7-1 produced higher yield than ALART BR (Bio) 11447-1-28-14-3 and check variety up to -10 kPa and -30 kPa. ALART BR8938-19-4-3-1-1-P2-HR3 and BR9651-15-2-1-4 were tested under ALART-1, disease resistance and BB along with BRRI dhan28 and BRRI dhan58 as susceptible and standard check respectively. ALART BR8938-19-4-3-1-1-P2-HR3 has water stress tolerance capacity up to -10 kPa. ALART BR9651-15-2-1-4 produced higher yield up to -60 kPa water stress compared to continuous standing water. ALART HR (Path)-11, Path 2441 and BR (Path) 12452-BC3-16-19 were tested along with standard check BRRI dhan58 and BRRI dhan29 under ALART-2, disease resistant, Blast. All the ALART has water stress tolerance capacity up to -30 kPa. BRRI dhan29 produced higher yield up to -10 kPa water stress compared to the other two ALART and BRRI dhan58.

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

The experiment was conducted at BRRI HQ farm, Gazipur to find out a suitable method of Boro cultivation under water limiting conditions. Nine treatments were: T1- Transplanting with maintaining continuous standing water (TP-CSW); T2- Transplanting with AWD (TP-AWD); T3- Transplanting with thin irrigation practice (TP-TI); T4- Dry direct seeding with maintaining continuous standing water (DS-CSW); T5- Dry direct seeding with AWD (DS-AWD); T6- Dry direct seeding with thin irrigation practice (DS-TI); T7- Wet direct seeding with maintaining continuous standing water (WS-CSW), T8- Wet direct seeding with AWD (WS-AWD) and T9- Wet direct seeding thin irrigation practice (WS-TI). Under WS rice, sprouted seeds were sowed with a drum seeder on the puddled soil with spacing 18 cm. BRRI recommended fertilizer doses were used. Table 6 shows that performance of irrigation scheduling treatments (CSW, AWD, TI) varied differently according to the rice establishment methods (TP, DS, WS). Irrespective of establishment method, shifting to AWD and TI practice from CSW practice saves irrigation water significantly. On the other hand, shifting from transplanting to dry direct seeding (DS) establishment method saves irrigation water significantly. Wet direct seeding with drum seeder can provide higher yield with less amount of irrigation. The experimental results show that good yield could be achieved with both dry direct seeding and wet direct seeding.

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. BRRI dhan29, BRRI dhan89 and BRRI dhan92 were grown under four water regimes as: T1 = Maintaining continuous standing water (CSW) from 1 to 5 cm; T2 = AWD irrigation practice (+5 to -15 cm); T3 = Aerobic condition (AWD: 0-25 cm) up to booting stage; and T4 = Aerobic condition (AWD: 0-25 cm) during the entire crop period. Table 7 shows that BRRI dhan89 has tolerance to non-ponding condition. Good yield could be achieved with maintaining CSW practice. AWD practice produced good yield for BRRI dhan92. BRRI dhan89 obtained similar yield for both AWD practice and aerobic conditions.

Table 4. Creek-wise possible agricultural land area coverage if cross dams are constructed across the creeks.

Creek	Village	Bolck	Union	Possible area coverage (ha)
Pine chora-1	Pine chora	Chingkha	2 no. Gaindhya	3
Pine chora-2	Pine chora	Chingkha		2
Boga chora-1	College para	Chingkha		10
Gaindhya chora	Gaindhya para	Gaindhya		4
Boga chora-2	College para	Poyaitu		10
Kudum chora	Kudum chora and Shafipur para	Kakrachori	3 no. Bangalhalia	2
Naikha chora	Naikhachora para	Kakrachoir		1
Kuturiya chora	Khangdong para	Dholia		2
Bangahalia chora	College para	Dholia		3
Hangiri chora	Shafipur	Banglahalia		2
Rahamatia chora	Chagolkhaiya para	Dholia		3
Dholiya chora	Dolia notun para and Muslim para	Dholia		3
Choto Kukyachori chora	Noyapara	Dhonuchori	1 no. Ghilachori	1
Khagrachori chora	Khagrachori para	Ghilachori		4

Table 5. Grain yield of tested varieties as affected by different levels of water stress at whole growing season during Boro, 2019-20.

ALART and check variety	Grain yield (t ha^{-1})				Tolerance capacity
	CSW	-10 kPa	-30 kPa	-60 kPa	
		ALART (Biotechnology, Bacterial Blight Resistance)			
BR (Bio)11447-1-28-14-3	7.14	7.05 (-1.27%)	6.46 (-10.5%)	6.04 (-18.2%)	-10 kPa
BR (Bio)11447-3-10-7-1	6.71	8.12 (+17.36%)	6.94 (+3.31%)	6.36 (-5.50%)	-30 kPa
BRRI dhan28 (Std. and sus.ck	7.57	7.63 (+0.78%)	6.92 (-9.4%)	5.37 (-40.9%)	-10 kPa
lsd0.05					ns
CV%					
		ALART-1, Disease Resistant rice, BB			
BR8938-19-4-3-1-1-P2-HR3	7.14	6.87 (-3.88%)	6.21 (-14.9%)	5.5 (-29.9%)	-10 kPa
BR9651-15-2-1-4	4.68	7.15 (+34.6%)	6.96 (+32.8%)	5.42 (+13.7%)	-60 kPa
BRRI dhan28 (sus. ck)	7.57	7.63 (+0.86%)	6.92 (-9.35%)	5.37 (-40.8%)	-10 kPa
BRRI dhan58 (std. ck)	7.09	7.09 (+0.04%)	6.88 (-2.96%)	6.69 (-5.88%)	-10 kPa
lsd0.05					0.9
CV%					0.2
		ALART-2, Disease resistant rice, Blast			
HR(Path)-11	7.91	7.12 (-11%)	7.95 (+0.54%)	7.29 (-8.55%)	-30 kPa
Path 2441	7.0	7.69 (+9%)	7.31 (+4.2%)	6.38 (-9.7%)	-30 kPa
BR(Path)12452-BC3-16-19	7.24	7.85 (+7.8%)	7.26 (+0.3%)	5.11 (-41.6%)	-30 kPa
BRRI dhan58 (std. ck)	7.09	7.09 (+0.04%)	6.88 (-2.96%)	6.69 (-5.88%)	-10 kPa
BRRI dhan29 (std. ck)	7.92	9.11 (+13%)	6.68 (-18.5%)	6.10 (-29.8%)	-10 kPa
lsd0.05					0.75
CV%					6.3

Table 6. Number of irrigations and amount of irrigation applied for different treatments along with rainfall in Boro 2019-20 at BRRI HQ, farm, Gazipur.

Treat	Establishment method	Growth duration (day)	Number of irrigation	Irrigation applied (mm)	Rainfall (mm)	Total water use (mm)	Irrigation water saving (%)	Yield (t ha^{-1})
T_1	TP-CSW	141	18	960	149	1109	-	6.15
T_2	TP-AWD	141	15	845	149	994	12.0	6.49
T_3	TP-TI	141	21	795	149	954	17.2	5.15
T_4	DS-CSW	134	21	900	183	1083	6.3	6.60
T_5	DS-AWD	134	18	813	183	996	15.3	5.87
T_6	DS-TI	134	23	672	183	855	30.0	5.55
T_7	WS-CSW	128	22	970	181	1151	-1.0	6.56
T_8	WS-AWD	128	19	863	181	1044	10.1	6.67
T_9	WS-TI	128	25	800	181	981	16.7	6.14

Table 7. Irrigation, rainfall and grain yield of the selected varieties under different treatments during Boro season 2019-20 at BRRI HQ, farm, Gazipur.

Treat	Variety	Total growth duration (day)	Number of irrigation	Irrigation applied (mm)	Rainfall (mm)	Total water use (mm)	Yield (kg/ha)	Mean yield (kg/ha)
T1V1	BRRI dhan29	170					7972.5	
T1V2	BRRI dhan89	170	19	913	212	1125	7909.8	8028.0
T1V3	BRRI dhan92	170					8201.7	
T2V1	BRRI dhan29	170					7230.1	
T2V2	BRRI dhan89	171	16	778	212	990	7218.2	7481.2
T2V3	BRRI dhan92	171					7995.4	
T3V1	BRRI dhan29	169					7059.6	
T3V2	BRRI dhan89	170	24	719	212	931	7128.9	6908.1
T3V3	BRRI dhan92	170					6535.9	
T4V1	BRRI dhan29	170					6738.4	
T4V2	BRRI dhan89	170	24	674	212	886	7102.1	6688.7
T4V3	BRRI dhan92	170					6225.8	

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 2019. BRRI dhan49 was used as test variety. Weather research and forecasting (WRF) model was used to forecast seven days daily minimum and maximum temperature, average relative humidity (%), wind speed. Forecasted rainfall and evapotranspiration were used as input of drought simulation model (DS model) (Towfiq, 2007) to quantify agricultural drought. CROPWAT 8.0 was used to compare the quantified drought. Thirty-day-old seedlings were transplanted on 3 August 2019 and harvested at 14 November 2019. Enough rainfall occurred during the T. Aman season 2019 and no drought occurred (Fig. 6). A good matching was found between observed and forecasted rainfall (Fig. 7). Yield parameters showed that there are no significant differences between treatments (Table 8).

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 polder number 30 and 31 situated at Botiaghata and Dacope, Khulna (Fig. 8). 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. 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 respectively in polder 30 and 660, 766 and 1030 ha-m, respectively in Polder 31. At present condition, 334 ha and 502 ha area can be brought under cultivation in polder 30 and 31 respectively if all the fresh water in canals trapped in December. Considering, 30%, 50% and 100% canal excavation, Boro area could be increased to 440, 511 and 688 ha respectively in polder 30 and 660, 766 and 1030 ha respectively in Polder 31.

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

A total of 82 hectares of fallow lands through 21 block demonstrations were brought under Boro cultivation using surface water from nearby canals in six upazilas of Barishal region (Fig. 9). Under these blocks, 286 beneficiary farmers were directly involved. Farmers were supplied 20 low lift pump (LLP) sets and flexible pipes. Transplanting of Boro rice in this region was late mainly due to late harvesting of Aman rice. Averaged across all locations, yield of BRRI dhan47, BRRI dhan58, BRRI dhan67, BRRI dhan74, and BRRI dhan89 ranged from 5.5 to 6.2, 5.3 to 6.2, 5.4 to 6.1, 5.7 to 7.1, 6.4 to 7.5 t/ha respectively. More than 500 tons of rice grains were harvested under the demonstration programme that eventually increased the crop productivity in this region. Most of the farmers expressed their preferences to BRRI dhan47 and BRRI dhan74. There is suitable irrigation water available during the season which can be beneficially used for Boro cultivation. So, farmers are interested to cultivate Boro rice if LLPs are available. Canal network narrowed for sedimentation needed to be re-excavated.

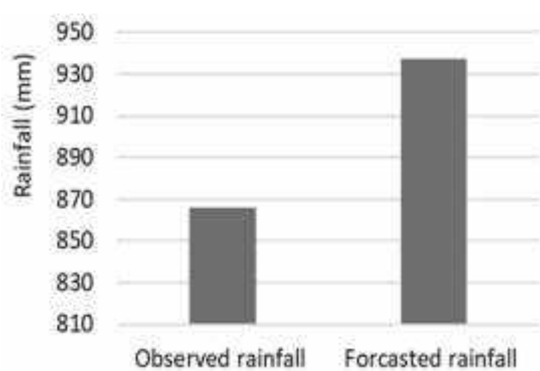


Fig. 6. Amount of observed and predicted rainfall.

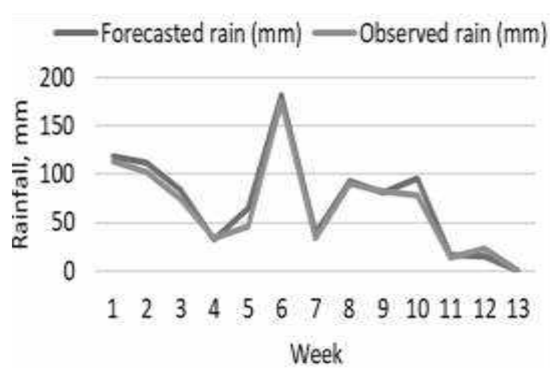


Fig. 7. Observed VS forecasted rainfall.

SUSTAINABLE MANAGEMENT OF WATER RESOURCES

Assessment of groundwater level depletion dynamics in selected locations of Bangladesh

This study was conducted in northwest region of Bangladesh to evaluate the groundwater fluctuation pattern and to assess the judicial use of groundwater for irrigation. The groundwater level has been analyzed for 16 districts (Fig. 10). Among the 108 upazilas, groundwater resources are getting scarce in 44 upazilas. Minimum groundwater level is increasing both in Pabna and Bogura region indicating that recharge amount is decreasing than withdrawal. Farmers are using 38% more water than actual water requirement during Boro season. In Rangpur, on average 0.2 billion cubic meter (BCM) per year groundwater shortage was faced for last l0 years due to over withdrawal following farmers practice (Fig. 11). But average 0.55 BCM per year excess groundwater was estimated following actual irrigation requirement approaches. To balance utilization of groundwater, 60%, 50%, 50%, 100% and 40% of Boro area needed to bring under irrigation based on actual irrigation requirement in Bogura, Pabna, Naogaon, Joypurhat and Rangpur respectively.

RENEWABLE ENERGY

Evaluation of smallholder surface water solar irrigation system for crop production

A field experiment at BRRI, Gazipur was conducted prior to setting the solar irrigation systems. The aim of this experiment was to develop a model to simulate the flow rate by using only the solar radiation data. We have collected flow rate and solar radiation data every half an hour interval from dawn to dusk. The flow rates from pump were measured at different solar irradiance intensities. Pyranometer was used to measure solar irradiance of PV array during the experiments. We have developed a correlation between solar radiation and flow rate keeping a constant pumping head of 2 m. We have proposed a 2nd degree polynomial model which allows us to contribute in the studies of photovoltaic (PV) water pumping system (Fig. 12). The site specific long term global horizontal irradiance (GHI), direct normal irradiance (DNI) and diffuse horizontal irradiance (DHI) data were collected from the Global Solar Atlas *(https://globalsolaratlas.info/)*. The highest discharge was found for Pirojpur sadar upazila in March and the lowest discharge was found in May at Bakerganj upazila of Barishal district. The highest monthly average daily simulated discharge (232 m^3/day) was found in March at sadar and Nazirpur upazilas of Pirojpur district and the lowest discharge was 171 m^3/day in May at Bakerganj upazila of Barishal district (Fig. 13).

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).

Selection of suitable T. Aman rice varieties for facilitating Rabi crops intensification. The experiment was setup in a RCBD at Dacope, Khulna and Amtali, Barguna to find out the suitable varieties for improving the facility for timely sowing of Rabi crops and to improve the land and water productivity with rice varieties such as BR23, BRRI dhan49, BRRI dhan71, BRRI dhan75, BRRI dhan76, BRRI dhan77 and BRRI dhan87 along with the popular local varieties. In Dacope area, BRRI dhan87 produced the highest grain yield (5.4 t ha^{-1}) followed by BR23, BRRI dhan77 and BRRI dhan76 (Table 9) and most of the farmers of that locality showed their interest to cultivate BRRI dhan87, BRRI dhan77, BRRI dhan76 and BR23 in next T. Aman season. In Amtali area, BRRI dhan76 produced the highest grain yield (5.6 t ha^{-1}) followed by BRRI dhan77 and BR23 and most of the farmers showed their interest to grow these varieties.

Performance of Boro rice under water saving conditions in saline areas. The study was conducted at Dacope, Khulna and Amtali, Barguna during the dry season of 2019-20. Due to the lower salinity (within then permissible limit of 4 dS/m) of canal water and rice field water in both the locations,

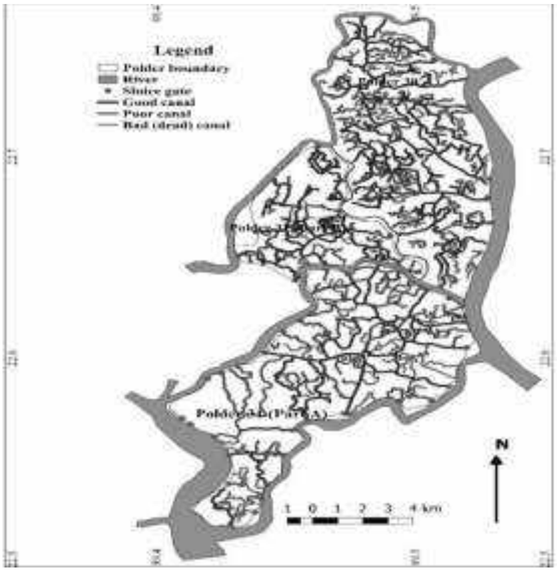


Fig. 8. Map of different canals inside the polder 30 and 31 in Khulna region.

there was no significant variation in rice yield in different water management systems, i.e. continuous standing water (CSW) and alternate wetting and drying (AWD) (Fig. 14). But there was a significant variation in rice yield found in different tested locations and among the varieties (Fig. 14). The lowest yield of BRRI dhan67 was found in both the locations. Due to the varietal potentiality, BRRI dhan89 produced the higher yield in both the locations. This may be happened due to the comparatively lower salinity during the rice production season.

Evaluation of different mulching materials in rice under saline areas. The study was conducted at Dacope, Khulna and Amtali, Barguna during the dry season of 2019-20. The experiment involved five mulching treatments namely no mulch, mulching with ash, mulching with saw dust, mulching with rich husk, and mulching with rich straw. The highest grain yield was found in ash mulching and the lowest grain yield was found in saw dust mulching in both the locations (Fig. 15). Ash mulching treatment produced comparatively higher yield in both the locations. It may be happened due to higher potassium content in ash, which reduced the salinity effect from rice field. Ash mulching showed 1.28 to 3.03% yield advantage over the conventional no mulching treatment at Dacope.

Block demonstration of Boro rice by using canal water. The experiment was setup in a RCBD at Dacope, Khulna and Amtali, Barguna with BRRI dhan67, BRRI dhan74, and BRRI dhan89. In Dacope area, all the tested varieties produced the highest grain yield compared to Amtali area (Fig. 16). The yield in Dacope area varied from 5.80 to 6.34 t ha^{-1} with an average of 5.82 t ha^{-1}, whereas in Amtali area rice yield varied from 5.52 to 5.84 tha^{-1} with an average of 5.70 t ha^{-1}. Salt tolerant BRRI dhan67 performed well in both the sites. Fresh water availability is the main constraints for Boro cultivation. However, farmers are interested to grow Boro rice by trapped canal water.

Planting time for Aus rice cultivation in saline areas. The study was conducted at Dacope, Khulna and Amtali, Barguna during the dry season of 2019-20. The trapped canal water was used for irrigation for seedling raising and sometimes for

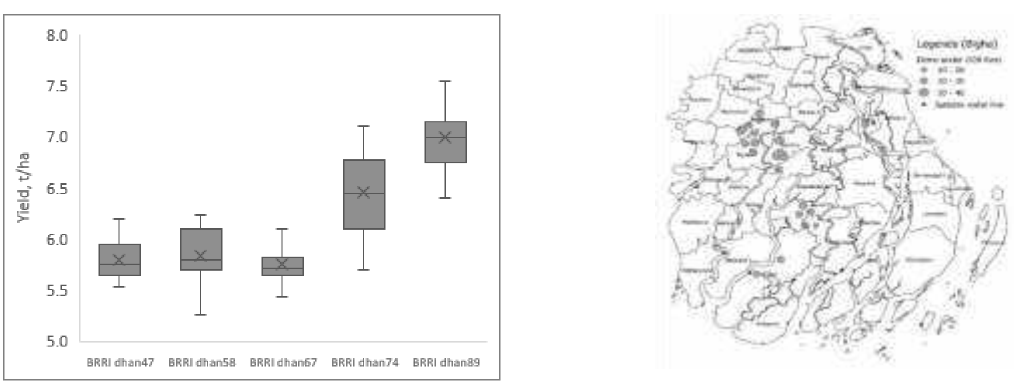


Fig. 9. Average yield (t ha^{-1}) of BRRI varieties cultivated at different locations in Barishal region and map showing locations and land cultivated under BRRI demonstrations in Boro 2019-20.

crop establishment. Among the seven sowing dates, 10 April to 30 April sowing date performed better irrespective of variety and location (Fig. 17). The average yield of the optimum window of sowing for both the tested varieties were above 4.5 t/ha in both the locations (Fig. 17). After that, the yield performance declined due to high soil salinity for lacking fresh water.

Performance of Aus rice for crop intensification in coastal zones. The experiment was setup in a RCBD at Dacope, Khulna and Amtali, Barguna with BRRI dhan48, BRRI dhan67 and BRRI dhan82. In both the locations, BRRI dhan48 performed the best (Fig. 18). In Dacope area, rice yield varied from 4.09 to 4.47 t ha^{-1} with an average of 4.16 t ha^{-1} and in Amtali area it varied from 3.92 to 4.30 t ha^{-1}, with an average of 4.11 t ha^{-1}. In both the locations, farmers faced troubles in seedling raising of Aus rice due to freshwater shortage and high soil salinity.

Climatic variability and crop production options for cropping intensification in the coastal Bangladesh. Long-term rainfall (1981-2018) were analyzed for Dacope, Khulna and Amtali, Barguna to find out the dry season crop production options in coastal Bangladesh. Ten millimeter and 20 mm rainfall were considered as heavy and very heavy rainfall, respectively for dry season non-rice crop production in heavy textured coastal soils (SMRC, 2008). Rainfall frequency for heavy and very heavy rainfall was about 90% and 40%, respectively for both the locations (Fig. 19). On the other hand, return period of those rainfall during the non-rice crop growing period was very frequent (Table 10). In very 1.5 to 2.0 years, Rabi crops establishment were delayed for early rainfall and similarly those were partially or fully damaged due to rainfall waterlogged at latter part of crops in both the locations. In contrast, heavy to very heavy rainfall can enhance rice production and soil salinity reduction as well.

Groundwater resource management for sustainable crop production in northwest hydrological region of Bangladesh

The NATP Phase-2 funded project has been running in Rangpur and Pabna region.

Study on groundwater availability assessment and its utilization. This study was done to analyze ground water table of Rangpur and Pabna districts of northwest region and to determine groundwater

Fig. 10. Maximum groundwater level at northwest region of Bangladesh during 2017.

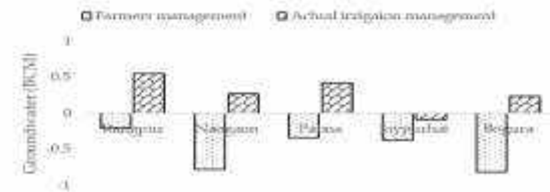


Fig. 11. Groundwater balance in farmer's management and actual irrigation requirement approaches in different districts of Bangladesh.

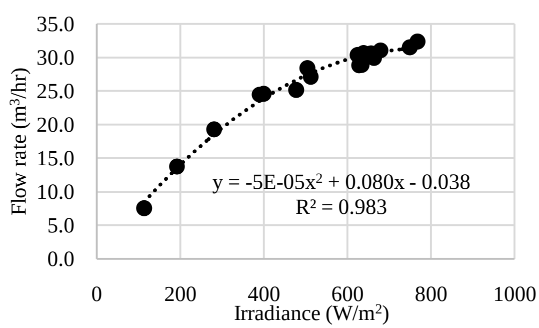


Fig. 12. Relationship between measured flow rate (Q_m) versus the incident solar radiation.

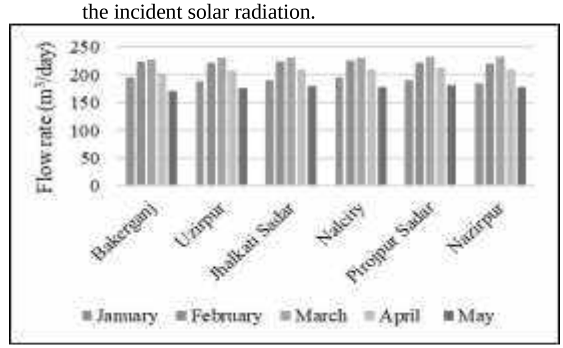


Fig. 13. Monthly average daily production of simulated flow rates in different locations of Barishal region using DNI data.

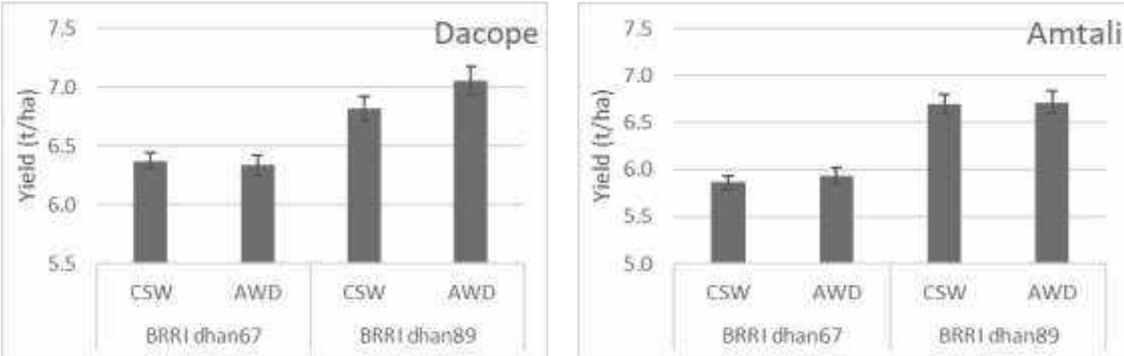


Fig. 14. Yield of different variety under CSW and AWD water management at Dacope and Amtali during Boro, 2019-20.

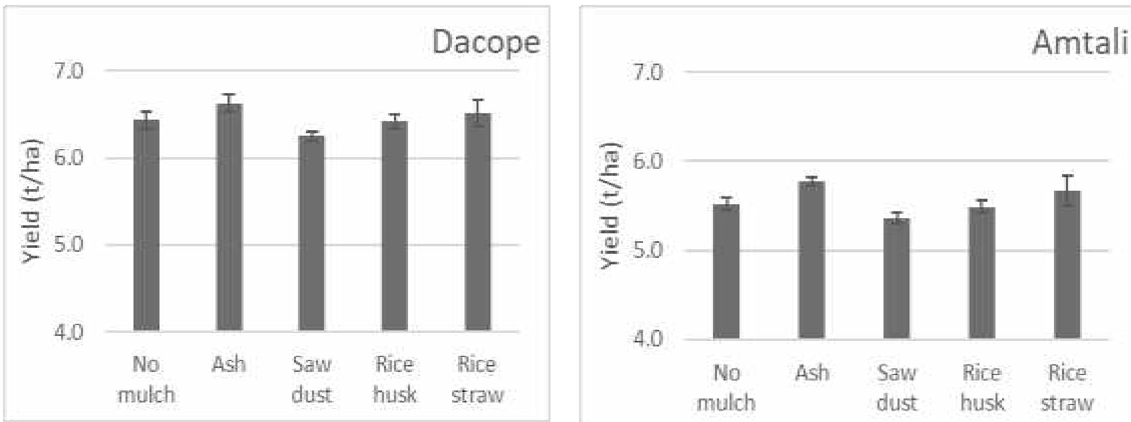


Fig. 15. Yield performance of different mulching materials at Dacope and Amtali during Boro 2019-20.

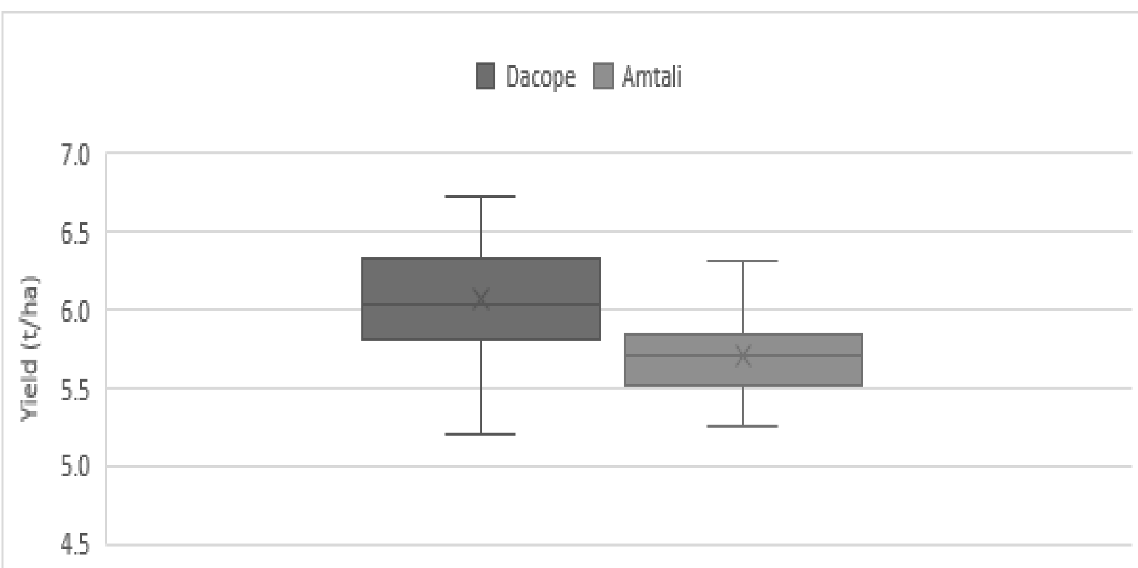


Fig. 16. Yield performance of Boro rice at Dacope and Amtali during Boro 2019-20.

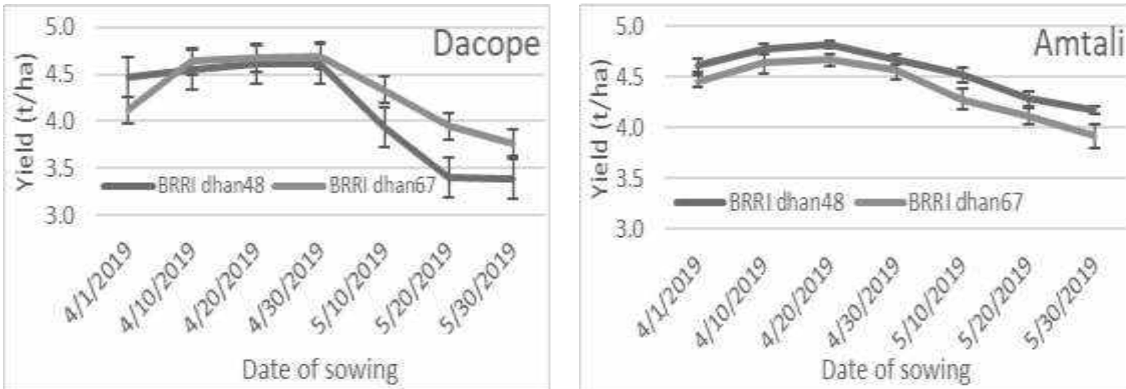


Fig. 17. Yield performance of Aus varieties under different date of sowing at Dacope and Amtali in 2019-20.

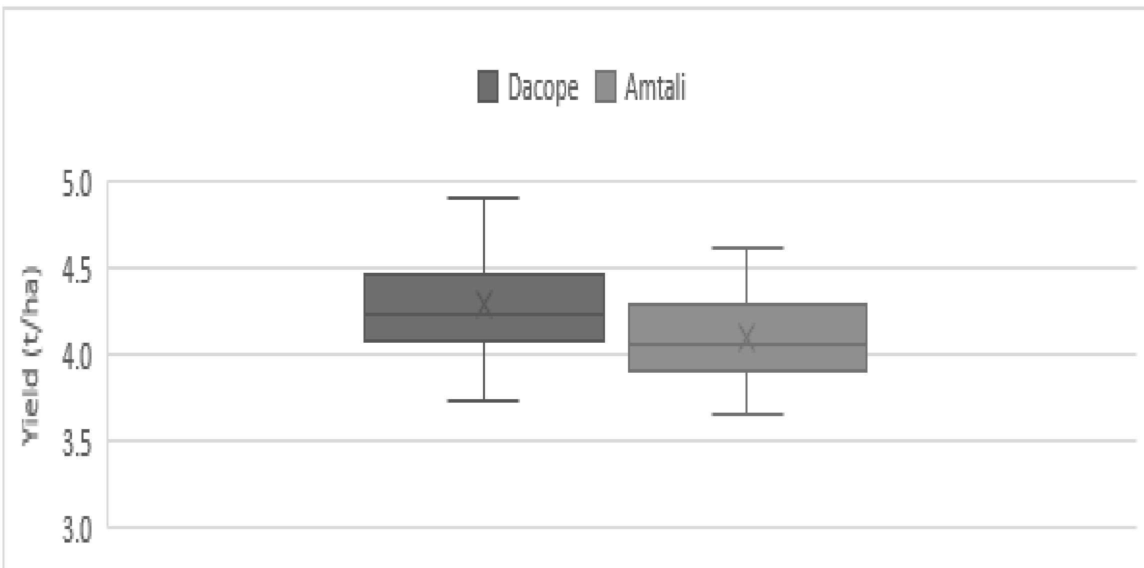


Fig. 18. Rice yield performance at Dacope and Amtali during Aus 2019.

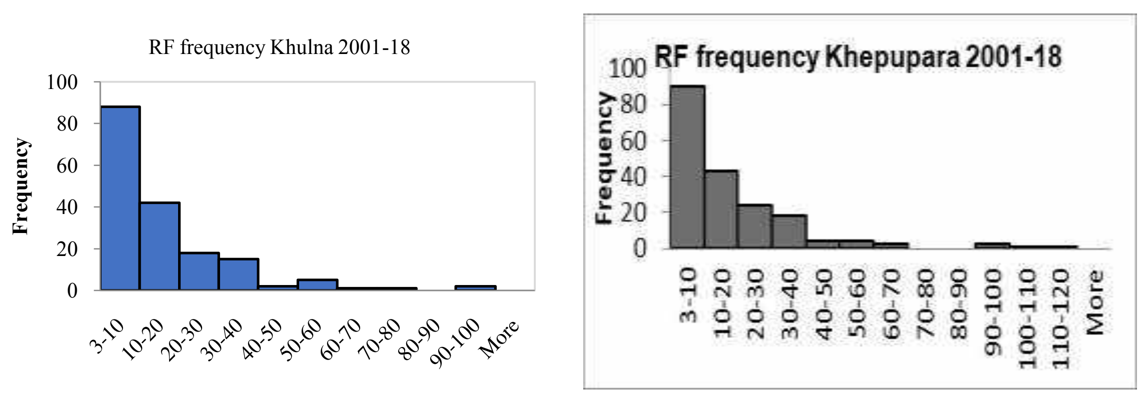


Fig. 19. Long term (2001-18) rainfall frequency at Khulna and Khepupara, Patuakhali areas.

Table 8. Average yield parameters under different treatments of BRRI dhan49 in T. Aman 2019.

Treatment	Grain/Penicle	Unfilled grain/Penicle	1000 grain wt (gm)	Yield (t ha^{-1})
Rainfed (I_0)	107.98	16.13	19.30	4.47
Supplemental irrigation based on weather forecasting (I_1)	104.83	24.55	19.43	4.43
Supplemental irrigation in rainfed condition if necessary (I_2)	110.83	27.88	19.45	4.45

Table 9. Performance of tested variety at Dacope, Khulna and Amtali, Barguna during T. Aman 2019.

Dacope, Khulna				Amtali, Barguna			
Variety	Sowing date	Growth duration (day)	Yield (t ha^{-1})	Variety	Sowing date	Growth duration (day)	Yield (t ha^{-1})
BRRI dhan49	26 July	122	3.6c				
BRRI dhan71	26 July	125	3.5cd				
BRRI dhan75	26 July	110	3.2d				
BRRI dhan76	25-Jul	145	4.1b	BRRI dhan76	14-17 Jul	159	5.6a
BRRI dhan77	25-Jul	145	4.2b	BRRI dhan77	15-17 Jul	156	5.5b
BRRI dhan87	26 July	126	5.4a				
BR23	15-25 Jul	146	4.4b	BR23	14-14 Jul	155	5b
LSD (0.05)			0.4				0.46
CV (%)			3.4				3.8

Table 10. Return period of heavy (>10 mm) and very heavy (>20 mm) rainfall for 1981-2018 during dry season at Khulna and Khepupara, Patuakhali.

RF category	Return period (Yr), Khulna				Return period (Yr), Khepupara			
	Nov	Dec	Feb	Mar	Nov	Dec	Feb	Mar
Heavy (10 mm)	1.4	2.5	1.4	1.3	1.3	1.7	1.4	1.4
Very Heavy (20 mm)	2.1	3.1	2.0	1.9	1.7	2.8	2.1	1.8

withdrawal level for retarding water table declining using TI model, a conceptual GWT model. Analysis results showed that range of maximum and minimum GWT depth are from 9.95 m to 6.92 m and from 6.1 m to 1.0 m respectively at Iswardi. Average withdrawal depth i.e. difference between minimum and maximum GWT depth is also the highest (6.20 m) at Iswardi. The TI model revealed that 56.22 percent area should cover under AWD irrigation for next five years to bring ground water table withing suction limit and it should be disseminated in 28.1% area for 10 years to bring the GWL within the desired limit.

Determination of less irrigation required cropping pattern for water scarcity area. This study was executed to identify the irrigation efficient cropping pattern in the water scarce area of Bangladesh using five cropping patterns in Mithapukur and Pirganj of Rangpur and Ishwardi and Santhia of Pabna. T. Aman-Potato-Boro cropping pattern produced the highest rice equivalent yield (REY) ranged between 21.9-30.4 t ha^{-1} at Mithapukur, Pirganj and Santhia sites. Lentil-T. Aus-T. Aman cropping pattern produced the maximum REY at Ishwardi site. Boro-Fallow-T. Aman cropping produced the lowest REY in all the locations ranging between 12.3-12.8 t ha^{-1}. The highest irrigation water productivity 3.5 kg/m^3 was found for Lentil-T. Aus-T. Aman cropping pattern followed by 3.3 kg/m^3 for Potato-Boro-T. Aman cropping pattern.

Plant Physiology Division

SUMMARY

Twenty-two experiments under six different projects have been carried out during 2019-20 in the Plant Physiology Division of BRRI. In salinity tolerance, around 607 rice germplasm and 335 advanced breeding lines were characterized, out of them 54 germplasm and 43 advance lines were found tolerant to moderately tolerant at seedling stage. For submergence tolerance, 120 germplasm and 12 advance breeding lines were tested, out of which two germplasm and one advance breeding line were selected. A total of 34 submergence tolerant germplasm were genotyped using *Sub1* gene specific molecular markers (RM8300, and GnS2) to identify new sources of non-*Sub1* submergence tolerance). Marker genotyping confirmed the presence of *Sub1A-1* allele in 16 germplasm but there is no evidence for the presence of any *Sub1* gene specific marker allele for 18 germplasm. Considering the marker allele evidences at DNA level, the following 18 germplasm could be the most valuable resources of non-*Sub1* submergence tolerance available for developing durable submergence tolerant variety. Under stagnant flooding tolerance, out of 49 genotypes, three advance breeding lines, three germplasm and BR23 showed better performance up to 60 cm stagnant water depth condition throughout life-cycle. In drought tolerance, 300 germplasm and 14 advance breeding lines were tested of which 18 germplasm and two advance breeding lines showed better performance. Under control drought condition in the rainout shelter, out of 27 germplasm BRRI Gene Bank Acc.1673 yielded highest followed by Acc.1630, 1684 and 1819 which had drought tolerance score remains 1 to 3 in the previous year field condition reveals that positive correlation with field performance.

Development of heat-tolerant BRRI dhan28 and BRRI dhan29 is underway through the introgression of high temperature spikelet fertility QTL (*qHTSF4.1*) by marker assisted backcrossing. From second backcross generation, one moderately heat tolerant (SES: 5) homozygous line of BRRI dhan28 background was selected for preliminary yield trial having yield advantage 0.5 tha^{-1} and finer grain (1000-grain weight: 19.62 gm) compared to parent BRRI dhan28. From third backcross generation, 12 introgression lines were selected having *qHTSF4.1*.

Some 280 rice genotypes were screened for seedling stage cold tolerance of which 37 germplasm, two advance breeding lines and BRRI dhan45 were selected as moderately tolerant. Out of 370 advance breeding lines, 63 genotypes showed cold tolerance at vegetative stage, but only 26 genotypes selected as moderately tolerant at reproductive phase. Eight BRRI varieties and three advance breeding lines were tested for reproductive stage cold tolerance in the Phytotron of which TP7594, TP16199, BRRI dhan67 and BRRI dhan45 showed moderate level of cold tolerance. Some 25 advanced breeding lines and four varieties were characterized in natural field condition where TP7594 and TP16199 were found as moderately cold tolerant at reproductive phase. Seven BRRI varieties were evaluated in natural field condition using five sets of seeding time starting from 1st November at 10 days interval. Results revealed that, to escape cold injury at reproductive phase BRRI dhan81 and BRRI dhan88 should be sown after 3rd week of November. BRRI dhan84 could be transplanted as like as BRRI dhan28. In contrast, early planted BRRI dhan89 and BRRI dhan58 could escape cold stress due to its longer growth duration. On the basis of relative photoperiod sensitivity among the 24 breeding lines, 10 lines showed relative photosensitivity (RPS) more than 83% and BR9178-7-2-4-4 showed strong photosensitivity as like as Nizersail. For improving yield potential of current high-yielding ideotype, morpho-physiological traits of 11 and 13 rice genotypes were characterized during Boro and T. Aman season respectively. BRRI dhan29 produced highest number of spikelet (48,298). The highest total dry matter (15 t ha^{-1}) was recorded from BR(BIO)9786-BC2-65-1-1. All the tested C3 and C4 species showed similar effective quantum yield of PSII under steady-state condition but Uri dhan showed significantly lower electron transport rate. For generation of male sterile rice line of two-line hybrid system a CRISPR/Cas9 targeting the *TMS5* gene in rice was designed, where a 19bp nucleotide sequence (5′-ACCGTCGAGGGCTACCCCG-3′) having a protospacer adjacent motif lying within the *TMS5* coding sequence (*LOC_Os02g12290.1*). The target site was ligated with an intermediate vector SK-gRNA sequence.

SALINITY TOLERANCE

Salinity tolerance of 3K Rice Genome Project Bangladeshi panel at seedling stage

A total of 186 Bangladeshi rice germplasm were sequenced by joint collaboration between IRRI and BGI under 3K Rice Genome Project. Out of 186 germplasm, 158 were tested for seedling stage salinity tolerance @ 12 dS m^{-1} in hydroponic culture. Four entries (UCP122, BORO394, PANKAIT31 and BRRI335) showed moderately tolerant (SES score ≤5) with shoot Na^+/K^+ ratio ranged from 1.01 to 1.61.

Exploring new sources of salinity tolerance from BRRI Gene Bank germplasm at the seedling stage

A total of 421 germplasm were screened for seedling stage salinity tolerance at 12 dS m^{-1} according to Gregorio *et. al.*, (1997) along with standard tolerant check IR58443-6B-10-3 and sensitive check IRRI154. Among them 50 germplasm (Acc. no.: 2289, 2292, 2293, 2351, 2439, 2440, 2444, 2445, 2502, 2508, 2513, 2514, 2520, 2521, 2522, 2530, 2531, 2532, 2533, 2536, 2538, 2539, 2541, 2542, 2543, 2549, 2550, 2557, 2561, 2564, 2565, 2570, 2571, 2572, 2573, 2577, 2578, 2582, 2589, 2590, 2600, 2601, 2631, 2649, 2665, 2669, 2670, 2681 and 2685) were found moderately tolerant (SES score ranged from 4.0-5.0).

Screening of advanced breeding lines for tolerance to salinity at the seedling stage

In total 335 advance lines from different sources (Plant Breeding, Biotechnology and Hybrid Rice Division) were screened along with standard tolerant check IR58443-6B-10-3 and sensitive check IRRI154 for seedling stage salinity tolerance at 14 dS m^{-1}. Among them 43 genotypes (BR11712-4R-232, BR11715-4R-186, BR11715-4R-196, BR11716-4R-108, BR11716-4R-129, BR47SC14-3-1-2, BR47SC14-3-6-1, BR9621-B-2-3-22, HR003, HR017, HR022, HR035, HR036, IR 104002-CMU 28-CMU 1-CMU-3, IR 126952-1699-41-8-10-8, IR 126952-1699-41-8-10-9, IR 126952-28-55-9-10-50-B, IR 126952-28-55-9-3-15-B, IR 126952-28-94-36-10-29-B, IR 126952-29-12-475-14-3, IR 126952-29-12-508-10-5, IR 126952-29-12-508-15-4, IR 126952-29-12-508-6-5, IR 126952-29-12-508-6-8, IR 126952-29-27-58-1-2, IR 126952-29-85-1-5-48-B, IR 126952-29-85-275-20-1, IR 126952-443-83-68-9-23-B, IR 126952-443-83-68-9-2-B, IR 126952-624-22-107-5-1, IR 126953-382-7-17-7-20-B, IR2860-33-CMU1-1-CMU2-AJYB, IR93915-82-CMU2-2-CMU3-AJYB, SVIN201, SVIN204, SVIN205, SVIN208, SVIN255, SVIN256, SVIN284, SVIN295, SVIN298, and SVIN381) were found tolerant to moderately tolerant (SES score ranged from 3.0 -5.0) at seedling stage.

SUBMERGENCE TOLERANCE

Identification of rice germplasm for two weeks of flash flood submergence

An experiment was conducted to identify tolerant germplasm under two weeks of complete submergence condition at the vegetative phase. A total of 120 germplasm and 3 advance lines were tested along with tolerant check BRRI dhan79 and FR13A and sensitive check BR5. Twenty-day-old seedlings were transplanted in a concrete submergence tank. Two weeks after transplanting plants were submerged completely at one-meter depth and kept in submerged condition for 14 days. After 21 days of receding of flood water survivability and SES score was taken.

Out of 120 germplasm only two germplasm (Acc. no. 1216 and 1301) was found moderately tolerant (SES score 5) having 77 percent survivability with non-elongating type. Advance line BR10230-1527-7B was found tolerant (SES score 1) having 100 percent survivability with non-elongating type.

Identification of advance breeding genotype for flash flood submergence

A total of nine rice genotypes from IRRI (IR118194-B-17-3, IR118194-B-10-1, IR118194-B-26-3, IR118194-B-3-3, IR118194-B-6-3, IR118194-B-6-2, IR118194-B-6-4, IR118194-B-12-1 and IR118194-B-51-1) along with FR13A, BRRI dhan79 and BR5 as check were tested for two weeks of complete submergence. Among the tested genotypes only two genotypes IR118194-B-17-3 and IR118194-B-3-3 were selected as their survivability were 55% and 48%, respectively, and SES score 7 and 9, respectively. The rest of the genotypes had 0-5% survivability with SES score 9.

From the results, rice genotypes IR118194-B-17-3 and IR118194-B-3-3 can be used for the varietal development programme.

Molecular characterization of submergence tolerant Bangladeshi rice germplasm by *Sub1* gene specific molecular markers.

A total of 34 submergence tolerant Bangladeshi rice germplasm along with three checks FR13A, BRRI dhan79 and BR5 were genotyped using *Sub1* gene specific SSR marker RM8300 (SC3), two STS markers Sub1BC2, ART5, and CAPS marker GnS2 to identify new sources of *Sub1* and non-*Sub1* submergence tolerant donors. PCR amplification with RM8300, Sub1BC2 and ART5 showed 16 germplasm having the expected marker allele similar to two tolerant checks FR13A and BRRI dhan79 but rest of the 18 germplasm having marker allele either the tolerant checks or the susceptible check BR5 or in combination of both**.** Genotyping with GnS2 primer after digestion with the restriction enzyme *AluI* having the allele about 242 bp from 16 germplasm (Pathor Nuti, Sada Danga Boro, Sada Boro, Moghal Sail (2), Madanga, Gasbar, Songa Tapi, Dholi Boro, Burma Biroin, Lal Balam, Soru Gati, Hogla Pata (3), Sonar Geye, Raja Sail, Jhur Dhan and Kartik Sail) including the two tolerant checks (FR13A and BRRI dhan79) indicating possesses *Sub1A-1* allele but rest 18 germplasm possesses different alleles (non-*Sub1*). All these might contain novel submergence tolerance genes (Fig. 1). In conclusion, genotypes having non-*Sub1* alleles could be used as a new submergence tolerance resources for developing durable submergence tolerant high-yielding varieties.

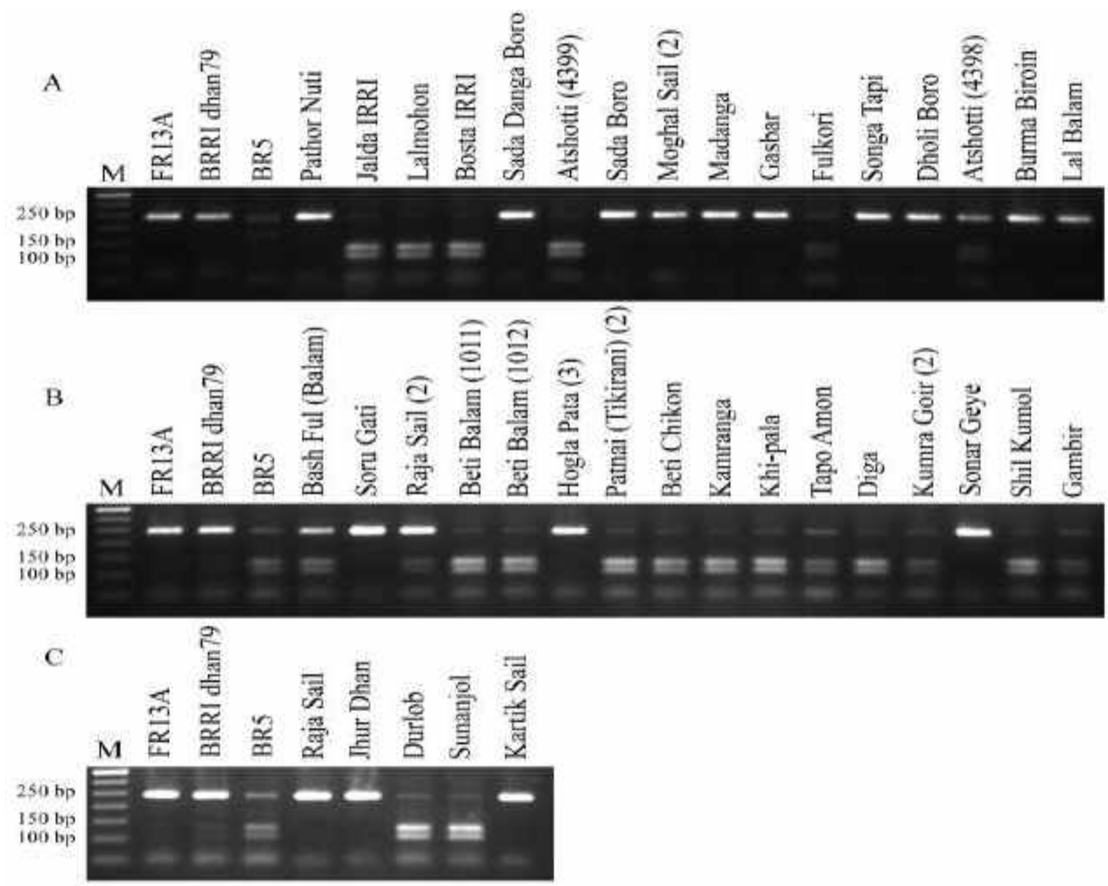


Fig. 1 (A-C). Genotyping of the selected germplasm using marker GnS2 after digestion with *AluI* restriction enzyme. FR13A, BRRI dhan79: tolerant checks; BR5: susceptible check; M: marker.

Screening of advance breeding lines, germpalsm and BRRI varieties under stagnant flooding (SF)

An experiment was conducted to identify tolerant rice genotypes at stagnant flooding condition. Twenty-seven germplasm, 16 advance line and six varieties were tested in this experiment. Twenty-five-day-old seedling was transplanted in concrete pool. Two weeks after transplanting water was added @ 5 cm each week till reached to a depth up to 60 cm for creating artificial stagnant condition for whole growth period. On the basis of tillering ability and survivability, three advance breeding lines (IR16F1081, BR9175-9-2-1-12-5 and IR13F458-5), three germplasm (Acc. no. 1061, Acc. No. 1007 and Acc. no. 3956) and a variety BR23 perform better at stagnant flood condition (Table 1).

DROUGHT TOLERANCE

Screening of rice germplasm for drought tolerance at reproductive phase in the T. Aman 2019 season

Three hundred rice germplasm collected from BRRI Gene bank along with check variety BRRI dhan56, BRRI dhan66, BRRI dhan71 and IR64 were evaluated during T. Aman season 2019 at BRRI farm, Gazipur following Field-managed screening protocol (IRRI, 2008). Thirty-day-old seedlings were transplanted at a spacing of 20 cm × 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 germplasm, 18 genotypes showed better performance in relation to yield under drought stress at reproductive phase.

Confirmation of performance for advance breeding lines under control drought condition at reproductive phase

Nine advance breeding lines along with check varieties BRRI dhan56, BRRI dhan71 and IR64 were evaluated in the Plant Physiology Net house shaded by polythene sheet at BRRI HQ, Gazipur during T. Aman 2019 season. Twenty-five-day-old seedlings were transplanted in drum (56 cm × 43 cm) containing 110 kg puddled soil in two sets where 1st set was grown in well-watered conditions and 2nd set under water 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 lifesaving 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 9 advance breeding lines, only one line (IR9880-Gaz-5-1-1-2) performed better and selected for further evaluation.

Evaluation of advance breeding lines of Deep Water Rice (DWR) under control drought stress at reproductive phase

Five advance breeding line of DWR along with check varieties BRRI dhan56, BRRI dhan66, BRRI dhan71 and IR64 were evaluated under control drought condition in the Plant Physiology Division at BRRI HQ, Gazipur during T. Aman season, 2019. The methodology was same as the previous experiment. Among the 5 advance breeding lines of DWR, only one line (BR10260-7-19-2B) showed better performance than the others under drought condition.

Evaluation of 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, 2019 to evaluate previously selected 27 germplasm with check variety BRRI dhan56, BRRI dhan66, BRRI dhan71 and IR64. Thirty day old seedlings were transplanted in puddled soil at a spacing of 20 cm × 20 cm. Standard agronomic management practices were followed. Weeds were controlled as and 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 27 germplasm, BRRI Gene Bank Acc. 1673 yielded highest followed by Acc. 1630, 1684 and 1819 which have drought tolerance score 1 to 3 in the previous year at field condition that reveals a positive correlation between rainout shelter and field.

Table 1. Tiller number and survivability of some rice genotypes under stagnant flooding.

Genotype	Tiller number per hill	Survivability (%)
IR16F1081	7	60
BR9175-9-2-1-12-5	7	80
IR13F458-5	7	90
Acc. No. 1061	15	90
Acc. 1007	14	90
Acc. No. 3956	14	90
BR23	9	100

HEAT TOLERANCE

Marker-assisted introgression of spikelet fertility QTL from N22 to two Bangladeshi mega rice varieties BRRI dhan28 and BRRI dhan29

Development of heat-tolerant BRRI dhan28 and BRRI dhan29 is underway through the introgression of high temperature spikelet fertility QTL (*qHTSF4.1*) by marker assisted backcrossing. Head to row selection were made during the T. Aman 2019 season and about 9 plants from 17 rows (BRRI dhan28 × N22) and eight plants from 24 rows (BRRI dhan29 × N22) were selected. During Boro 2019 season, again head to row was followed and one line from the BRRI dhan28 background was chosen for the final yield assessment. In turn, the other lines were taken for further improvement of homogeneity through head to row.

From second backcross generation, one moderately heat tolerant (SES: 5) homozygous line of BRRI dhan28 background was selected for preliminary yield trial having yield advantage 0.5 t ha^{-1} and finer grain (1000-grain weight: 19.62 gm) compared to parent BRRI dhan28. From third backcross generation, 12 introgression lines at BC_3F_5 were selected with reference to the respective recurrent parents (BRRI dhan28 and BRRI dhan29).

COLD TOLERANCE

Screening of rice genotypes for seedling stage cold tolerance

Some 250 BRRI Gene Bank germplasm, six BRRI varieties and 24 advance breeding lines 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 × 30 cm breadth × 2.5 cm height) filled with granular soil free from gravels and crop residue 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, 37 BRRI Gene Bank germplasm (Acc. no. 1929, 1941, 1958, 1966, 1993, 2035, 2038, 2048, 2066, 2067, 2077, 2078, 2079, 2083, 2092, 2095, 2096, 2097, 2098, 2099, 2100, 2186, 2187, 2188, 2189, 2190, 2216, 2220, 2221, 2225, 2227, 2234, 2236, 2238, 2245, 2246, 2249), two advanced breeding lines (TP7594, TP16199) and BRRI dhan45 showed moderately cold tolerant at seedling stage.

Screening of advance rice genotypes for cold tolerance under natural field condition

Some 370 advance breeding lines along with check varieties namely BRRI dhan69, Bhutani dhan and HbjB-VI were evaluated in natural field condition with collaboration of Plant Breeding Division. Forty-day-old seedlings were transplanted in the main field on 18 November with a view to expose reproductive phase at cold stress. Cold tolerance ability at vegetative and reproductive phases was measured visually on the basis of leaf discoloration and grain filling respectively. Out of 370 advanced breeding lines 63 rice genotypes showed cold tolerance at vegetative phase but only 26 genotypes were selected as moderately cold tolerant at reproductive phase. The selected genotypes are BR11894-R-R-R-345, BR11894-R-R-R-351, BR11894-R-R-R-365, BR11894-R-R-R-383, BR11894-R-R-R-384, BR11894-R-R-R-393, BR11894-R-R-R-395, BR11894-R-R-R-403, BR11894-R-R-R-410, BR11337-5R-20, BR11337-5R-34, BR11337-5R-96, BR11337-5R-135, BR11337-5R-147, BR11337-5R-188, BR11338-5R-9, BR11338-5R-12, BR11338-5R-28, BR11338-5R-36, BR11338-5R-39, BR11338-5R-41, BR11338-5R-50, BR11338-5R-58, BR11338-5R-73, BR11338-5R-104, BR11338-5R-109.

Screening of rice genotypes for reproductive phase cold tolerance in the Phytotron

Eight BRRI varieties and three advance rice genotypes (TP7594, TP16199 and TP27175) were tested along with BRRI dhan28, BRRI dhan36, Mineasahi and HbjB-VI as checks for reproductive phase cold tolerance in BRRI, Gazipur in the Phytotron facilities during May to September 2019. Twenty-day-old seedlings were transplanted in pots at the Plant Physiology Net house. Three pots of each genotype at reduction division stage were placed into a Phytotron for 30 days at 22-23 ^{0}C. On the other hand, a set of three pots of the same genotype were kept under natural condition serve as control. Only mother and primary tillers were kept for measuring data therefore rest of the tillers were removed. Pollen development was estimated using the auricle distance method. When each entry showed auricle distance between -3 to +10 cm then each pot was placed into Phytotron. The cold-treated pots were returned to the warmer Net house, where they remain until maturity. Data on growth duration, panicle exertion, spikelet sterility, plant height and last internode length of different rice genotypes were measured for evaluating their cold tolerance level. Spikelet sterility was calculated based on the percentage of the number of sterile spikelet relative to the number of total spikelet.

Results revealed growth duration was increased by 12 days in the cold treated BRRI dhan45, BRRI dhan67, BRRI dhan84, BRRI dhan88, TP7595, TP16199 and BRRI hybrid dhan5 which was comparable to BRRI dhan28 and BRRI dhan36, but significantly higher than the tolerant check varieties Mineasahi and HbjB-VI. The duration was increased for 14 days of the BRRI dhan58, BRRI dhan81 and TP25175 but 15 days for BRRI dhan89 (Table 2).

Cold treatment reduced plant height by around 15 cm of BRRI dhan67, TP7594 and TP16199 which was significantly lower than BRRI dhan28 and BRRI dhan36, but higher than the tolerant checks. Plant height reduction of other genotypes was 18-20 cm which was comparable to BRRI dhan28 and BRRI dhan36. However, it was 17 cm for BRRI hybrid dhan5 (Table 2).

Cold treatment also affects panicle exertion, in TP7594 (95%), BRRI dhan67 (90%) and TP16199 (90%) was statistically similar to HbjB-VI (95%) and Mineasah (98%). On the other hand, panicle exertion of BRRI dhan84 (85%), BRRI dhan45 (80%), BRRI hybrid dhan5 (75%) and BRRI dhan88 (75%) was comparable to BRRI dhan28 (80%) and BRRI dhan36 (75%), but significantly lower than tolerant check varieties. Cold treatment caused 70% panicle exertion in TP25175, BRRI dhan81 and BRRI dhan89 (Table 2).

Cold treatment caused a significant increase of spikelet sterility in all the tested genotypes than the tolerant checks. Cold treatment increases sterility of BRRI dhan67 (48.3%), TP7594 (51.5%), TP16199 (53.3%) and BRRI dhan45 (55.4%) lower than BRRI dhan28 (65.7%) and BRRI dhan36 (73.2%) (Table 2).

Table 2. Effect of cold treatment on the duration and phenotypes of rice genotypes evaluated in the Phytotron at reduction division stage.

Genotype	Growth duration (day)		Plant height (cm)		Panicle exertion (%)		Sterility (%)	
	Cold treat	Control	Cold treat	Control	Cold treat	Control	Cold treat	Control
TP7594	143	131	89.6	103.4	95	100	51.5	26.6
TP16199	147	135	85.3	100.5	90	100	53.3	27.4
TP25175	149	135	74.3	93.2	70	100	75.2	27.5
BRRI dhan45	142	130	75.6	93.6	80	100	55.4	27.7
BRRI dhan58	149	135	77.8	97.4	75	100	68.2	28.1
BRRI dhan67	147	135	82.7	98.3	90	100	48.3	23.8
BRRI dhan81	144	130	76.6	96.6	70	100	79.4	25.3
BRRI dhan84	143	131	81.2	99.4	85	100	60.6	24.5
BRRI dhan88	143	131	79.5	97.3	75	100	60.7	23.4
BRRI dhan89	161	146	78. 3	98.2	70	100	82.5	38.2
BRRI hybrid dhan5	152	140	81. 3	98.2	75	100	60.5	40.2
Mineasahi (Tol ck)	130	125	95.6	105.8	98	100	32.6	29.6
HbjB-VI (Tol ck)	143	135	105.7	116.2	95	100	32.9	26.3
BRRI dhan28	143	130	79.4	98.3	80	100	65.7	22.7
BRRI dhan36	148	135	76.7	96.5	75	100	73.2	24.5
LSD $_{5\%}$ Genotype (G)	2.73		6.45		8.12		11.32	
LSD$_{5\%}$ Cold treat (T)	1.34		2.62		4.85		14.68	
LSD$_{5\%}$ for G*T	3.92		9.12		12.42		17.65	

Considering growth duration, plant height, panicle exertion and especially spikelet sterility TP7594, TP16199, BRRI dhan67 and BRRI dhan45 had better cold tolerance than BRRI dhan28 and BRRI dhan36. These findings should be reinvestigated as cold treatment in the Phytotron chamber was not homogenous in all areas.

Characterization and evaluation of some selected rice genotypes for cold tolerance

Some 25 advance breeding lines, an exotic variety Koshihikari, three BRRI varieties (BRRI hybrid dhan5, BRRI dhan45 and BRRI dhan67) along with four check varieties namely BRRI dhan28, BRRI dhan36, Mineasahi and HbjB-VI were evaluated in natural field condition in the Boro season. There were three seeding dates 15 October, 1 November and 15 November (control). Thirty-day-old seedlings were transplanted in the main field. Early sowing (15 October and 1 November) was done with a view to expose reproductive phase at cold stress.

All rice genotypes experienced cold stress in early planted crops. Natural cold stress at reproductive phase changed different physiological parameters. It caused longer growth duration, shorter last internode length, poor panicle exertion, higher percentage of sterility and shorter plant height over control treatment (15 November sowing) in all rice genotypes. Growth duration was increased by 14 days in 15 October seeded BRRI dhan45, TP7595 and TP16199 which was statistically similar to BRRI dhan28 and BRRI dhan36, but significantly higher than tolerant the check varieties Mineasahi and HbjB-VI. In first set, plant height reduced by around 10 cm in BRRI dhan67, TP7594 and TP16199 which were significantly lower than BRRI dhan28, but higher than the tolerant checks. Plant height reduction of other genotypes was ranged from 15-20 cm which was comparable to BRRI dhan36. Early sowing caused significantly higher spikelet sterility in all tested genotypes over tolerant checks. Sterility of TP7594 (45.2%), TP16199 (45.8%) BRRI dhan67 (58.4%), and BRRI dhan45 (55.4%) was lower than BRRI dhan28 (62.4%) and BRRI dhan36 (63.5%). Only two advance rice genotypes TP7594 and TP16199 were found as moderately cold tolerant at reproductive phase. However, BRRI dhan45 and BRRI dhan67 showed moderately susceptible reaction.

Optimization of sowing and planting times of Boro varieties for minimizing cold injury

Seven BRRI varieties (BRRI dhan28, BRRI dhan36, BRRI dhan58, BRRI dhan81, BRRI dhan84, BRRI dhan88 and BRRI dhan89) were evaluated in natural field condition. There were five sets of seeding started from 1 November at 10-days interval. Thirty-five-day-old seedlings were transplanted in the main field on 6 December, 17 December, 27 December, 6 January and 16 January. Data on tillering pattern, plant height, first heading, flowering, growth duration, panicle exertion, spikelet degeneration, yield, yield components, sterility and harvest index were recorded.

Tiller per hill increased significantly in all the varieties at early planted rice than the late planted one. Plant height of all rice varieties except BRRI dhan89 was reduced significantly in first set (transplanted on 6 December) than the other sets of planting. It took longer flowering period (first heading to 50% flowering) at first set of planting than the other sets. Irrespective of rice varieties poor panicle exertion and spikelet degeneration were recorded in the first set of planting. BRRI dhan81 had incomplete panicle exertion and spikelet degeneration up to transplanting on 27 December (3rd set), while it was 17 December (2nd set) for BRRI dhan28, BRRI dhan36, BRRI dhan58, BRRI dhan84 and BRRI dhan88. However, a little bit spikelet degeneration at panicle tip was recorded in BRRI dhan58 in all five sets of planting. Irrespective of planting time BRRI dhan89 had higher grain yield with longer growth duration than the other tested varieties. BRRI dhan81 had significantly higher spikelet sterility than BRRI dhan28 and BRRI dhan36 in first three sets of planting indicating its reproductive phase cold susceptibility. BRRI dhan89 and BRRI dhan58 could escape cold stress in early transplanting (6 December) due to its longer growth duration in Gazipur condition. However, BRRI dhan89 had slightly higher spikelet sterility in fifth set of planting than the other tested varieties. Spikelet sterility of BRRI dhan88 was comparable to BRRI dhan28 and BRRI dhan36 in all sets of planting except the first set indicating its reproductive phase cold susceptibility. Spikelet sterility of BRRI dhan84 in earlier sets of planting was comparable to BRRI dhan28 and BRRI dhan36.

Results revealed that none of the varieties were cold tolerant at reproductive phase. For escaping cold stress two short duration varieties BRRI dhan81and BRRI dhan88 should be transplanted a week later than BRRI dhan28. Those varieties should not be recommended in cold prone areas of Bangladesh where farmers transplanted Boro rice earlier. In those areas BRRI dhan84 could be a supplemental variety of BRRI dhan28.

YIELD POTENTIAL

Response to photoperiod of some rice genotypes

An experiment was conducted to know the response to photoperiod. Twenty-four advance breeding lines were tested along with Bina dhan13, Kalizira, BRRI dhan34, Kataribhog, Radhunipagol, BRRI dhan37, Nizersail (strongly sensitive) and BR11 (moderately sensitive) used as check. Sprouted seeds of all genotypes were sown and 10-hour photoperiodic treatment was started from seed sowing. One set were grown at natural day length. Observations were made on dates of seeding and heading and basic vegetative phase (BVP), photoperiod sensitive phase (PSP) relative photoperiod sensitivity (RPS) were determined. On the basis of relative photoperiod sensitivity among the twenty-four breeding lines 10 lines showed relative photoperiod sensitivity (RPS) more than 83% and BR9178-7-2-4-4 showed strong photosensitivity as like as Nizersail.

Physiological characterization for morpho-physiological traits of rice for improving yield potential of current high-yielding ideotype

Semi-dwarf1(*sd1*) gene for HYV development and heterosis in hybrid made great breakthrough in rice production in the past centuries. Since then none of the concept such as New Plant Type (NPT) and MAS for pyramiding of major effect QTLs/Genes able to produce desirable ideotype expected by researchers for boosting yields at least 20%. Therefore, the current research aimed to explore the desirable physiology through trait discovery required to maintain good balance between source-sink relationships for boosting future rice yield potential through ideotypic approach. Two experiment conducted during Boro (2018-19) and T. Aman (2019) season considering 11 and 13 genotypes respectively. In Boro season, BRRI dhan29 produced 48,298 spike lets per square meter that remain within the reference range (45,000-55,000). But the highest total dry matter produced by BR(BIO)9786-BC2-65-1-1 and BRRI dhan29 about 15 t ha^{-1}, which is quite lower than targeted range (18-20 t ha^{-1})). BRRI dhan47, BRRI dhan86, BRRI dhan29 and Bash Full (3954) showed better top 3-leaf character in the Boro season (Fig. 2). However, during T. Aman 2019 season, Fatema dhan, BRRI dhan79, BRRI dhan87, BRRI dhan47 and BRRI dhan29 showed better top 3-leaf character (Fig. 3) but flag leaf photosynthesis was found significantly higher in BRRI dhan28, CN6 and Fatema dhan (Fig. 4).

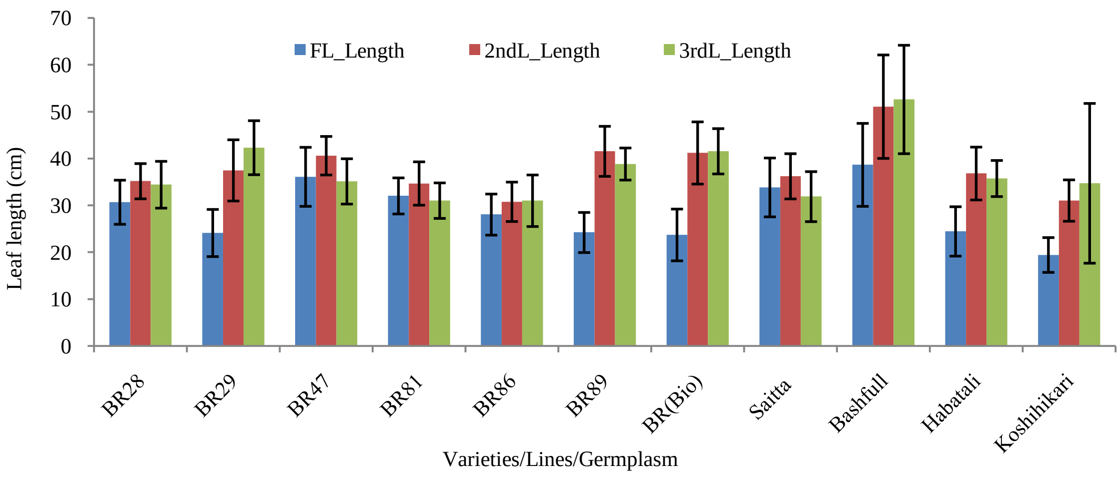


Fig. 2. Top 3-leaf length of 11 variety/line/germplasm tested in the Boro 2018-19 season. Each bar represents mean±SD (n=8).

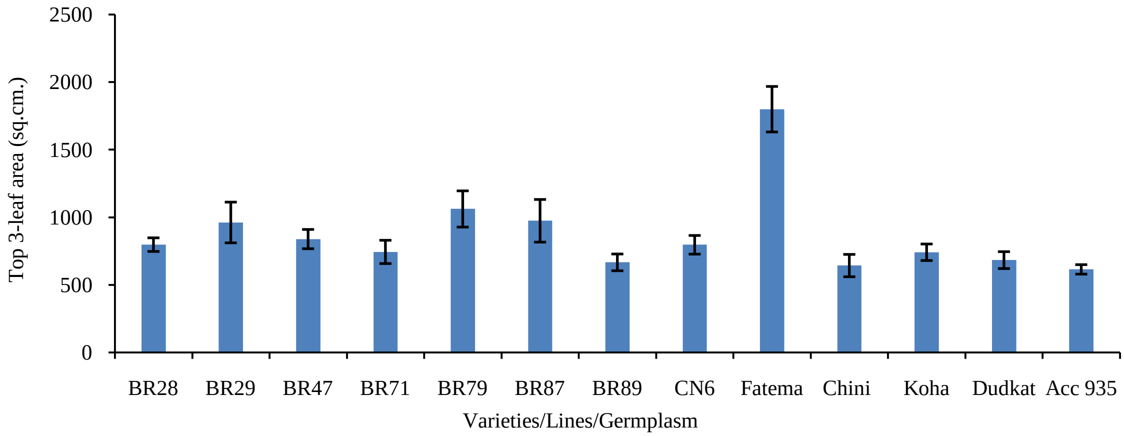


Fig. 3. Top 3-leaf area of 13 variety/germplasm tested in the T. Aman 2019 season. Each bar represents mean±SD (n=8).

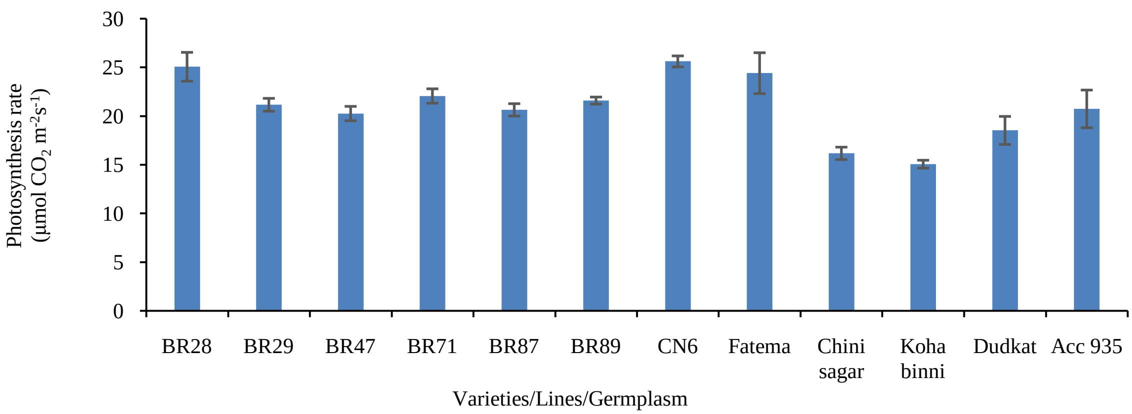


Fig. 4. Flag leaf photosynthesis of 12 variety/line/germplasm tested in the T. Aman 2019 season. Each bar represents mean±SD (n=9).

Investigation of photosynthetic capacities of C3 and C4 species

Most of the C4 species adapted in the arid or semi-arid environments. However, C4-*Echinochloa glabrescens* (Shayma or Barnyard grass), which is an aggressive weed of paddy rice but have operated the C4 pathway in waterlogged conditions for a significant period of time. Uri dhan *(Porteresia coarctata)* is another interesting species resembles C3-rice *(Oryza sativa)*, but differs in the nature of embryo and leaf anatomy. Uri dhan is naturally grown in the saline estuaries of the coastal regions of Bangladesh, highly salt tolerant, and is seen as a possibly important source of salt tolerance genes. Therefore, all these species grown in waterlogged, nutrient-replete conditions provided an opportunity to investigate the differences of photosynthetic capacities. Results revealed that Shayma maintained higher net CO_2 assimilation rate (Fig. 5) but maintained significantly lower intercellular CO_2 concentration (Fig. 7). Again, Shayma maintain lower stomatal conductance (Fig. 6) than C3 species (rice and Uri dhan), and have lower rates of water loss per unit of carbon fixed and higher water-use efficiencies (Fig. 8). Interestingly, Uri dhan showed intermediate values for net assimilation rate, intercellular CO_2 concentration and stomatal conductance but have higher transpiration rate compared to rice (C3) and Shayma (C4) (Fig. 8). In terms of photosynthetic efficiencies, all tested species showed similar effective quantum yield of PSII (Fig. 9) under steady-state condition but Uri dhan showed significantly lower electron transport rate (ETR) (Fig. 10).

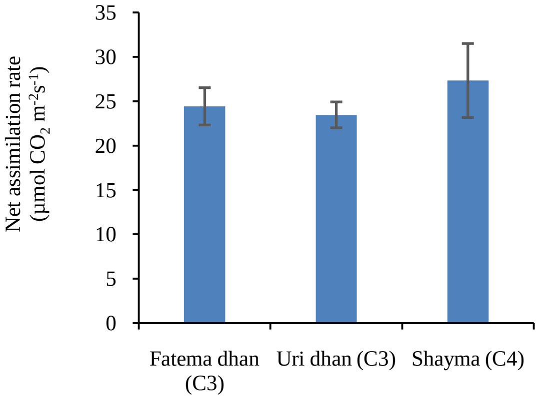


Fig. 5. Flag leaf photosynthesis of C3 and C4 species. Each bar represents mean±SD (n=9).

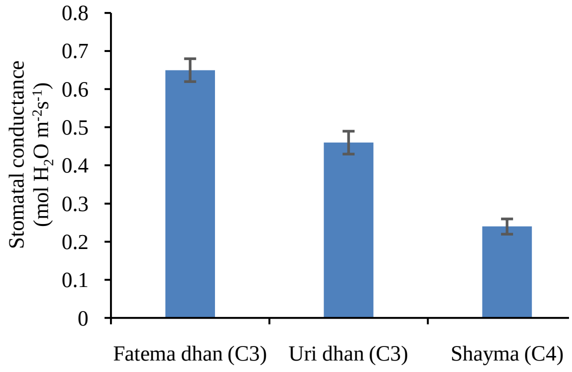


Fig. 6. Stomatal conductances of C3 and C4 species. Each bar represents mean±SD (n=9).

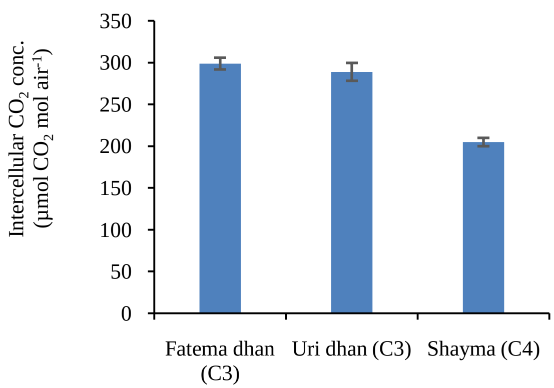


Fig. 7. Intercullular CO_2 concentration of C3 and C4 species. Each bar represents mean±SD (n=9).

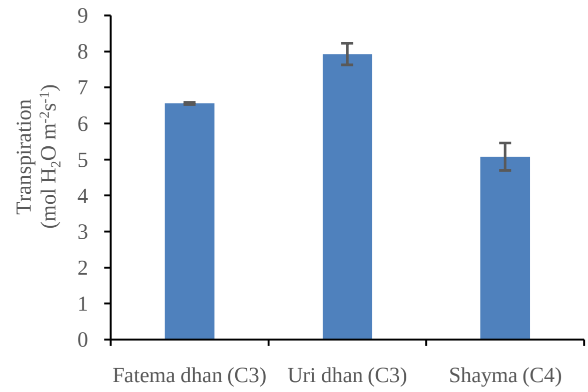


Fig. 8. Transpiration of C3 and C4 species. Each bar represents mean±SD (n=9).

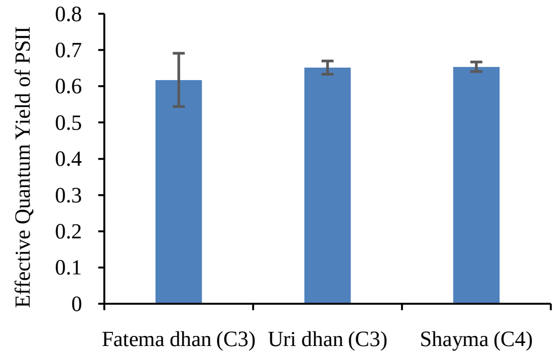


Fig. 9. Effective quantum yield of PSII or light adapted Y(II) of C3 and C4 species. Each bar represents mean±SD (n=9).

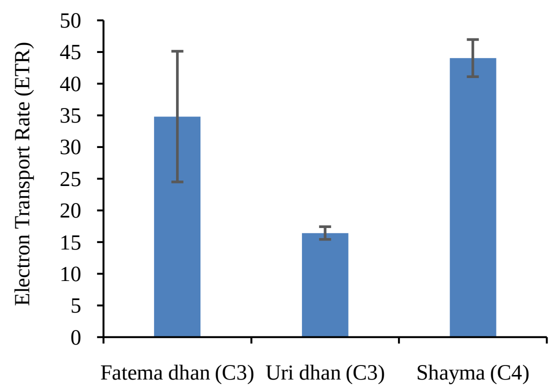


Fig. 10. Electron transport rate (ETR) of C3 and C4 species. Each bar represents mean±SD (n=9).

Effect of seedling age on yield and duration of some BRRI Boro varieties

An experiment was conducted to find out the effect of seedling age on yield and field duration of some Boro rice. Three Boro rice varieties (BRRI dhan81, BRRI dhan88 and BRRI dhan89) were evaluated. Seeds were sown on 17 November 2019. Four different aged (30, 40, 50 and 60 days) seedlings were transplanted into the main field. The short duration variety BRRI dhan81 and BRRI dhan88 produced higher yield when 40-day-old seedlings were used followed by 30-day-old seedling. Over aged seedlings (50 and 60 days) gave lower yield (Fig. 11). On the other hand, BRRI dhan89 had the highest yield when 30-day-old seeding were transplanted. Yield was decreased sharply when aged seedling was used. The decrease in yield with aged seedling can be explained by the lower field duration. Younger seedling got maximum time to produce its dry matter which ultimately contributed to yield. Older seedlings (50 and 60 days) got less time to produce maximum dry matter for higher yield (Fig.11). Irrespective of seedling age there was no significant difference in growth duration for short duration variety. On the other hand, BRRI dhan89 had the higher growth duration for the youngest (30-day-old) seedlings and gradually declined of growth duration for 40, 50 and 60-day-old seedlings.

Generation of male sterile rice line for two-line hybrid system by editing *TMS5* gene using CRISPR/Cas9 system

The two-line hybrid 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). 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 nucleotide sequence (5′-ACCGTCGAGGGCTACCCCG-3′) having a protospacer adjacent motif lying within the *TMS5* coding sequence (*LOC_Os02g12290.1*). The target site was ligated with an intermediate vector SK-gRNA (Fig. 12). Final vector construction will be completed by ligation of the target with SK-gRNA into pC1300-Cas9 vector.

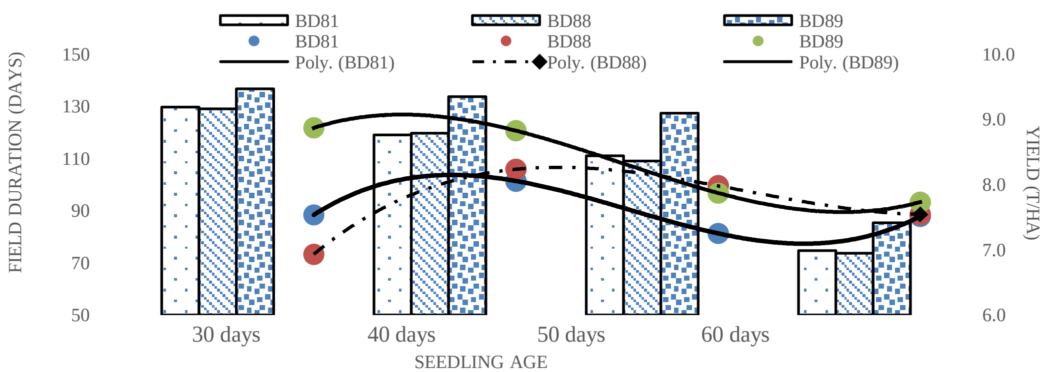


Fig. 11. Yield performance and field duration of three Boro varieties using different aged seedling (Bar represent field duration and line shows yield data fitted with 3rd order polynomial model (secondary axis).

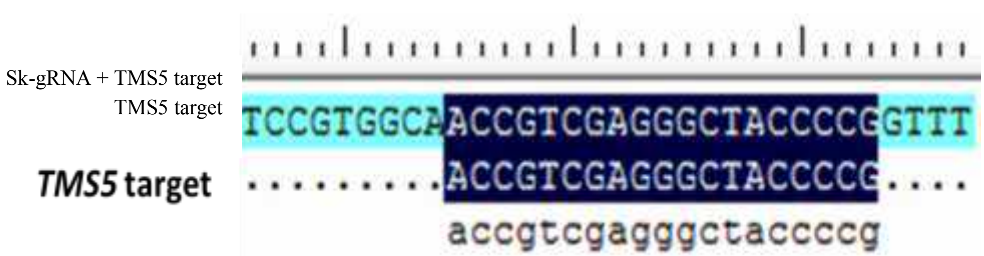


Fig. 12. Alignment of the target site of *TMS5* and the sequence of SK-gRNA ligated with the target site of *TMS5*.

Entomology Division

SUMMARY

Insect incidence was the highest in grass fallow habitat followed by seedbed and rice ratoon during Aus season. The trend was changed in T. Aman and Boro season. Seedbed and irrigated rice was more harbored of insect pests in this two season respectively. Considering season, higher incidences of insect pests were found in Aus and T. Aman seasons than Boro season. Irrespective of different natural enemies more incidences were observed in rice bunds, seed bed grass fallow during Aus, Aman and Boro season respectively.

Highest number of insect pests were caught in the light trap at BRRI RS, Rajshahi followed by BRRI RS, Barishal, Habiganj and BRRI HQ, Gazipur but natural enemies were found highest in BRRI RS Habiganj followed by BRRI RS Barishal, Rajshahi and BRRI HQ. Immediate after sunset to first three hours showed the highest number of insects trapped in light and thereafter declined.

AEZ survey revealed that insect pests were below the economic threshold level (ETL) during Aus and T. Aman 2019 except yellow stem borer (YSB) and leafroller (LR) in some areas of Rangpur region. The highest number of YSB was found in Rangpur (7.30/20 sweep) followed by Barishal (3.42) and Cumilla (1.63/20 sweep). Same trend was found in LR population comprising the highest at Rangpur (3.86/20 sweep) followed by Barishal (3.42/20 sweep) and Cumilla (1.28/20 sweep).

The outbreak insect in Teknaf, Cox's Bazar was collected and identified as a species of spotted coffee grasshopper, *Aularches miliaris* (Linn).

Natural enemies destroyed almost all BPH released in field and reduced 95% and 80% pest population in Satkhira and Patuakhali respectively. Higher arthropod species diversity was found in Chattogram due to very higher diversity index than Satkhira and Patuakhali irrespective of crop growth stage. Thus, higher habitat heterogeneity of Chattogram induces the higher number of arthropods in crop field.

The highest natural enemies percent RH egg parasitism by *Trichogramma zahiri*, *YSB egg parasitism by T. chilonis* and *Telenomous rowani* and BPH egg parasitism by *Anagrass* sp. were observed in rice field with nectar-rich flowering plants on bunds. However, least natural enemies and parasitism were found in rice field where three times insecticides were applied. Moreover, there was no yield reduction observed in rice field surrounding by flowering plants on bunds compared with 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 crops.

Sex pheromone showed significant reduction of leafroller in rice field indicating a promising tool for pest management in rice field.

A total of 290 advanced breeding lines and INGER IRBPHN materials were evaluated at greenhouse of Entomology Division. Among them nine, six and four lines were found moderately susceptible (score 5) to BPH, WBPH and GLH respectively. Five hundred rice germplasms were also evaluated against BPH and 31 were found moderately susceptible (score 5) to BPH.

SURVEY AND MONITORING OF RICE ARTHROPODS

Pest and natural enemy incidence at BRRI farm, Gazipur

Rice insect pests, their natural enemies and crop damage intensities in six habitats (seedbed, rice ratoon, grass fallow, irrigated rice, rice bund and upland rice) were monitored weekly by 100 complete sweeps from each habitat at BRRI research farm, Gazipur. The overall insect pest incidence was low in all the habitats and season except grasshopper (GH). Grasshoppers, green leafhopper (GLH) and white leafhopper (WLH) were the most abundant pests in all habitat and seasons. Grasshopper was found the highest in rice bund (20.98/20 sweep) during Aus season followed by grass fallow (9.17) and seedbed (6.25). But the trend was changed in Aman and Boro season and found highest in seed bed and irrigated rice (29.37 and 4.29/20 sweep respectively. No definite trend was observed in case of incidences of different insects in various seasons. Total insect incidence was the highest in grass fallow habitat followed by seedbed and rice ratoon during Aus season the trend was changed in Aman and Boro season. Seedbed and irrigated rice was more harbored of insect pests in this two season respectively. Again, considering season, higher incidences of insect pests were found in Aus and T. Aman seasons followed by Boro season. Spider (SPD), damsel fly (Dam. fly), ladybird beetle (LBB) and carabid beetle (CDB) were the dominant predators in all the seasons and habitats. Spider found highest in irrigated rice of Aman and Boro season followed by rice bund of Aus season. LBB found the highest in grass fallow habitat in Boro season whereas Dam. fly on rice bunds in the same season. Irrespective of different natural enemies more incidences were observed in rice bunds, seed bed grass fallow during Aus, T. Aman and Boro season respectively. Visual counting of randomly selected 20 hills showed that the population and the damage done by insect pests were below the ETL in all the three rice seasons.

PI: Sadia Afrin, **PL:** Sheikh Shamiul Haque

Incidence of insect pest and natural enemies in light trap

Rice insect pests and their natural enemies were monitored throughout the year by Pennsylvanian light trap from dusk to dawn throughout the year at BRRI headquarter, Gazipur and six regional stations of BRRI. The highest number of insect pests were found at BRRI RS, Rajshahi followed by BRRI RS, Barishal, Habiganj and BRRI HQ, Gazipur but natural enemies were found the highest in BRRI RS, Habiganj followed by BRRI RS, Barishal, Rajshahi and BRRI HQ (Fig. 1). In contrast, incidence of both insect pests and natural enemies was comparatively lower in BRRI RS, Rangpur, Cumilla and Sonagazi.

The abundance of BPH, WBPH, YSB and GLH was observed almost in all the locations (Fig. 2). The highest number of BPH was observed in November at Gazipur and Rangpur. But that was highest in December at Rajshahi. The highest peak of WBPH was observed in October at Gazipur but the peak was observed in November at Barishal and Rajshahi (Fig. 2). Another small peak was found in May at Gazipur. The highest peak of YSB was observed at Rajshahi in May, followed by Barishal and Sonagazi in November (Fig. 2).

Another small peak observed in August at Sonagazi. The highest peak of GLH was found in November at Sonagazi followed by Barishal, Gazipur, Rangpur and Rajshahi (Fig. 2).

Among the natural enemies major pea of carabid beetle (CDB) was found in the months of December at Habiganj followed by Barishal. Peak of CDB also observed in November at Gazipur and Barishal (Fig. 3). Several peaks of staphylinid beetle (STPD) were observed in the same locations of Barishal. In Barishal, the highest peaks were found in March and October. Small peaks of STPD were found in March at Gazipur followed by December in Sonagazi and Rajshahi (Fig.3). One major peak of green mirid bug (GMB) was observed in November at Habiganj followed by Rajshahi and Gazipur. Another small peak was observed in January at Rangpur (Fig. 3).

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PL: Sheikh Shamiul Haque

Impact of lighting period on the trapping of insect pests and natural enemies

The experiment was conducted at Gazipur and Barishal to identify the impact of lighting period on the incidence of insects in light trap. The insects which were caught in light trap were collected at every hour intervals after sunset and continued up to 11:00 PM. Immediate after sunset to fist three hours showed the highest number of insects trapped in light and thereafter declined (Fig. 4). Both insect pest and natural enemies showed the similar trends during the tested hours. However, the catches of hoppers and moths showed different trends at different time intervals after sun set. Different hoppers (BPH, WBPH and GLH) showed the decline trend with increasing the night time, but moth (Stem borer and leaffolder) showed opposite direction to hoppers (Fig. 5). It indicates that moths attract light at late night. More studies are required to identify the best time to capture the highest number insect using light trap.

PI: Md. Panna Ali, **CI:** Mir Md. Moniruzzaman Kabir, PL: Sheikh Shamiul Haque

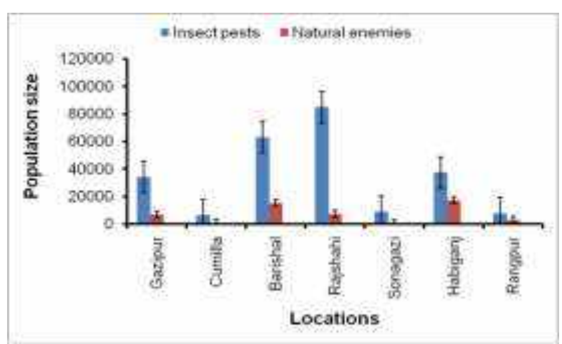

Fig 1.Total population of insect pests and natural enemies at BRRI HQ, Gazipur and six regional stations (RS).

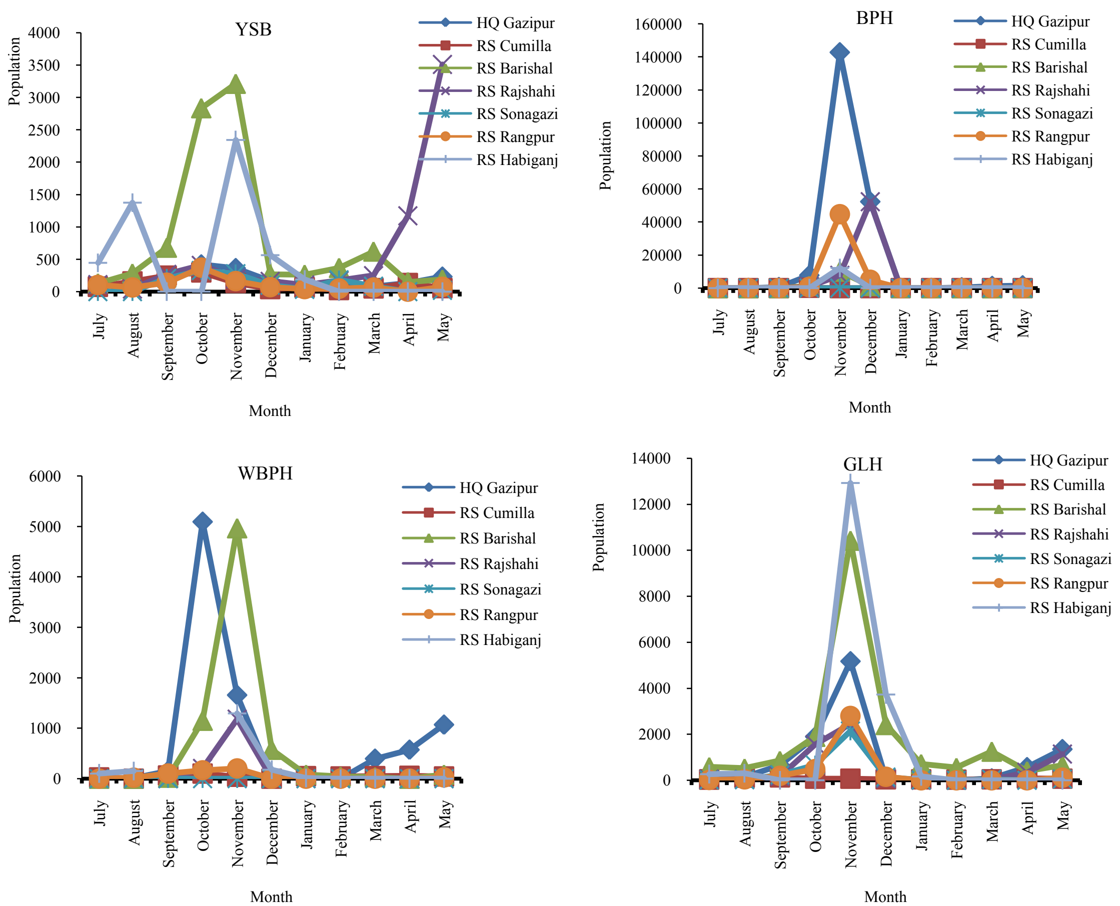

Fig. 2. Incidence pattern of major insect pests in light trap, BRRI HQ, Gazipur and regional stations during July 2019-June 2020.

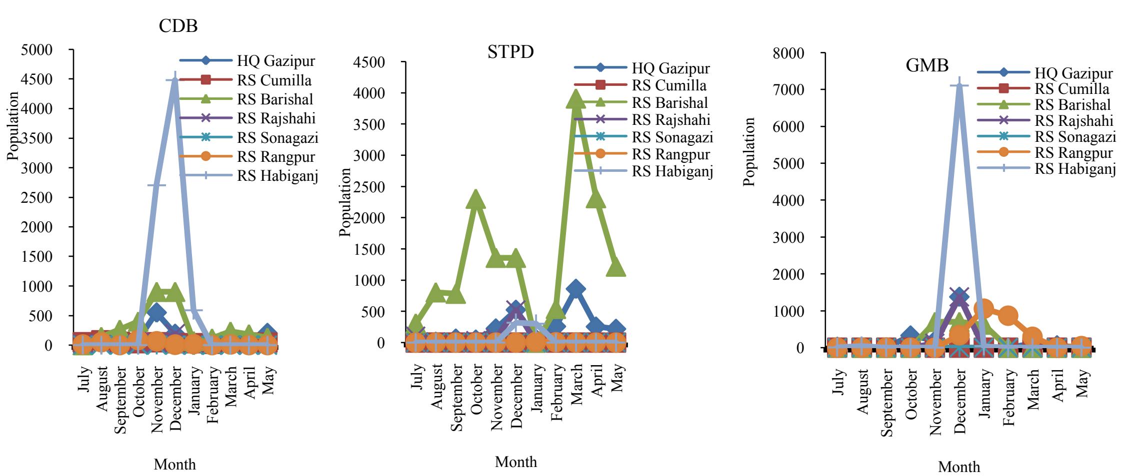

Fig. 3. Incidence pattern of natural enemies of rice insect pest in light trap, BRRI, Gazipur and regional stations, during July 19-June 20.

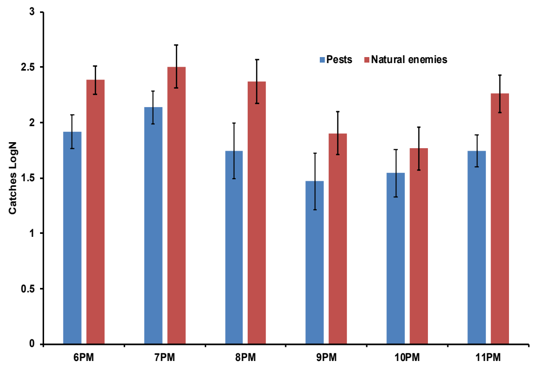

Fig. 4. Catches of pests and natural enemies in light trap at different time intervals at BRRI research farm during July19-June 20. Note: Bar represents the mean value of one-week data. Error bar indicates the standard error.

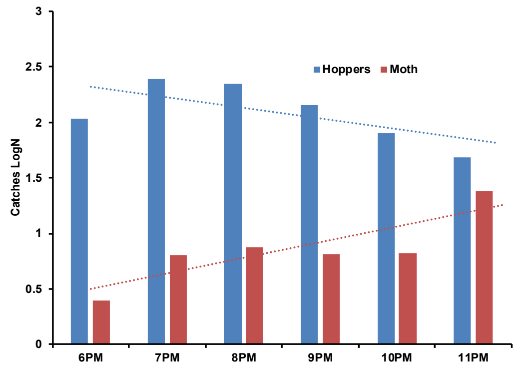

Fig. 5. Catches of hoppers and moths in light trap at different time interval after sunset at BRRI research farm during July19-June 20. Note: Bar represents the mean value of one-week catches. Error bar indicates the standard error.

Survey of rice insect pests in selected Agro-ecological zones (AEZs) of Bangladesh

The insect pest population, their damage intensities and abundance of the natural enemies were surveyed during Aus and T. Aman 2019 in transplanted rice field of Barishal, Rajshahi, Sirajganj, Cumilla, Habiganj and Rangpur region to find out the incidence patterns of major insect pests and their natural enemies in different AEZs of Bangladesh and to create a data base of insect pests and natural enemies. Unfortunately data were not collected during Boro season due to lock down situation all over Bangladesh for COVID 19. Insect pests were below the economic threshold level (ETL) during Aus 2019 except YSB and LR in some areas of Rangpur region. The highest number of yellow stem borer (YSB) was found in Rangpur (7.30/20 sweep) followed by Barishal (3.42) and Cumilla (1.63/20 sweep). Leafroller (LR) population was found the highest at Rangpur (3.86/20sweep) followed by Barishal (3.42/20sweep) and Cumilla (1.28/20 sweep). Abundance of GLH was the found highest in Cumilla (4.97/20 sweep) followed by Barishal (2.31/20 sweep) and Rajshahi (1.60/20 sweep). Irrespective of season and locations spider populations was found higher than the other natural enemies. The highest spider (7.62/20 sweep) was found in Rangpur followed by Cumilla (6.09/20 sweep), Rajshahi (5.92/20 sweep) and Sirajganj (5.21/20 sweep). In T. Aman season, YSB population was found the highest in Barishal (4.19/20 sweep) followed by Rajshahi (2.84/20 sweep) and Cumilla (2.70/20 sweep). But LR population found highest in Cumilla (3.13/20 sweep) followed by Rangpur (2.80/20 sweep) and Barishal (2.64/20 sweep).

PI: Md. Nazmul Bari, **CI:** All entomologist, **PL**: Sheikh Shamiul Haque

STUDIES ON RICE INSECT PEST AND NATURAL ENEMY BIO-ECOLOGY

Collection and identification of outbreak of grasshopper from Teknaf, Cox's Bazar

A grasshopper like insect was first seen on 18 April 2020 in about 15 decimal of homestead forest of Uttar Lambari village Teknaf upazila, Cox's Bazar (Fig. 6). This outbreak created a panic among the local people since the insect was confused with concurrent outbreak of invasive desert locust in two neighbouring countries like India and Pakistan. We collected samples from Uttar Lambari village (20.874692º E, 92.265º N) on 2 May 2020 and reared in laboratory upto adulthoods. Cytochrome c oxidase subunit I (COI) gene has been widely utilized to identify unknown species. We sequenced the COI gene of the collected samples and constructed phylogenetic tree. The sample sequence showed 87.58% similarity with known species of spotted coffee grasshopper, *Aularches miliaris* that was reported in India. Based on morphology and current sequence data of COI gene it can be said that recent outbreak of grasshopper like insect is *A. miliaris* (Linn.). The outbreak of insect was not new in Bangladesh. Similar species, *A. miliaris* was previously recorded by Alam (1967) in the then East Pakistan. In addition, a similar species was also observed in Bogura. But later it was identified as *A. punctatus* Drury (Khan and Mannan 1990). However the insect infestation of that area (Uttar Lambari) was successfully controlled by spraying insecticides through local DAE initiatives. So, this local problem was not related to the recent outbreak of destructive desert locust in some parts of India and Pakistan. We also tested the consumption rate of collected insects. Each insect (nymph) can consume 1.12 cm^2 area of mango leaf/day.

PI Md. Panna Ali, **CI:** Md. Nazmul Bari and **PL**: Sheikh Shamiul Haque

Landscape structure influences the natural pest control services in rice field

Ten field experiments were conducted at Patuakhali and Satkhira during Boro 2019-20 to quantify the pest control services in rice field. Ten gravid female BPH were released in nine hills and confined with a fine mesh nylon net cage (Fig. 1). Four cages were used in this experiments. Another 40 gravid female BPH were also released in other four open places in the same field (without caging) for exposed to natural enemies. Fields were monitored every alternative day up to crop harvest to check either any natural enemies enter into cage or not. Results showed that significant number of BPH developed in cage which can cause damage to grain yield (Fig. 7). Natural enemies destroyed almost all BPH released in field and reduced 95% and 80% pest population in Satkhira and Patuakhali respectively (Fig. 7).

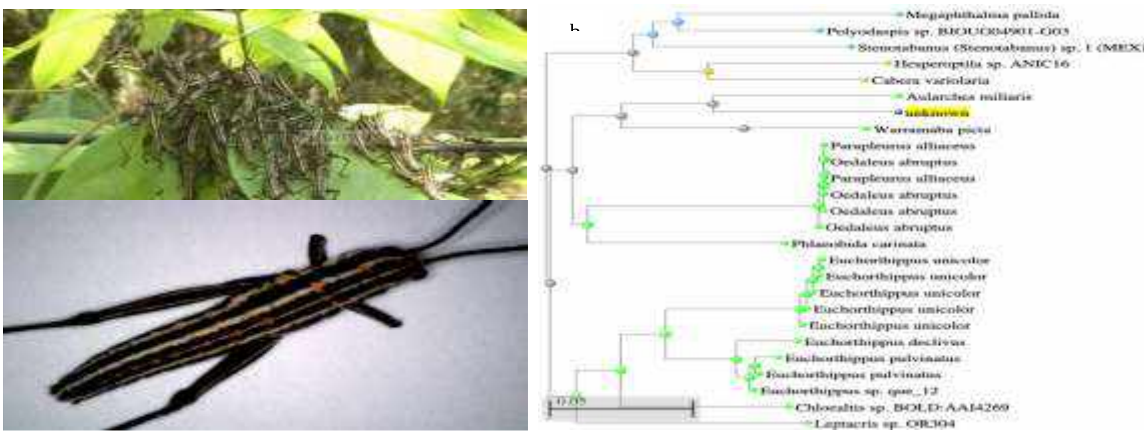

Fig. 6. (a) Photo of outbreak insects on plants observed in Uttar Lambari (20.874692ºE, 92.265ºN) village of Teknaf upazila, Cox's Bazar. (b) Neighbour joining phylogenetic tree and the position of collected sample (yellow shaded, unknown) among other reported species based on COI gene sequence.

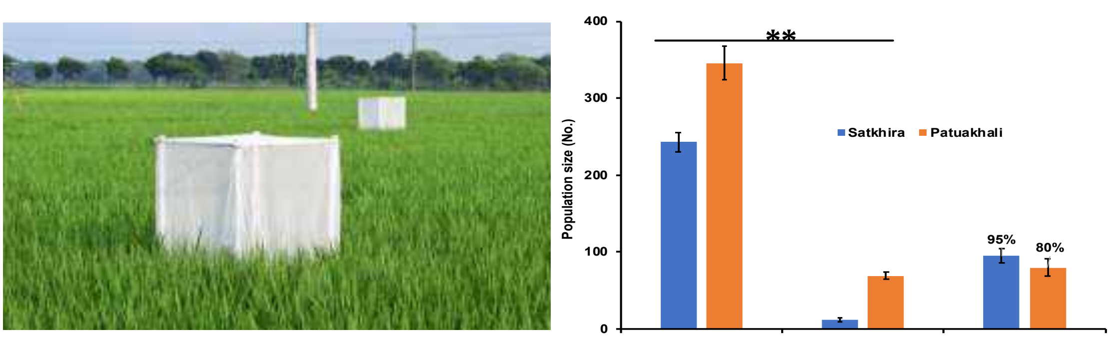

Fig. 7. Field view and BPH development in cage and open field. Error bar indicates the standard error. ** indicate significantly differed at the 1% level of significance.

Population development in cage significantly higher than in open field because natural pest control agents including LBB, spiders, STPD and GMB were active in the open field. This result indicated that significant amount of natural pest control services occurs in crop field. Significantly higher number of LBB and spiders was observed in Patuakhali compared to Satkhira (Fig. 8).
PI: Md. Panna Ali and **PL**: Sheikh Shamiul Haque

Impact of salinity on rice insect BPH and rice growth

The experiment was established in greenhouse of Entomology Division, BRRI, Gazipur. Five levels of salinity (2.0, 4.0, 6.0 and 8.0 dS/m) including control (0.0 dS/m) were used as treatment. Plants of BRRI dhan47 in earthen pots were used in this experiment. After hatching, total numbers of BPH were the highest in control followed by 4 and 2dS/m. There after declined with increasing salinity level. After 45 days, the highest population of BPH developed at 0dS/m and 2dS/m and the lowest was at 8dS/m salinity (Fig. 9).

The reason behind the highest population of BPH was found at 0dS/m might be due to growth and development of plants was better in control than the saline treated plants. Nymphal survival rate was also the highest in 0dS/m and the lowest in 4dS/m. In higher salinity level, plant growth hampered therefore BPH could not get sufficient food from the plant. This might be a cause for low survival rate in high salinity level (Fig. 10).
PI: Farzana Nowrin, **CI:** Md. Panna Ali, PL: Sheikh Shamiul Haque

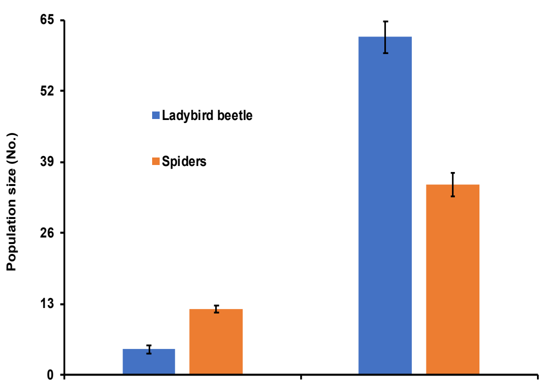

Fig. 8. Abundance of natural enemies in rice field during July19-June 20. Error bar indicates the standard error.

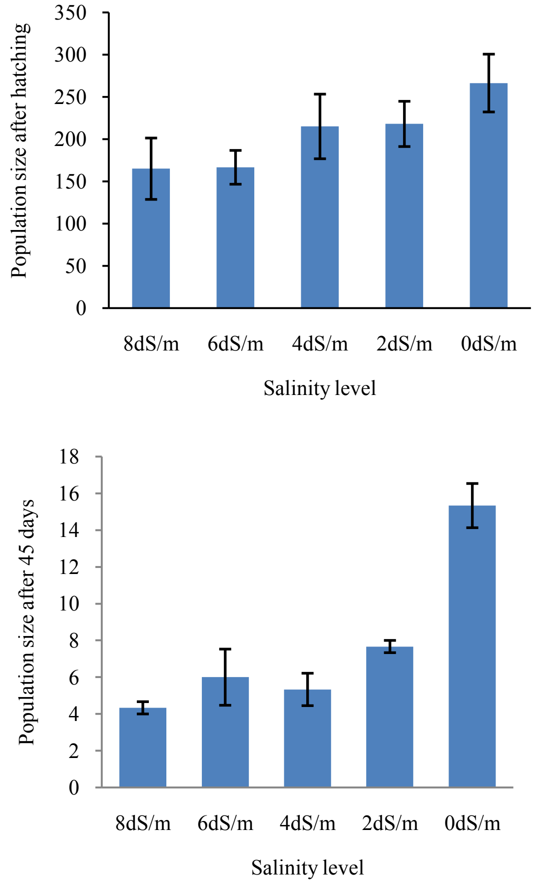

Fig.9. Effect of salinity on population development of brown planthopper during July19-June 20.

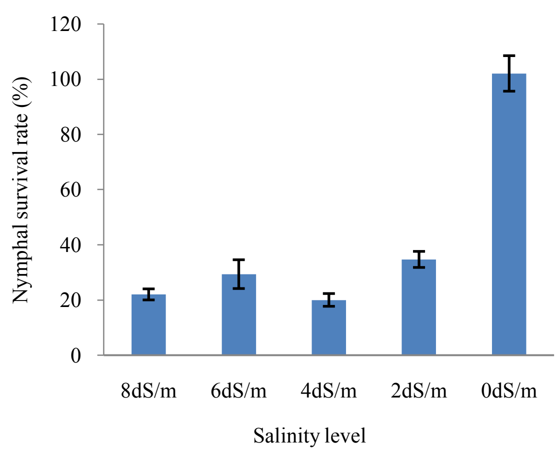

Fig.10. Effect of salinity on nymphal survival rate (%) of brown planthopper.

Geographic heterogeneity influences the species diversity of rice arthropods

The habitat heterogeneity hypothesis proposes that regions with higher habitat heterogeneity can provide more niches for coexisting of more species. In addition, human disturbance has strongly altered global ecosystems especially in the past century and thus may be an important factor modifying geographic diversity patterns. Here, we evaluated these explanations with geographic diversity data of insects. First, we measured the LUM index diversity of Satkhira, Patuakhali and Chattogram districts considering land use patterns of extensive agriculture, intensive agriculture, land without crop and vegetation. Data were collected from 30 locations of each geographic area for species diversity analysis. Sampling was conducted at three stages of rice growth in each field. Results showed that Chattogram has abundant very highly diversified area (mixed nature) followed by Satkhira. However, Patuakhali has no very highly diversified areas (Fig. 11). Higher arthropod species diversity was found in Chattogram than Satkhira and Patuakhali irrespective of crop growth stage (Fig. 2). This can be explained that higher arthropod diversity was observed in Chattogram due to its very high diversity index (Fig. 12). Thus, higher habitat heterogeneity of Chattogram induces the higher number of arthropods in crop field.

PI: Md. Panna Ali and **PL**: Sheikh Shamiul Haque

BIOLOGICAL CONTROL OF RICE INSECT PESTS

Leveraging diversity for ecologically based pest management

Three experiments on Leveraging diversity for ecologically based pest management were conducted in BRRI HQ farm, Gazipur, BRRI RS, Rajshahi and farmers' field in Alimganj, Paba, Rajshahi during T. Aman season and five experiments in 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 in all locations remains below the ETL in both the treatments T_1 and T_2 . In T_2 insecticides were used three times. Irrespective of season and location more natural enemies were observed in T_1 where flowering plants/sesame were grown on rice bunds. Brown plant hopper and YSB egg parasitisim and RLF larval parasitism were observed highest in T_1 (23.67, 34.25 and 29.23% respectively) compared to T_2 (3.60, 0 and 4.4 respectivley) at BRRI, Gazipur (Fig. 13). Though grain yield obseved simillar both in T_1 and T_2 (5.60 and 5.65 t ha^{-1} respectivley). But additional sesame produced in T_1 which increase the rice equivalent yield (REY) in T. Aman season (Fig. 13). In T_2 insecticide used 3 times during T. Aman season but yeild was similar to that of T_1. But extra profit comes from T_1 with additional sesame production and no use of insecticide. More or less simillar results were also observed from five experiments of Boro season. The highest natural enemies, percent RH egg parasitism by *Trichogramma zahiri, YSB egg parasitism by T. chilonis* and *Telenomou srowani* and BPH egg parasitism by *Anagrass* sp. were observed in rice field with nectar-rich flowering plants on bunds. However, least natural enemies and parasitism were found in rice field where three times insecticides were applied. Moreover, there was no yield reduction observed in rice field surrounding by flowering plants on bunds compared with insecticide application. So, farmers should avoid the toxic and hazardous insecticides to control the insect pests by growing nectar-rich flowering plants on the bunds of rice crops.

PI: Md. Nazmul Bari, **CI:** Farzana Nowrin, **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 entomogenous fungi against BPH. Potted BR3 plants were infested by 10 3^{rd}-4^{th} instar BPH nymphs of greenhouse populations and confined by mylar film cages. Two different doses of entomopathogenic fungi were sprayed to the plants. There were control plants with BPH without any spraying of fungi. Number of alive BPH was collected after one, three and seven days of spraying. No significant difference was found on mortality of BPH after one and three days of inoculation of fungi compared to the control (Table 1). However, fungi showed 33.0 to 41.7% efficacy to control BPH after seven days of inoculation which was significantly different from control (Table 2).

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 35 days after transplanting (DAT). Another four hills from the same plots were also selected as control. On average 0.94% dead heart and 2.81% 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 uninfested hill. But significantly higher filled grain number (929.31/hill) was found in infested hill compared to uninfested hill (736.63/hill). As a result grain weight was found highest (22.22 g/hill) in infested hill compared to uninfested hill (16.66 g/hill). This indicated that when YSB larvae damaged any tiller of a particular hill the plant produce additional tiller of the same hill which compensate the loss of damaged tiller. If YSB damages panicle of a hill plant supply more nutrient to the other panicle. As a result more filled grain number is found in other panicle of infested hills. So, no yield loss is done by the damage of YSB at early crop stage when dead heart and white head remain below 1 and 3% respectively. BRRI dhan87 compensate the dead heart tiller by producing additional tiller and white head damage compensate by producing more filled grain in other panicles of the same hill. It is the one season results so it needs further study for confirmation.

PI: Md. Nazmul Bari, PL**:** Sheikh Shamiul Haque

INTEGRATED PEST MANAGEMENT

Use of solar light trap for insect pest management in rice field

Pilot scale research and field trials were conducted in rice field at BRRI field, Gazipur. Twelve solar light traps were installed at west byed research field and insect pest catches from each light trap were recorded every day. Significant numbers of insect pests were caught in each month (Fig. 14). The highest numbers of insect pests were trapped in October followed by June and November and the lowest in January. The highest number of GLH and YSB were recorded in October 2019 (Fig. 14). Among the natural enemies, staphylinid beetle commonly trapped in all months and the highest abundance was observed in June followed by October (Fig. 15). The predator green mirid bug was found in May, June, October and November. This result indicated that solar light trap would be a promising tool for monitoring and integrated pest management (IPM) in rice field.

PI: Md. Panna Ali; **CI:** Md. Golam Kibria Bhuyan; **PL:** Sheikh Shamiul Haque

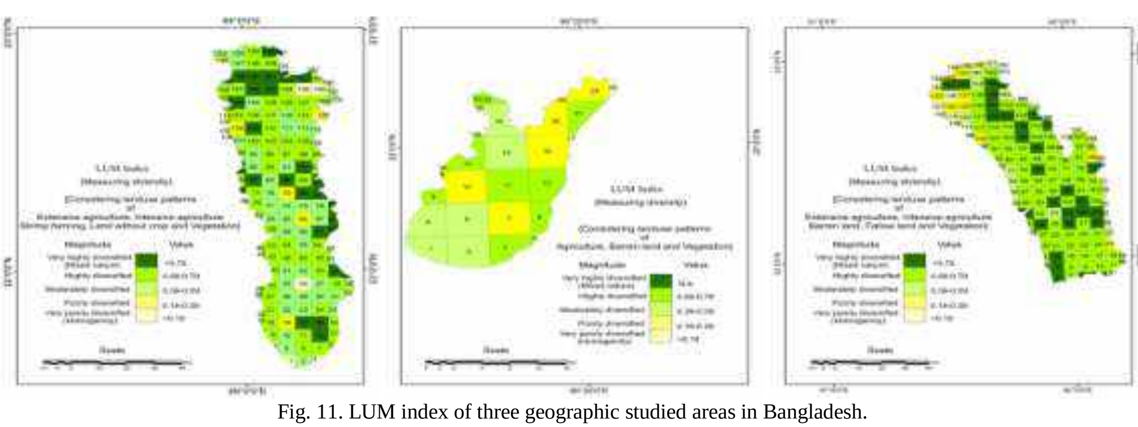

Fig. 11. LUM index of three geographic studied areas in Bangladesh.

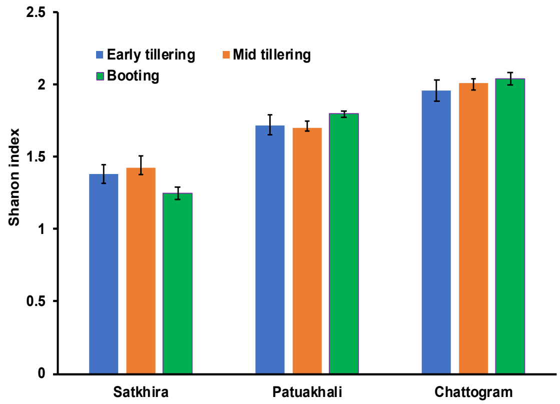

Fig. 12. Species diversity (Shanon index) at three geographic areas in Bangladesh. Error bar indicates the standard error.

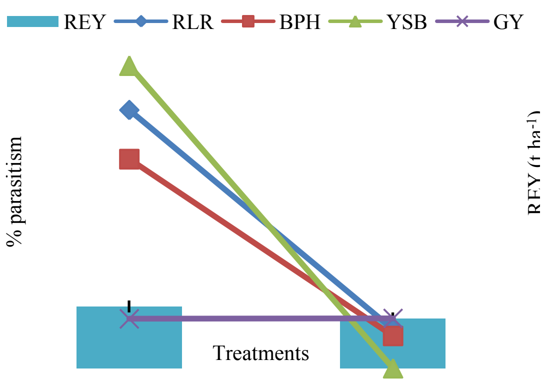

Fig. 13. Rice equivalent yield (REY) and % parasitism of BPH, YSB and RLR larvae during T. Aman 2019, BRRI Gazipur. (T_1=Sesame plant on rice bunds, T_2= Farmers' Practice i.e., insecticide application)

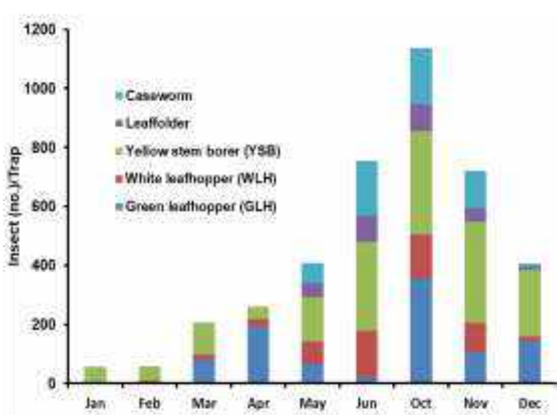

Fig. 14. Monthly catches of insect pests in solar light trap at BRRI, Gazipur. Each bar segment represents the mean value of three trap catches.

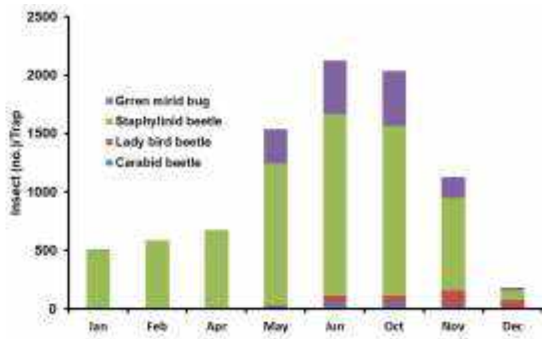

Fig. 15. Monthly catches of natural enemies in solar light trap at BFRRI, Gazipur. Each bar segment represents the mean value of three trap catches.

Use of sex pheromone to control rice leaffolder, *Cnaphalocrosis medinalis*

Pheromone lures were collected from China and used for field evaluation in Gazipur during T. Aman 2019. The optimal blend of used pheromone was Z11-18:Ald, Z13-18:Ald, Z11-18:OH and Z13-18:OH at a ratio of 3 : 25 : 3 : 3. The optimal dosage is 500 µg Z13-18:Ald per poly-vinyl chloride (PVC) tubing lure. Traps were installed in three blocks of west and east byed of BRRI research field @ of 15-20 traps/ha. Catches of leaffolder in trap varied in different block of BRRI research field (Fig.16). The highest number of leaffolder was caught in A block of West byed. This result indicated that pheromone trap would be a very effective method to monitor as well control leaffolder in rice field.

PI: Md. Panna Ali; **CI:** Farzana Nowrin, Zhonxian Lu and **PL:** Sheikh Shamiul Haque

Strengthening environment friendly research on insect pests for rice yield maximization

The experiment strengthening environment friendly research on insect pests for rice yield maximization was conducted in farmers' fields to demonstrate sustainable insect pest management practices in farmers' field and to reduce insecticide use in rice production. A total of 100 demonstrations were established during the reporting period which covered 93.57 acres of land in 24 districts. One portion of each farmer's field was remained under the respective farmers' supervision without any intervention treated as T_2 (Farmers' practice). The other portion was managed with BRRI recommended practices treated as T_1 (Researchers' practice). BRRI released popular varieties including new varieties were used in different locations of Bangladesh. Same varieties were used both in T_1 and T_2. In T_1, rice field was refrained from insecticide use up to 30 days after transplanting (DAT) to increase natural enemies in rice field. Insect pest in the rice field was monitored fortnightly by sweeping and visual counting of randomly selected 20 hills. Perching @100/ha was also used in T_1 and insecticide used ETL based or not. In T_2 treated plot the farmers used insecticide three times to control the insect pests. On average 0.48 t ha^{-1} yield increase in researchers practice plot compared to farmers practice plot. The national average yield gap is 20-25% but in the demonstrations irrespective of season and variety the yield gap was observed 9.27% which indicated yield gap also reduced. The demo farmers sometimes tried to follow the researchers' practice also. So yield gap reduced to some extent. As a result, 18.24 ton additional rice produced in researchers' practice plot compared to the farmers' practice plot during the reporting year. Not only that insecticide application reduced two times in researchers' practice which save insecticide 760 kg (granular). The market value of this insecticide is 91,200 /- (ninety-one thousand two hundred) only. Moreover it saves environment from insecticidal pollution. Most of the farmers in Bangladesh habituated to use granular insecticide during 1st urea top dressing without thinking its need. The demo farmers of these programmes are motivated that no need to use insecticide application at early crop stage (30-40 DAT). So it needs such type of more demonstrations in farmers' field all over Bangladesh.

EVALUATION OF CHEMICALS AND BOTANICALS AGAINST RICE INSECT PESTS

Fumigation action of botanical oils against stored grain insect pests

The experiment was conducted in the field lab of Entomology Division. Air tight glass fumigation chambers ($12 \times 12 \times 12$ $inch^3$) with sliding doors were used for this study. Both neem and mahogany oil mixed with 70% ethanol separately. Five ml from this mixture were kept in mosquito liquid vaporizer machine (Good knight). Each machine was placed into the respective glass fumigation box, and the boxes were tightly closed. Ten insects, rice weevils (adult) and angoumois grain moth (adult) collected and kept them in fine mesh cloth covered plastic jar (capacity 500 ml). Fumigation procedure continued for 48 hours. The experiment was conducted in CRD with 10 replications. At the end of the fumigation period, insects were transferred to plastic jars containing natural diet (rice grain). Mortality was recorded 48 hours after treatment (HAT). Mahogany oil fume caused significant mortality to both rice weevil and angoumois grain moth compared to the control. But, neem oil did not cause significant mortality. Mahogany oil caused 90.0 to 98.41% death whereas neem oil caused12.2 to 22.7% in the rice weevil and angoumois grain moth respectively (Fig. 17). This study indicates that mahogany oil would be an effective product for controlling stored grain insect pests through fumigation process. However, more research is required for mechanism of this mortality by mahogany oil.

PI: Md. Panna Ali; **PL:** Sheikh Shamiul Haque

Use of nanoparticle for controlling rice insect pests

Two nanoparticles (Cu and Ag) were gifted from a Japanese Professor Dr Enoch Y. Park. The efficacy of Ag and Cu nanoparticles against BPH was tested at three different concentrations (500, 250, and 125 $\mu g\ mL^{-1}$), which were prepared by dilutions with distilled water. Distilled water was used as a negative control treatment. Ten-15-day-old rice seedlings were dipped into each nanoparticle solution at three concentrations. After 60s seedlings were removed from the solution and allowed to air dry. The rice roots were wrapped in moistened cotton. The treated seedlings were then placed into a 25 mm test tube. The 3rd -4thinstar nymphs of BPH (10) were released into each test tube. The test was conducted at 27 ± 1°C and 16:8 h L:D. Mortality was recorded after 48 and 120 h. The nymphs were considered dead if they failed to move when gently prodded with a fine bristle. None of the tested nanoparticles showed 80% or above 80% mortality against BPH (Fig. 18). This result indicated that tested nanoparticles are not effective against BPH. However, Ag nanoparticle showed comparatively higher mortality than Cu. More experiments with new synthesis nanoparticles are planned to test again.

PI: Md. Panna Ali, **PL:** Sheikh Shamiul Haque

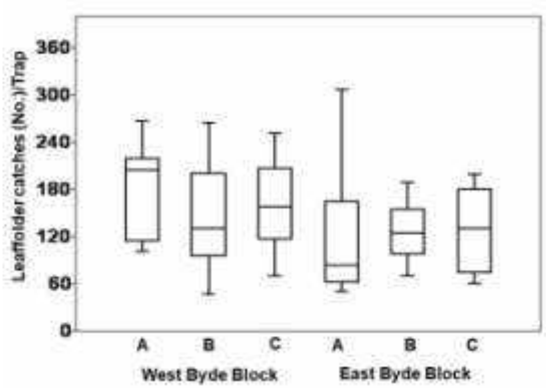

Fig. 16. Catches of leaffolder in pheromone trap at BRRI, Gazipur during T. Aman 2019.

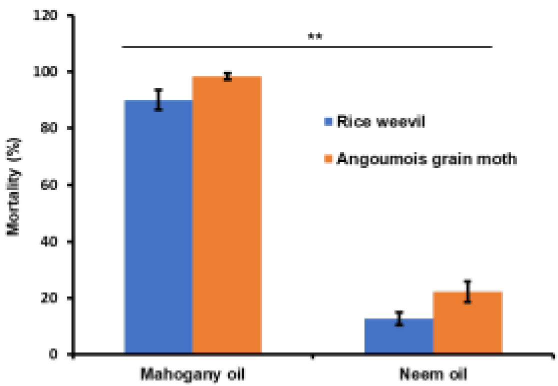

Fig. 17. Fumigation action of mahogany and neem oil against rice weevil during July 2019-June 2020. ** indicates significantly differed among the treatments at the 1% level of significance. Error bar represents standard error.

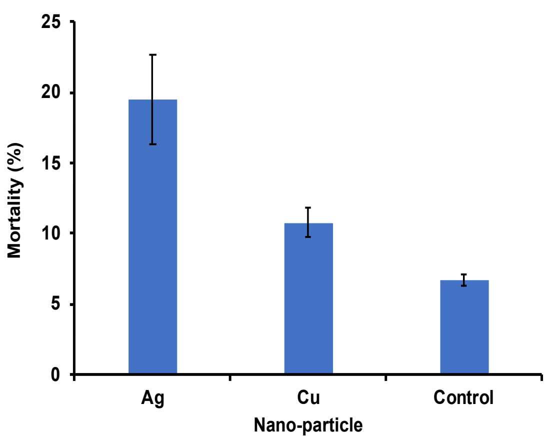

Fig. 18. Effect of Ag and Cu nanoparticles on the mortality of BPH during July 2019-June 2020. Error bar indicates standard error

Analysis of insecticide residues in rice

Pesticide residues from rice sample were detected using LC-MS. Four milliliter (4ml) of water was added to 2 g of rice powder in 50 ml falcon tube. Kept them in room temperature for soaking. After 30 minutes, 4 ml acetonitrile (ACN) was added to the falcon tube and vortexed for one minute. Added 2g AOAC to the sample and again vortexed for one minute and then centrifuged at 4000 rpm for 15 min at 10°C. An aliquot of the extract (1.5 ~ 2.0 ml) was transferred to a 5 ml centrifuge tube and 50 mg primary secondary amine (PSA) was added. After shaking vigorously on vortex for 60s, the tube was centrifuged at 2000 rpm for 10 min. The supernatant was collected and filtered through a 0.22µm filter. Finally collected the filtered supernatant in injection vial (supplied by company) for residue analysis. Detection was carried out by a LCMS-2020 fitted with electrospray ionization (ESI) probe operated in the positive ion mode. The following parameters were optimized for chlorantraniliprole: flow rate: 0.8 ml/min, Nebilize gas flow rate: 1.5, ion source temperature: 150°C; using drying gas (N_2), LC stop time: 1 min, DL temperature: 280°C. Detection was carried out in multiple reaction monitoring (MRM) mode. The retention time of chlorantraniliprole was 2.3 min. Table 1 presents of the concentrations of chlorantraniliprole in three tested samples. However, the detected amount of both chlorantraniliprole and thiamethoxam in the samples were below the maximum limit of residues (MRL).

Test of different insecticides against major insect pests of rice

A total of 132, 09, 10 and 4 commercial formulations of insecticides were evaluated against BPH, YSB, RLF and rice weevil respectively. Among them 124, 03, 03 and 04 were found effective against BPH, YSB, RLF and rice weevil respectively.

PI: Md. Panna Ali,**CI:** Farzana Nowrin; PL: Sheikh Shamiul Haque

Table 1. chlorantraniliprole and thiamethoxam residues in polished rice grains.

Sample name	Detected insecticide (mg/kg)		MRL (mg/kg)	
	chlorantraniliprole	thiamethoxam	European Union	United States
Chinigura rice	0.028		0.4	0.15
Jasmin rice	0.055			
Indian white rice		0.28	0.6	0.02

PI: Md. Panna Ali; **CI:** Md. Nazmul Bari, Farzana Nowrin, Sadia Afrin ; **PL:** Sheikh Shamiul Haque

HOST PLANT RESISTANCE

Screening of advanced breeding lines against major insect pests of rice

A total of 290 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 seven breeding lines (Path 2441,IR98849-GAZ-2-2-4-1, BR9880-27-4-1-18, BR9880-2-2-2-1, BR9880-40-1-3-34, BR9880-45-2-2-38 and BR(Bio)10376-AC11-3-1) and two IRBPHN lines (SVIN350, SVIN351 and SVIN357, SVIN266) showed moderately susceptible (score 5) reaction to BPH, six breeding lines (BR (Bio) 11447-1-28-14-3, BR 9669-21-2-1-19, IR 98841-GAZ-4-2-1-2, IR98841-GAZ-8-1-3-1, BR(Bio)10376-AC9-1-3 and BR (Bio)10376-AC11-3-1) were found moderately susceptible to WBPH and four breeding lines BR (Path) 12452-BC3-16-19, BR (Bio) 11447-3-10-7-1,IR 105837-8-45-1-1and BR 9891-19-2-2-8) to GLH (Score 5).

Susceptible check: BR 3 (for all), resistant ck: 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

Identification of BPH resistant sources from local germplasm

A total of 500 rice germplasms were evaluated against BPH in the net house of Entomology Division to identify BPH resistant rice accession. Among them 31 rice accessions namely Acc480, Acc481.Acc482, Acc485, Acc486, Acc487, Acc490, Acc559, Acc572, Acc577, Acc578, Acc579, Acc589, Acc591, Acc601, Acc602, Acc614, Acc694,Acc719, Acc811, Acc812, Acc834, Acc860, Acc874, Acc875, Acc883, Acc884, Acc885, Acc994, Acc995, and Acc996 showed moderately susceptible reaction (score 5) to BPH.

PI: Sadia Afrin, **PL:** Sheikh Shamiul Haque

Suppression of serotonin synthesis in rice using CRISPR Cas9 for insect control

The study was undertaken to develop insect resistant rice variety using clustered regularly interspaced short palindromic repeats (CRISPR) Cas9 genome editing tool.The oligonucleotide sequence of target insertion part of CYP71A1 gene was purchased from Macrogencompany (Humanizing Genomics, Seoul, Korea) via Biotech Concern (Dhaka, Bangladesh). The SK - gRNA vector was cultured overnight in 25 ml LB (Luria-Bertani) liquid medium added with ampicillin antibiotic and DNA was extracted from cultured cells using the FavorPrep Plasmid DNA Extraction Mini Kit (Cat No. FAPDE050, FAVORGEN, Biotech CORP, Taiwan). Purified SK - gRNA was quantified using Nano Photometer® (Implen GmbH, München, Germany) and 1 µg DNA was used for each digestion reaction. The DNA of SK-gRNA was digested with AarI restriction enzyme for ligation with target gene. Respective amount of each component (outlined in Table 2) in a restriction reaction was taken in a 1.5 ml microtube and incubated at 37°C for 60 min. After 60 min, the digested product was checked using agarose gel electrophoresis and digested SK-gRNA DNA was again purified from agarose gel using FavorPrep Gel/PCRpurification Mini Kit (Cat No. FAGCK001, FAVORGEN, Biotech CORP, Taiwan).

In the production of CYP71A1 knockout (CYP71A1-KO) rice plant, a 19 bp fragment (5'-GGTCGCGTTGAGGAGGAGC -3') of CYP71A1 gene was designed as the target and inserted into the vector $p^{C1300\text{-}cas9}$ for CRISPR/Cas9 knockout. The purified SK-gRNA DNA digested with AarI restriction enzyme was used for ligation with target part of CYP71A1. The target part of CYP71A1 gene was inserted at the AarI - site in SK-gRNA following the ligation protocol. The target fragment of CYP71A1 gene and SK-gRNAvector were ligated in a reaction mixture containing 3µltarget fragment (primer F+R), 20 – 50 ng of SK-gRNA fragment, 0.5 µl of 10X buffer (T4 ligation buffer) and 0.5 µl of T4 DNA ligase, followed by incubation at 16°C for 8 h (overnight). After 8h, 5µl of ligation reaction product was transformed into chemically DH5α cells following the standard transformation protocol. The transformation product was kept for culture in LB plate at 37°C for overnight. Recombinant SK-gRNA was checked by PCR, electrophoresis, and sequencing. The purified recombinant SK-gRNA vector DNA was sent to National Institute of Biotechnology (NIB), Savar, Dhaka for sequencing. Sequencing result shows 100% similarity with original target sequence and recombinant SK-gRNA – CYP71A1 (indicated by *) (Fig. 19). The recombinant SK-gRNA – CYP71A1will be cloned again into $p^{C1300\text{-}Cas9}$vector for next step.

VERTEBRATE PEST MANAGEMENT

Ecologically based management of rats in rice field

The use of bamboo trap is becoming popular among the farmers as it can be easily made by local people using available indigenous raw materials. The trap can also be placed in crop field easily for trapping rats. Therefore, a trial was designed to identify the best food to attractiveness of rats in bamboo trap. The attractiveness of each food was calculated as the number of rats trapped. Different foods including coconut, dried fish and paddy were used in this study and compared their attractiveness in rice field. Field trials were conducted at BRRI Charbadna research farm in Barishal. Results indicated that coconut has the highest power to attract rats in bamboo trap overnight in field condition (Fig. 20). Significant differences were found among the tested food in bamboo trap. Bamboo trap was also applied without any food, but no rat was trapped. This indicates that bamboo trap can't be used without any food for rat management. However, more trials with diverse food sources are recommended to identify the best food for higher attractiveness to the rats.

PI: Md. Panna Ali, **CI:** Hirendra Nath Barman, Hisham Al-Rabbi and **PL:** Sheikh Shamiul Haque

Table 2. Component and their amount of a restriction system.

Component	Amount (µl) for 50 µl	Amount (µl) for 100 µl
SK-gRNA DNA	2 (1-2µg)	4
10X buffer	5	10
50X oligonucleotide	2	4
Restriction enzyme AarI	2	4
ddH$_2$O	39	78

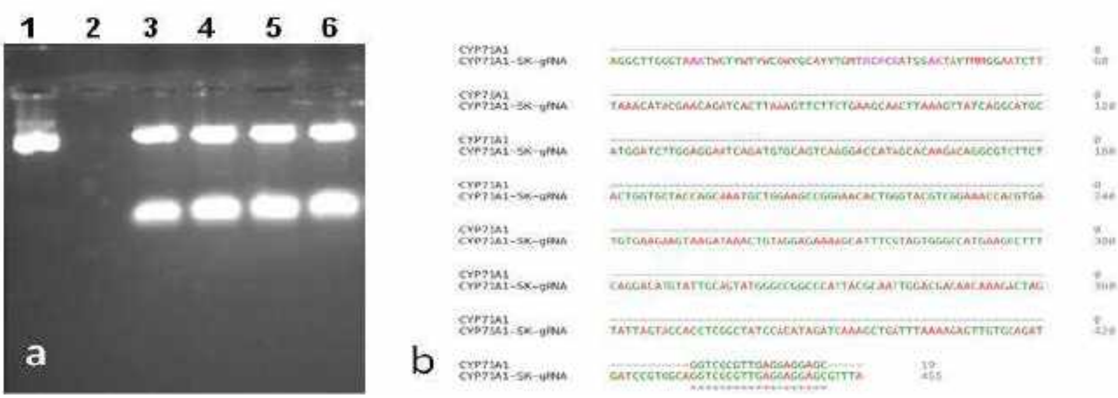

Fig. 19. (a) Electrophoresis of digested SK-gRNA for ligation with target site of CYP71A1. Lane 1: SK-gRNA; lane 2: Blank; lanes 3 – 6: SK-gRNA digested with AarI. (b) Alignment of the original target site of CYP71A1 and the sequence of recombinant CYP71A1-SK-gRNA. * indicates the similarity between original target site and recombinant CYP71A1-SK-gRNA.

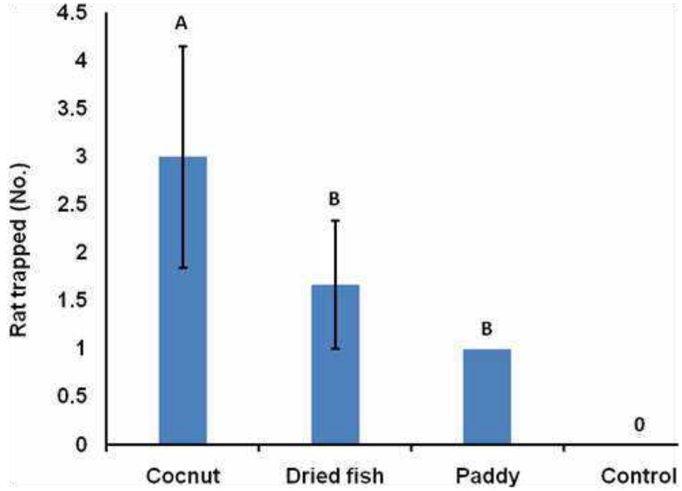

Fig. 20. Effect of different foods used in bamboo trap for rat attraction. Bar bearing the same letter did not differ significantly at the 5% level of significance. Error bar indicates the standard error.

PI: Md. Panna Ali; **CI:** Mir Md. Moniruzzaman Kabir; **PL:** Sheikh Shamiul Haque

Plant Pathology Division

SUMMARY

Survey was conducted in different districts based on different ecosystems during T. Aman, 2019. Bacterial Blight was severe followed by brown spot, sheath blight and blast in Habiganj. Prevalence of bacterial blight, sheath blight and brown spot were predominant in all the surveyed areas with lower severity. Incidence of bacterial leaf streak was alarming in Gazipur.

The conditions for successful isolation of *Ustilaginoidea virens* (causal agent of false smut) in axenic cultures have been standardized and the growth conditions were optimized. The fastest growth rate was achieved with potato sucrose agar (PSA) medium. Beside morphological identification, the identity of the fungal pathogen was confirmed through ITS sequencing (>1st_BASE_3656919_A1_ITS_4) which showed up to 98 % identity with *U. virens* in NCBI-BLAST analysis.

A total of 400 bacterial blight infected samples were collected from the 17 different districts of Bangladesh. From the collected samples, 300 bacterial blight isolates were isolated and preserved. Among the isolates, 10 physiological races were identified based on the reaction pattern against NILs of bacterial blight resistance. From this study *Xa21* and *xa13* were identified as effective gene for the development of bacterial blight resistance in Bangladesh.

The reaction pattern of single spore inoculation of isolates to 25 differential varieties harboring 23 blast resistance genes were similar to the last year pattern. It indicated that there was no change of blast races within a year. This year, no new differential isolates were included in the existing differential system.

The study on development of an effective inoculation technique for sheath rot disease showed injection and wrapping with mycelium plug as the best methods for 100% disease development under artificial inoculation condition. The estimation of yield loss due to sheath rot disease revealed that the trend of increasing every unit of each disease severity (DS) scale, the weight of filled grains decreasing 0.27 g/panicle. A standard evaluation system for sheath rot disease scoring has been initially developed based on three criteria of sheath rot disease such as lesion length, panicle exertion length, and % sterility of sheath rot disease infected rice panicles.

On average 24% yield loss was calculated due to blast disease. On average 18% yield loss was calculated for sheath blight disease.

Fusarium equiseti was identified as one of the rice seedling blight causing fungi through ITS sequencing. Pathogenic variability of *R. solani* was done using the primer ITS1 and ITS4. Further evaluation will be done although no difference was observed among the tested isolates. Advanced homozygous breeding lines possessing *Pi9* gene were evaluated against blast disease in uniform blast nursery (UBN) and hot spots. BR(Path)12452-BC3-35-21-8-5, BR(Path)12452-BC3-42-22-11-4, ZM81 and ZM82 were selected for advanced trial which showed both field resistance and screening resistance under artificial inoculation condition in UBN (score-0) according to SES, IRRI. Observational yield trial (OYT) indicated the statistical similar yield (5.1-6.0 t/ha) and growth duration of these materials with the check BRRI dhan28 (5.7 t/ha). Advanced backcross generations with single Pi9 or *Pita2* gene as well as pyramiding lines having Pita2 and Pi9 genes have been developed in the background of BRRI dhan28, BRRI dhan29 and BRRI dhan63. Among the tested local germplasm, Acc no. 5056 (20% RLH), Acc no. 499 (25% RLH) and Acc no. 4362 (30% RLH) showed moderate resistance against the sheath blight disease. Among the tested fungicides six fungicides eg., Alix, Azonil. Limostar top, M-zole and Tramp were found effective against seedling blight as like the standard check fungicide Amistar top which produced no infection.

Among 168 INGER materials obtained from IRRI, 29 showed moderately resistant against a major BB isolate but no resistant material was found in T. Aman 2019.

Among 54 genotypes, BR9871-29-1-3-B was found as resistant and three materials like BR9571-28-2-1-2-1, BR10001-94-2-B and BR (Bio)10376-AC4-1-3) were found as moderately resistant against bacterial blight disease during T. Aman. In Boro19-20, among 37 tested germplasms, two materials like BR (Bio) 11447-1-28-14-3 and BR (Bio) 11447-3-10-7-1 and four materials like BR8912-12-6-1-1-1-1, BR9669-23-3-2-23,

BR9891-17-2-2-23 and BR (Path) 12452-BC3-16-19 were found as resistant and moderately resistant, respectively against bacterial blight disease.

Ninety germplasms were screened out and six were found resistant against bakanae disease.

A total of 833 advanced breeding lines including OYT, AYT and RYT materials were inoculated with most virulent bacterial blight (BB) isolate during Boro 2019-20 season. Among them 139 materials were found resistant.

A total of 350 rice germplasm along with checks were screened against bacterial blight pathogen. Among the 350 tested germplasm, 14 entries were found resistant.

To improve the genetic background of popular rice variety BRRI dhan28, BRRI dhan29, BRRI dhan63 and BRRI dhan64 against blast disease, a marker assisted backcross breeding followed by pathogenicity tests were started with the collaboration of JIRCAS, Japan in 2014. The materials were advanced by modified field RGA system. Among the tested 3,982 lines (LST), 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.

Blast resistant gene (*Pi9 and Pb1)* and bacterial blight resistant gene (*Xa21 or Xa13*) were introgressed in the background of BRRI dhan28, BRRI dhan29 and BRRI dhan58. Introgression of *Xa21*, *xa13*, *Pi9* and *Pb1* gene in the background of BRRI dhan81, BRRI dhan49 and BRRI dhan63 has been done. Progenies were selected from different backcross generations and advanced for the development of homozygous pre-breeding materials for further use. Seeds of different generations i.e. F1, BC1F1, BC2F1, BC3F1, BC4F1 were produced from different crossings. *Pi9* and *Pb1* was detected using the primer NMSMPi9-1/ RM8225 and RM206 respectively. F1, BC1F1, BC2F1 and BC3F1 seeds produced in T. Aman, 2019 were used for pyramiding *Pi9* and *Pb1* genes in the background of recurrent parents. BC1F1, BC2F1, BC3F1 and BC4F1 seeds of *Pi9* and *Pb1* in the same background was crossed again and obtained advance generation seeds with both targeted genes in Boro 2019-20. For the development of pyramid line of bacterial blight disease, resistant genes (*xa13* and *Xa21*) were introgressed in the background CN6 and BC3F4 generations were produced.

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 and TW-16) and tungro susceptible variety (BRRI dhan48, BRRI dhan71 and BRRI dhan87). For the mapping of QTL in tungro resistant Kumragoir, hybridization was done between Kumragoir and BRRI dhan48 to produce mapping populations. Genotyping was done through 98 polymorphic markers in 384 plants of BC2F2 population. Thirty-nine genotypes were collected from IRRI and screened with rice tungro disease. Among the genotypes, nine were resistant, nine were moderately resistant and 21 were found susceptible after screening. Moreover, a survey was conducted during Aman 2019 in three upazilas of Rajshahi to determine the disease status of rice.

For developing resistant variety, candidate resistant genes *Pi9* for blast and *Xa21* for BB have already identified using differential system in Bangladesh. IRRI has already done rice genome sequence (3K rice genome database) including Bangladeshi 186 germplasm. Data showed that 6.45% germplasm harboured blast resistant *Pi9* gene and 18.28% harboured BB resistant *Xa21* gene in their genetic background. In addition, 12 materials were found those harboured both *Pi9* and *Xa21* in their genetic background.

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 neck blast disease has completed.

Enhancing the resistance of rice to blast 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 *ERF922* coding sequence (*LOC_Os01g54890*). The target site was ligated with an intermediate vector SK-gRNA sequence. Final vector construction will be completed by ligation of the target with SK-gRNA to pC1300-Cas9 vector.

A total of 22 new chemicals including trooper (check) were evaluated during Boro 2019-20. Among them, only seven fungicides (mostly Tricyclazole group fungicide) were controlled more than 80% blast disease.

To develop a nano particle mediated fungicide, a greenhouse experiment was conducted at Plant Pathology Division, BRRI where AgN and commonly used blast control fungicide trooper were used at the rate of 0.8 g/l. In addition, 0.4g AgN and 0.4g trooper were also dissolved in a liter of water for evaluating combine effect of them. A total of four treatments including untreated control with four replications were maintained in this study. Results showed that AgN, Trooper and AgN+Trooper were reduced 58.8%, 82.4% and 64.7% leaf damage area over untreated control.

Five fungicides namely VAI-Two 35 SC, SR TOP 32.5 SC, Cropstar 32.5 SC, Ulka Plus 35 SC and Admine Top 35 SC of 20 tested fungicides controlled sheath blight disease successfully (equal or above 80%) in both BRRI HQ, Gazipur and BRRI RS, Rajshahi farm.

Tricho-compost application T1 (2t/ha) and Trichoderma formulation T2 (1000L/ha) reduced %RLH and increase yield compare to chemical treatment T5 (Nativo 2 spray) and healthy control (T7). Yield was increased and % RLH was reduced when Tricho-compost and Trichoderma formulation was applied compared to diseased control.

TRANSFERABLE TECHNOLOGY

Six fungicides eg., Alix, Azonil. Limostar top, M-zole, Tramp and Amister top (check) were found effective when treated the seeds at 0.3% for 18 hours which produced no infection of seedling blight disease in tray seedling.

EPIDEMIOLOGY OF RICE DISEASE

Survey and monitoring of rice diseases

Survey was conducted in different districts based on different ecosystems during T. Aman 2019. Prevalence of bacterial blight, sheath blight and brown spot were predominant in all the surveyed areas (Figs. 1 and 2). But severity level of these diseases was lower in most of the cases except for BB in Gazipur and Hobiganj. Blast disease severely affected BRRI dhan34 at Cumilla. Incidence of bacterial leaf streak was 55% in Gazipur with severity score 5.5 which indicated an alarming situation of the disease. Incidence and severity of other diseases were low across the districts.

■ T H Ansari, M A Latif, Q S A Jahan, M Hossain, M S Mian, M A I Khan, S Akter, Mst. Tuhina-Khatun, M M Rashid, B Nessa, A Ara, M Ahmed, S A I Nihad and H R Hera

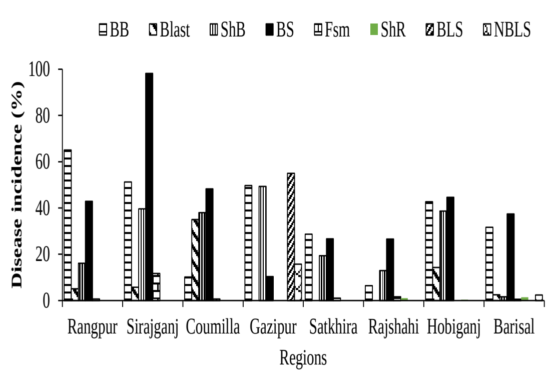

Fig. 1. Disease incidence of different diseases in T. Aman 2019 rice in different regions of Bangladesh.

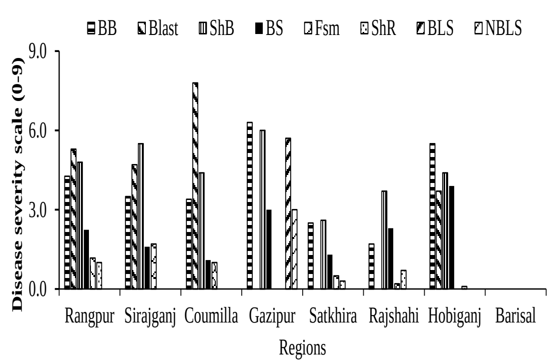

Fig. 2. Disease severity of different diseases in T. Aman 2019 rice in different regions of Bangladesh.

Isolation, purification, confirmation and inoculation of rice false smut pathogen (*Ustilaginoidea virens*)

False smut disease is caused by *Ustilaginoidea virens* (Cooke) Takahashi on rice. It has become a serious pathogen in almost all rice-growing areas in the world. The conditions for successful isolation of pathogen in axenic cultures have been standardized and the growth conditions were optimized. The outer portion of dark powdery mass of spores was teased out into small pieces which were then inoculated into water agar petri-dish and incubated at 27±2°C. To avoid bacterial contamination Streptomycin @100 ppm, was added in the medium at lukewarm stage before pouring into petriplates. To get the pure culture of the fungus, hyphal tip method was used for sub-culturing the fungus in media slants/Petri-plates. The culture was periodically transferred to fresh media of PSA and PDA. The fastest growth rate was achieved with potato sucrose agar (PSA) medium. These conditions could be useful for the best isolation of the pathogen for different studies. Beside morphological identification, the identity of the fungal pathogen was confirmed through ITS sequencing (>1st_BASE_3656919_A1_ITS_4) which showed up to 98 % identity with *U. virens* in NCBI-BLAST analysis. The proposed isolation technique coupled with information on optimization of culture conditions of *U. virens* will immensely contribute to further studies on this fungus and the disease in Bangladesh.

■ M A I Khan, B Nessa, M M Rashid and M A Latif

PATHOGEN POPULATION STRUCTURE AND BIOLOGY

Identification of physiological races of bacterial blight and its distribution patterns (NATP-2)

A total of 400 bacterial blight infected samples were collected from the 17 different districts of Bangladesh. From the collected samples 300 bacterial blight isolates were isolated, purified and preserved. To identify the physiological races, pathogenicity tests of 300 BB isolates were done on NILs and Pyramid lines of bacterial blight resistance. In total, 10 races were identified according to the reaction pattern of the BB isolates against BB resistant NILs. From this study *Xa21* and *xa13* identified as effective gene for the development of bacterial blight resistance in Bangladesh. But this needs further experiment to conclude the result.

■ M A Latif, M A I Hasan, T Ferdous, S Das, M M Rashid and M A I Khan

Improvement of differential system for rice blast disease in Bangladesh

To improve the existing differential system for rice blast disease resistance, 74 blast infected samples were collected from two hot spots of Cumilla and Gazipur districts of Bangladesh during Boro season 2019-20. The isolates were collected from the severely blast infected plots of BRRI dhan28 and BRRI dhan81. The reaction pattern of single spore isolates to 25 differential varieties harboring 23 blast resistance genes were similar to the last year pattern. It indicated that there was no change of blast races within a year. This year, no new differential isolates were included in the existing differential system.

■ M A I Khan, S A I Nihad, M R Bhuiyan, M M Rashid, M A Latif and Y. Fukuta

Development of a new disease rating scale for sheath rot disease scoring

The aim of the study was to develop an easy and accurate standard evaluation system for sheath rot disease scoring. Three criteria of sheath rot disease such as lesion length, panicle exertion length and % sterility was considered for this purpose.

The lesion length (LL) of 388 sheath rot infected panicles was measured. The LL varies from 1 mm to 200 mm. The colour and shape of the lesion was brown, dark brown, grey, blackish and

Fig. 3. Sheath rot infected panicle sorted under different disease rating scales (0–9).

reddish-brown lesion which showed round, oblong or irregular on the upper leaf sheath near emergence of panicle (Fig. 3). Based on lesion length (LL) the following scale has been proposed: Healthy: No lesion at all, Scale 1: 1 mm-40 mm, Scale 3: 41 mm-80 mm, Scale 5: 81 mm-120 mm, Scale 7: 121 mm-160 mm, Scale 9: 161 mm-200 mm or greater than 200 mm. Panicle exertion length was recorded from 250 sheath rot infected panicles. Data range from 0 cm to 26.5 cm. Based on panicle exertion length the following scale has been proposed: Healthy: Fully exerted panicle, Scale 1: 20 cm- >20 cm, Scale 3: 15 cm-19.9 cm, Scale 5:10 cm-14.9 cm, Scale 7: 5 cm-9.9 cm, Scale 9: 1 cm-4.9 cm.
Percent sterility of 480 sheath rot infected panicles was counted. The data ranged from 0.59% to 100%. Based on %sterility we have proposed the following scale: Healthy: 0-20% sterility (no sheath rot lesion), Scale 1: 21%-35%, Scale 3: 36%-50%, Scale 5: 51%-65%, Scale 7: 66%-80%, Scale 9: 81%-100% sterility.
■ M Tuhina-Khatun and B Nessa

Development of an effective inoculation technique for mass screening of sheath rot disease of rice
The objective of this study was to find out an effective and efficient inoculation method for mass screening of sheath rot disease. There were four methods namely i) spraying spore suspension, ii) injection with spore suspension, iii) wrapping with mycelium plug, and iv) control. Injection and wrapping with mycelium plug were initially found as the best methods for 100% disease development under artificial inoculation condition (Table 1). The panicle exertion length drastically reduced compared to other method (Fig. 4) and it was found as the most effective method for sheath rot screening. However, injection technique is laborious. Wrapping with mycelium plug probably has scope for mass population inoculation in green house condition. The experiment will be repeated to verify the results.
■ M Tuhina-Khatun, B Nessa and M A Latif

Pathogenic variability of *R. solani*
Fifty samples were collected from different parts of the country. DNA extraction of nine samples was done followed by polymeric chain reaction and visualization in agarose gel electrophoresis. ITS1 and ITS4 primers were used for confirmation and detection of variability of collected samples. No differences were found among the tested samples collected from different areas.
■ T H Ansari, M Ahmed and S Akter

Molecular identification of seedling blight causing fungi
The fungi causing rice seedling blight were isolated for identification. Fungus was primarily detected by amplifying internal transcribed spacer (ITS1 and ITS2) region of isolated fungi through PCR amplification using ITS4 and ITS5 primers. Gel electrophoresis picture produced a clear band size of 550 bp indicating that they were *Fusarium sp*. Later ITS sequencing was done and the sequence were searched in NCBI-BLAST for sequence alignment. The sequence similarity with the reference sequences in NCBI-BLAST were found 99.8% in ITS4 and 99.5% in ITS5 sequence. Neighbour joining tree of sequences similarity indicated that the tested isolate was closest to the *Fusarium equiseti* (KU565729) in ITS4 and similarly to the *Fusarium equiseti* (MN258582) in ITS5.
■ T H Ansari and M Ahmed

Table 1. Disease incidence (DI) and disease severity (DS) in different inoculation methods.

Method	DI (%)	DS
Control	8	3-9
Spraying	36	3-9
Injection	100	5-9
Wrapping with mycelium plug	100	5-9

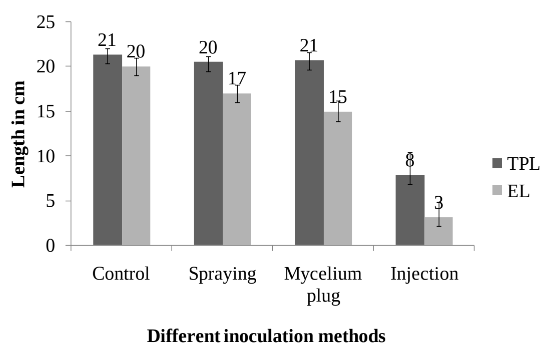

Fig. 4. Total panicle length (TPL) and panicle exertion length (EL) under different inoculation methods.

Estimation of yield loss due to sheath rot disease in rice

The objective was to determine the relationship between sheath rot disease severity (DS) and yield reduction in rice. The results showed the lesion length increases with increasing of sheath rot DS. Although total panicle length remain almost similar under different disease scale, however panicle exertion length decline with increasing of DS (Fig. 5). The trend of increasing every unit of DS scale made the weight of filled grains decreasing up to 0.27 g/panicle (Fig. 6).

■ M Tuhina-Khatun, B Nessa and M A Latif

Estimation of yield loss due to blast disease in rice

The objective of this study was to measure the yield loss due to blast disease of rice in farmers' fields and develop an equation relating to the DS and yield loss. One severely rice blast infected farmer's field in Guari village of Bhaluka upazila under Mymensingh district was selected for this study. The variety was BRRI dhan28 grown in Boro season of 2018-19. Data on panicle length, number of filled and unfilled grains per panicle, and weight of filled grains per panicle were recorded. The disease was scored following 1-9 scale, but modified into continuous sliding scale (1 step interval). Total sample size was randomly collected 882 panicles, of which 61.5% was infected. The yield loss was calculated comparing healthy panicles to diseased panicles in each category of disease score. The yield loss increased linearly @ 11.97% per unit across the disease score (R^2=0.99). The yield loss caused predominantly due to variation in the filled grains per panicle, which decreased linearly @ 9.08% per unit across the disease score (R^2=0.99). A strong negative correlation (r= -0.99) was observed between yield loss and % filled grains per panicle (Fig. 7). On average 24% yield loss was calculated for the studied blast infected field.

■ B Nessa, T Khatun and MA Latif

Estimation of yield loss due to sheath blight disease in rice

The objective of this study was to measure the yield loss due to sheath blight disease of rice in farmers' fields and develop an equation relating to the DS and yield loss. One severely rice sheath blight infected farmer's field in Kapasia upazila under Gazipur district was selected for this study. The variety was BRRI dhan51grown in T. Aman season of 2019. Data on panicle length, number of filled and unfilled grains per panicle, and weight of filled grains per panicle were recorded. The disease was scored as relative lesion height (RLH) as a percent of culm length. Total sample size was randomly collected 956 panicles, of which 71.2% was infected. The yield loss was calculated comparing healthy panicles to diseased panicles in each category of RLH. The yield loss increased linearly but slowly @ 3.73% per DS scale up to 7 (R^2 = 0.72); thereafter, the loss was very rapid (@ 19.95% (R^2 = 1.0) (Fig. 8). The predominant yield loss, was due to variation in the filled grains per panicle, which decreased slowly @ 1.498% per DS scale up to 7 (R^2 = 0.68), but rapidly afterwards (@ 14.67% (R^2 = 1.0). A strong negative correlation (r = -0.98) was observed between yield loss and % filled grains per panicle. On average 18% yield loss was calculated for the studied sheath blight infected field.

■ B Nessa, T Khatun and MA Latif

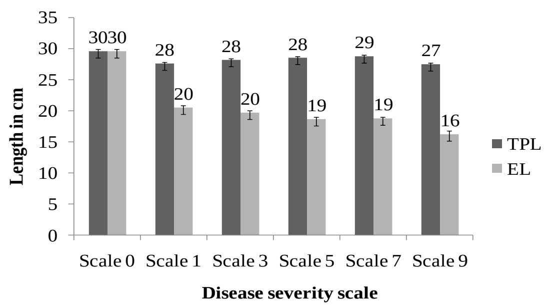

Fig. 5. Total panicle length (TPL) and panicle.

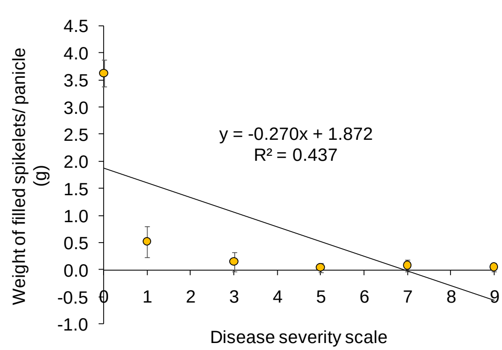

Fig. 6. Relationship between weight of filled spikelets/panicle and disease severity scale.

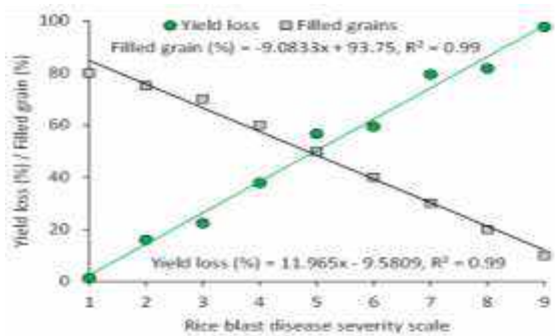

Fig. 7. Relationship between rice blast disease severity and yield loss, and % filled grains per panicle.

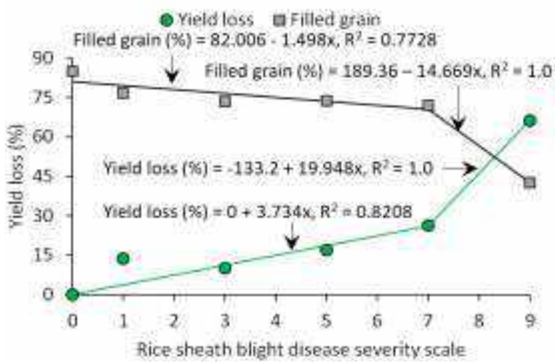

Fig. 8. Relationship between DS scale of rice sheath blight disease and yield loss, and % filled grains per panicle.

Evaluation of bacterial community in rice field of Kansai region, Japan

The 16S amplicon sequencing (Illumina MiSeq 250bp) was used to analyze the bacterial community in paddy fields of soil taken from five locations under conventional and organic systems. *Xoo* and *R. solani* were detected in sampled soil, however, no clear difference was noted, regarding systems. From amplicon sequencing data, *Chloroflexi*, *Acidobacteria*, *Proteobacteria*, *Actinobacteria*, *Planctomycetes* were the dominant phyla of rice soil in Kansai region. The phylum *Kazan-3B-28* was found more in organic system than conventional. The bacterial community was more affected by location and soil type than by management systems.

■ H A Dilzahan

DISEASE RESISTANCE AND MARKER ASSISTED SELECTION STUDIES

Improvement of BRRI dhan28 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 2019 and Boro 2019-20. Four set of parents were grown with seven days interval for the synchronization of flowering among the parents. Seeding was started from 15 July 2019 in Aman season and for Boro season it was started from 19 December 2019. In Aman 2019 seven backcrosses and two intercrosses were made to obtain BB and blast resistant genes among the parents; whereas in Boro season seven backcrosses and a single intercross were made to obtain seeds of advanced generation. (Tables 2 and 3). Heterozygosity of the populations was confirmed through respective marker.

■ M A Latif, M A I Hasan, A Kabir, A Hossain and M A I Khan

Table 2. List of backcrosses and number of seeds for respective cross, T. Aman 2019.

Generation	Cross	No. of seeds
BC2F1	BRRI dhan28*IRBB58	15
BC2F1	BRRI dhan28*IRBB60	16
BC2F1	BRRI dhan28**Pi9* (US)	24
BC2F1	BRRI dhan28**Pb1*/ BRRI dhan28**Pi9*(IR64)	9
BC3F1	BRRI dhan28*ST3/ BRRI dhan28**Pi9*(IR64)	32
BC_3F_1	BRRI dhan58**Pb1*/BRRI dhan58**Pi9*(IR64)//BRRI dhan58	69
BC_3F_1	BRRI dhan58* *Pi9* (IR64)	26
BC_3F_1	BRRI dhan58* *Pb1*	49
BC_2F_1	BRRI dhan58*ST3	18

Table 3. List of backcrosses and number of seeds for respective cross, Boro 2019-20.

Generation	Cross	No. of seeds
BC3F1	BRRI dhan28*IRBB58/ BRRI dhan28**Pi9* (US)	50
BC3F1	BRRI dhan28*IRBB60	75
BC2F1	BRRI dhan28**Pb1*/BRRI dhan28**Pi9*(IR64)//BRRI dhan28*IRBB58	29
BC4F1	BRRI dhan28*ST3/ BRRI dhan28**Pi9* (IR64)	80
BC_4F_1	BRRI dhan58**Pb1*/ BRRI dhan58**Pi9*(IR64)// BRRI dhan58	116
BC_4F_1	BRRI dhan58**Pi9*(IR64)	209
BC_4F_1	BRRI dhan58**Pb1*	80
BC_2F_1	BRRI dhan58**Pb1*/BRRI dhan58**Pi9*(IR64)// BRRI dhan58*ST3	160

Pyramiding of bacterial blight and blast resistance genes into the genetic background of BRRI dhan29 (BAS project)

To introgress bacterial blight (BB) and blast resistant genes in high yielding variety, parent materials were grown during T. Aman 2019 and Boro 2019-20. Four sets of parents were grown with seven days interval for the synchronization of flowering among the parents. Seeding was started from 15 July 2019 in Aman season and for Boro season it was started from 19 December 2019. In Aman 2019 four backcrosses were made to obtain BC3F1 seeds whereas in Boro season four selfing were made to obtain BB and blast resistant genes among the parents (Tables 4 and 5). Heterozygosity of the populations was confirmed through respective marker. After confirmation crossing was done to make next generation.

■ A K M S Islam, M A Latif, A H Khan

Gene pyramiding of BB resistance genes into the genetic background of BRRI dhan49, BRRI dhan63 and BRRI dhan81 (NATP-2)

To introgress bacterial blight (BB) resistant genes in high yielding variety, parent materials were grown during T. Aman 2019 and Boro 2019-20. Four sets of parents were grown with seven days interval for the synchronization of flowering among the parents. Seeding was started from 14 July 2019 in Aman season and for Boro season it was started from 22 December 2019. In Aman 2019 six backcrosses were made to obtain BC2F1 seeds whereas in Boro season, six backcrosses were also made among the parents to obtain BC3F1 population (Tables 6 and 7). Heterozygosity of the populations was confirmed through respective molecular marker. After confirmation, crossing was advanced to make next generation.

■ M A Latif, M A I Hasan, M A I Khan

Table 4. List of backcrosses and number of seeds for respective cross. (T. Aman 2019).

Generation	Cross	No. of seeds
BC3F1	BRRI dhan29*IRBB58	87
BC3F1	BRRI dhan29**Pi9* (IR64)	46
BC3F1	[BRRI dhan29**Pi9* (US)**Pb1* (US2)]	61
BC3F1	[BRRI dhan29*IRBB58*{BRRI dhan29**Pi9* (US)**Pb1* (US2)}]	53

Table 5: List of backcrosses and number of seeds for respective cross. (Boro 2019-20).

Generation	Cross	No. of seeds
BC3F2	BRRI dhan29*IRBB58	71
BC3F2	BRRI dhan29**Pi9* (IR64)	54
BC3F2	[BRRI dhan29**Pi9* (US)* *Pb1* (US2)]	59
BC3F2	[BRRI dhan29*IRBB58*{BRRI dhan29**Pi9*(US)**Pb1* (US2)}]	57

Table 6. List of crosses and number of seeds for respective cross combinations. (T. Aman 2019).

Generation	Cross combination	No. of seeds
BC_2F_1	BRRI dhan49*IRBB60	32
BC_2F_1	BRRI dhan63-Pb1*IRBB58	45
BC_2F_1	BRRI dhan81*IRBB60	50
BC_2F_1	BRRI dhan81*IRBB58	19
BC_1F_1	BRRI dhan63-Pb1*IRBB60	22
BC_1F_1	BRRI dhan49*IRBB58	16

Table 7. List of backcrosses and number of seeds for respective cross (Boro 2019-20).

Generation	Cross combination	No. of seeds
BC_3F_1	BRRI dhan49*IRBB60	35
BC_3F_1	BRRI dhan63-*Pb1**IRBB58	23
BC_2F_1	BRRI dhan81*IRBB60/ BRRI dhan81-*Pb1*	29
BC_2F_1	BRRI dhan81*IRBB58/ BRRI dhan81-*Pi9*	70
BC_2F_1	BRRI dhan63-*Pb1**IRBB60/ BRRI dhan63-*Pi9*	52
BC_2F_1	BRRI dhan49*IRBB58	46

Gene pyramiding for BB resistance (BAS project)

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. Tables 8 and 9 present the results. Pathogenicity results showed that a number of progenies of BC_4F_1, BC_3F_1 and BC_3F_3 developed from the crosses were resistant to the most virulent BB isolate BX_O93.

■ MA Latif, MK Hassan, AKMS Islam, MAI Khan

Screening of rice germplasm against BB disease (NATP-2)

A total of 350 rice germplasm along with checks were screened against virulent bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) isolates in T. Aman 2019 and Boro 2019-20. The experiment was conducted under field conditions using artificial inoculation. Among the 350 tested germplasm, 14 entries found resistant (Acc. no. 3101, 3103, 3105, 3124, 3134, 3155, 3159, 3160, 3161, 3163, 3165, 3169, 3179, 3277), eight were found moderately resistant and the others were moderately susceptible to highly susceptible to BB. The resistant checks were also showed resistance against BB.

■ M A Latif, M A I Hasan, T Ferdous, and M A I Khan

Confirmation of resistant genes of BB through gene base SSR markers through and pathogenicity test

A total of 78 rice germplasm was evaluated for confirmation of resistant genes against bacterial blight through gene base SSR markers and pathogenicity test in T. Aman 2019 and Boro 2019-20. Pathogenicity test was conducted under field conditions using artificial inoculation and confirmation of resistant genes were conducted in molecular lab, Plant Pathology Division, BRRI. Five specific SSR markers were used for confirmation of *Xa4, xa5, xa13, Xa21* and *Xa23* gene among the germplasm. Out of 78 germplasm (according to molecular data), three germplasm (Acc. no. 4216 and 7370) contained three resistant genes (*Xa4, xa5* and *xa13/Xa21*), 21 germplasm contained two resistant genes (*Xa4* and *xa5/ xa13/Xa21*) and the others had single or no resistant gene.

■ M A Latif, M A I Hasan, A Kabir, A Hossain and M A I Khan

Table 8. Development of BB resistant materials from the crosses of BRRI varieties and BB resistant pyramid lines of IR24 (T. Aman 2019).

Recipient/Recurrent	Donor		Present status
	Designation	Target *R* gene	
BRRI dhan29	IRBB58	*Xa4, xa13, Xa21*	29 seeds of BC3F1
CN6	IRBB60	*Xa4, xa5, xa13, Xa21*	24 seeds of BC3F2
BRRI dhan28	IRBB57	*Xa4, xa5, Xa21*	135 seeds of BC3F1
BRRI dhan28	IRBB60	*Xa4, xa5, xa13, Xa21*	22 seeds of BC3F1
BRRI dhan28	IRBB58	*Xa4, xa13, Xa21*	9 seeds of BC2F1
BRRI dhan28	ST3	*xa13, Xa2, Xa23*	15 seeds of BC2F1
BRRI dhan29	ST4	*xa13, Xa2, Xa23*	54 seeds of BC2F1
BRRI dhan58	ST3	*xa13, Xa2, Xa23*	55 seeds of BC2F1

Table 9. Development of BB resistant materials from the crosses of BRRI varieties and BB resistant pyramid lines of IR24 (Boro 2019-20).

Recipient/Recurrent	Donor		Present status
	Designation	Target *R* gene	
BRRI dhan29	IRBB58	*Xa4, xa13, Xa21*	30 seeds of BC4F1
CN6	IRBB60	*Xa4, xa5, xa13, Xa21*	70 seeds of BC3F3
BRRI dhan28	IRBB57	*Xa4, xa5, Xa21*	135 seeds of BC3F1
BRRI dhan28	IRBB60	*Xa4, xa5, xa13, Xa21*	75 seeds of BC4F1
BRRI dhan28	IRBB58	*Xa4, xa13, Xa21*	35 seeds of BC3F1
BRRI dhan28	ST3	*xa13, Xa2, Xa23*	70 seeds of BC3F1
BRRI dhan29	ST4	*xa13, Xa2, Xa23*	240 seeds of BC3F1
BRRI dhan58	ST3	*xa13, Xa2, Xa23*	160 seeds of BC3F1

Screening of blast, BB and tungro resistant monogenic lines in disease hot spots of Cumilla and Gazipur during T. Aman 2019 (BMZ)

Two field trials consisting of 98 near isogenic and advanced lines of BLB, blast and tungro including checks were conducted to evaluate against major diseases such as blast, BB and tungro in farmers field condition in disease hot spots of Cumilla and Gazipur during T. Aman 2019 and Boro 2019-20 seasons. No pesticides were applied in the field.

In Gazipur, during T. Aman 2019, only the local check BRRI dhan34 and IRBL20-IR24 showed susceptible reaction against blast. Due to low blast pressure, no symptoms were found in other materials. IRBB21, IRBB55, IRBB57, IRBB58, IRBB61, IRBB62, IRBB63, IRBB64 and IRBB66 showed resistant reactions while IRBB23 and IRBB53 showed moderately susceptible reaction against BB under field condition. IRRI134 showed highly susceptible reaction, IR77966-1-5-1-3-B-1 and IR108963-B (RTSV4-4-10-4) showed susceptible, and IR71030-2-2-1-4, IR77470-3-3-3-2-2 and IR108963-B (RTSV4-3-3-3) showed moderately susceptible reactions against tungro. No tungro symptoms were developed in rest of the tested materials. But no symptom of blast, BB and tungro were developed during Boro 2019-20 in natural condition.

In Cumilla, during T. Aman 2019, only five materials IRBL 1-CL, IRBL 5-M, IRBL 9-W, IR107736-7-1-2-1 including resistant check BRRI dhan74 showed resistant reaction and IRBL-sh showed moderately resistant reaction against blast. Only IRBB11 showed susceptible reaction against BB under field condition. IR73886-9-2-4-2-1 showed susceptible reaction against tungro under field condition. No tungro symptoms were developed in rest of the materials. No disease was observed in nine genotypes (Entry # 16, 42, 44, 45, 46, 76, 84, 86, 87 and 108) including BRRI dhan74 (Entry # 29, 53, 82). Among the blast resistant entries #1-46, # 95-98, # 16, 42, 44, 45, 46, 95 along with check BRRI dhan74 showed both leaf and neck blast resistant and entry # 5, 26, 96, 97, 98 showed neck blast resistant in the natural field condition. The bacterial blight resistant entries #47-73 including susceptible check didn't show bacterial blight symptom. All the tungro resistant lines # 74-91 along with checks didn't show tungro disease. Thirty-six genotypes including BRRI dhan29, BRRI dhan58, BRRI dhan74, BRRI dhan89 and BAU dhan-3 showed more than 6 t ha^{-1} yield during Boro 2019-20.

■ M A Latif, M M Rashid, S Miah, M A I Hasan and M A I Khan

Development of partial resistant pre-breeding materials for blast disease.

In T. Aman 2019, a total of 94 individuals of BC2F6 generation were evaluated for blast resistant *Pi9*, *Pb1* and *pi21* gene to develop partial resistant advanced line for blast disease. Three SSR markers *i.e.* RM8225, RM206 and RM1359 were used to detect the plants having *Pi9*, *Pb1* and *pi21* gene respectively. Out of 94 individuals, 71 had homozygous allele for *Pi9*, *Pb1 and pi21* gene; 17 had homozygous allele for *Pi9 and Pb1* gene and six had homozygous allele for *Pi9 and pi21* gene.

■ M A Latif, M A I Hasan, S A I Nihad, A Kabir, A Hossain and M A I Khan

Introgression of blast resistant genes into BRRI dhan47

In T. Aman 2019, a total of 68 homozygous (BC3F5) plant with *Pi40* gene (confirmed by RM547) were selected for RGA trial. In Boro 2019-20, the selected materials were in RGA. These materials were selected for LST in next season.

■ M A Latif, M T Islam and M A I Khan

Development of pre-breeding materials of tungro resistance

To introgress tungro resistant gene in high yielding variety, parent materials were grown during Aman 2019 and Boro season of 2019-20. Five sets of parents with seven days interval were grown for the synchronization of flowering among the parents. Seeding was starting from 14 July 2019 in Aman season and for Boro season it was starting from 6 December 2019-20. In Aman 2019 nine crosses (Tables 10 and 11) and in Boro season nine crosses (Table 11) 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, Q S A Jahan, T H Ansari, M A I Khan, M A Latif

Table 10. List of crosses and the number of seeds for the respective cross (T. Aman 2019).

Generation	Cross	No. of seeds
F1	BRRI dhan87*TW-16	95
F1	BRRI dhan87* IR71605-3-1-1-2-6	87
F1	BRRI dhan48* IR71605-2-1-5-3-4	84
BC2F1	BRRI dhan48*Kumragoir	70
BC2F1	BRRI dhan71*Sonahidmota	65
BC3F4	BRRI dhan71*TW-16	Seed harvested from 300 plants
BC3F4	BRRI dhan48*IR69705-1-1-1-4-2	Seed harvested from 300 plants
BC5F2	BRRI dhan71*TW-16	Seed harvested from 10 plants

Table 11. List of crosses and the number of seeds for the respective cross (Boro 2019-2020).

Generation	Cross	No. of seeds
BC1F1	BRRI dhan87*TW-16	74
BC1F1	BRRI dhan87* IR71605-3-1-1-2-6	72
BC1F1	BRRI dhan48* IR71605-2-1-5-3-4	68
BC3F1	BRRI dhan48*Kumragoir	76
BC3F1	BRRI dhan71*Sonahidmota	69
BC3F5	BRRI dhan71*TW-16	Seed harvested from 600 plants By following RGA method
BC3F5	BRRI dhan48*IR69705-1-1-1-4-2	Seed harvested from 600 plants By following RGA method
BC5F2	BRRI dhan71*TW-16	Seed harvest from 20 plants by following RGA.
BC5F2	BRRI dhan71*TW-16	Seed harvest from 20 plants by following RGA.

Linkage and QTL mapping of tungro resistance in rice (KGF project)

To identify QTLs with linked marker for tungro resistance in rice landrace Kumragoir; three sets of parents (Kumragoir and BRRI dhan48) were planted with seven days interval for flowering synchronization for hybridization. After successful crosses, BC2F1 and consecutively BC2F2 seeds were produced. A total of 400 SSR primers were surveyed and 98 primers (Fig. 9) were found polymorphic between two parents. Phenotyping and genotyping of 384 plants of BC2F2 generation were done by 98 SSR markers in Aman 2019 and Boro 2019-20. GLH was collected from the rice field of BRRI and reared in a cage (80 cm × 45 cm × 45 cm) for virus acquisition and transmission. Tungro virus particles (RTBV and RTSV) were detected by using molecular markers.

■ S A I Nihad, M A Rahman, M A Latif

Screening of rice genotypes against rice tungro disease

Thirty-nine genotypes were collected from the International Rice Research Institute (IRRI) and screened with rice tungro virus using susceptible check BRRI dhan11, BRRI dhan48, BRRI dhan49, BRRI dhan71. Myler cage as well as tray method were used to screen the rice genotypes. Briefly, 21-day-old seedlings were inoculated with green leafhopper (2 insect/per seedling) which is previously feed in infected tungro plants. After 21 days of inoculation, data were recorded on disease severity and incidence following the standard evaluation system (SES, 2014). Among the genotypes nine were resistant (IR69705-1-1-1-4-2, IR69705-1-1-1-4-3, IR71605-2-1-5-3-4, IR71605-3-1-1-2-6, IR81244 (TW-16), Matatag 9, Utri Merah-16680, Utri Merah-16682, Utri Rajapan.), nine were moderately resistant and 21 were found susceptible after screening.

■ S A I Nihad, A Kabir, M A I Hasan and M A Latif

Introgression of *Pi9* or *Pita2* gene in BRRI dhan29/BRRI dhan63 (KGF project)

Advanced breeding lines having *Pi9* gene were introgressed in the background of BRRI dhan29 and BRRI dhan63. Different back cross generations of BRRI dhan29-*Pi9* (BC1F4, BC2F3, BC3F3) and BRRI dhan63-*Pita2* (BC6F4, BC5F5, BC4F6, BC3F7) were selected for further evaluation.

■ T H Ansari, M Ahmed, M S Rahman and M A Rahman

Pyramiding blast resistant *Pita2* and *Pi9* genes into Boro varieties (KGF project)

Introgression of both leaf blast resistant *Pita2* and leaf as well as panicle blast resistant *Pi9* genes were introgressed in the background of BRRI dhan28, BRRI dhan29, BRRI dhan63. BC2F1 seeds of BRRI dhan28, BC1F1 seeds of BRRI dhan29 and BRRI dhan63 were harvested for further advancement.

■ T H Ansari, M Ahmed, M S Rahman and M A Rahman

Linkage and QTL mapping of BR16

BR16 has been detected as resistant to rice blast in Plant Pathology Division, BRRI. An attempt has been made to identify blast resistant QTLs in BR16. F1 seeds were produced by hybridization between BR16 and a universal blast susceptible variety US2 in T. Aman 2019. Further BC1F1 seeds were produced through back crossing with US2.

■ T H Ansari, M Ahmed and M S Rahman

Screening of rice germplasm against sheath blight

Thirty-five local rice germplasm were tested in Aus 2019 against sheath blight disease following standard protocol. The relative lesion height (RLH) ranged from 20-100%. Among the tested materials, Acc. no. 5056 (20%), Acc no. 499 (25%) and Acc no. 4362 (30%) showed moderate resistance against the sheath blight disease.

■ T H Ansari, M S Mian and M Ahmed

Screening of rice germplasm against bakanae disease.

Ninety germplasms were screened out against virulent isolate of bakanae disease following standard protocol. Six entries were found resistant against bakanae disease.

■ Q S A Jahan and M A Latif

Screening of advanced breeding lines against bacterial blight (TRB)

A total of 833 advanced breeding lines including OYT, AYT and RYT were inoculated with most virulent bacterial blight (BB) isolate during Boro 2019-20 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 833 entries, 139 materials were found resistant. These materials are needed to evaluate further for confirmation.

■ M A I Khan, S Das, M Al-Imran Hasan, A Ara, M Khatun, P S Biswas and M A Latif

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 marker 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 BC2F2 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 2019-2020 at BRRI HQ, Gazipur for yield performance and blast hot spot in 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 will be cultivated in coming T. Aman season 2020 and then again will be evaluated for neck blast resistance at blast hot spot of Gazipur and Cumilla during Boro 2020-21 season.

■ M A I Khan, 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

Studies are being conducted with 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 studies between BRRI dhan33 and US2, a universal blast susceptible variety. Among 625 markers, 184 showed polymorphic. The phenotyping against neck blast disease has been completed (Fig. 10) and phenotyping against gall midge is going on at Entomology Division. Genotyping and also phenotyping against different blast races will be done in next year.

■ M A I Khan, M A I Hasan, S A I Nihad, Mofazzel Hossain, Y Fukuta and M A Latif

Disease severity index (0–9) of neck blast was calculated following SES 2013, IRRI, Philippine.

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

Blast and bacterial blight (BB) are the two major rice diseases in Bangladesh. For developing resistant variety, candidate resistant genes *Pi9* for blast (Khan et al. 2016) and *Xa21* for BB (Khan et al. 2010) have already identified using differential system in Bangladesh. IRRI has already done rice genome sequence (3K rice genome database) including Bangladeshi 186 germplasm but this information is not yet used substantially for disease resistance studies at BRRI. To find out the sources of blast and bacterial blight disease resistance, a dry lab characterization of these germplasm was done using bioinformatics tools. Data showed that 6.45% germplasm harboured blast resistant *Pi9* gene and 18.28% harboured BB resistant *Xa21* gene in their genetic background. In addition, 12 materials were found those harboured both *Pi9* and *Xa21* in their genetic background. This information will immensely contribute to develop disease resistant varieties in Bangladesh.

■ M A I Khan, Md Ruhul Quddus, M Rafiqul Islam, M Sazzadur Rahman, Anjuman Ara, S A I Nihad, Montasir Ahemd, M M Rashid and M A Latif

Development of blast resistant 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 *ERF922* coding sequence (*LOC_Os01g54890*). The target site was ligated with an intermediate vector SK-gRNA sequence (Fig. 11). Final vector construction will be completed by ligation of the target with SK-gRNA to pC1300-Cas9 vector.

■ M A I Khan, Hirendronath Barmon, S A I Nihad, Rumana Akter and M A Latif

Screening of advanced breeding line against sheath blight of rice

In T. Aman 2019-20, a total of 40 materials including six checks were screened against sheath blight disease to identify resistant genotypes. The experiment was conducted in BRRI farm by artificial inoculation. Plants were inoculated with pathogen at maximum tillering to booting stage using mycelial plug placement in the center 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. None of the materials showed resistant reaction against the disease.

■ S. Akter and M A Latif

Disease reactions and characterization of upland rice germplasm

The experiment was conducted to know the different disease status and to identify the best genotype for yield. A total of 24 upland germplasm was evaluated and four genotypes namely Chirikata 2, IR 5533-50-1-10, IR 9559-PP 871-1, and Ja No Naq were found resistant to moderately resistant against all diseases and produced high yield under natural infection.

■ M Tuhina-Khatun, B Nessa and M A Latif

Screening of INGER materials obtained from IRRI against blast disease of rice, Boro 2019-20.

A total 136 INGER materials were collected from IRRI. Among them 91 materials were tested against leaf blast disease in blast nursery, BRRI, Gazipur. The rest 45 materials were not germinated in the 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, 22 entries such as SVIN366, SVIN360, SVIN322, SVIN345, SVIN368, SVIN421, SVIN370, SVIN309, SVIN349, SVIN420, SVIN293, SVIN363, SVIN314, SVIN360, SVIN334. SVIN362, SVIN334, SVIN313, SVIN349, SVIN369, SVIN316 and SVIN350 showed resistance. But these materials need further test to confirm the resistance.

■ M S Mian and M A Latif

Screening of advanced breeding lines against blast disease of rice, Boro 2019-20

Thirty advanced breeding lines (twenty-seven lines from Plant Breeding Division and three from Biotechnology Division) were found for screening against blast disease. The advanced breeding lines were tested under artificial inoculation method in blast nursery, BRRI, Gazipur. Among the tested materials, only one line (BR9891-8-2-1-41) showed resistance. This line needs further test to confirm the resistance.

■ M S Mian and M A Latif

Screening of INGER materials against bacterial blight disease

INGER materials from IRRI were tested against BB diseases to find out the durable BB resistant materials. A total of 168 materials were screened against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen including resistant check as IRBB60, IRBB65 and susceptible check as Purbachi, TN1. The experiment was conducted under field condition during T. Aman,2019. Plants were inoculated with most virulent isolate of major race (BXO97) at maximum tillering stage. Data on percent leaf area damage were collected 21 days after inoculation. A total of 168 materials excluding susceptible and resistant checks, 29 of INGER materials such as SVIN365, SVIN350, SVIN228, SVIN222, SVIN341, SVIN313, SVIN310, SVIN227, SVIN334, SVIN237, SVIN442, SVIN446, SVIN281, SVIN438, SVIN362, SVIN223, SVIN303, SVIN327, SVIN313, SVIN281, SVIN226, SVIN440, SVIN368, SVIN225, SVIN216, SVIN360, SVIN367, SVIN300, LC1 showed moderately resistance against major BB isolate but no resistant material was found.

■ A Ara, M A I Khan, M M Rashid and M A Latif

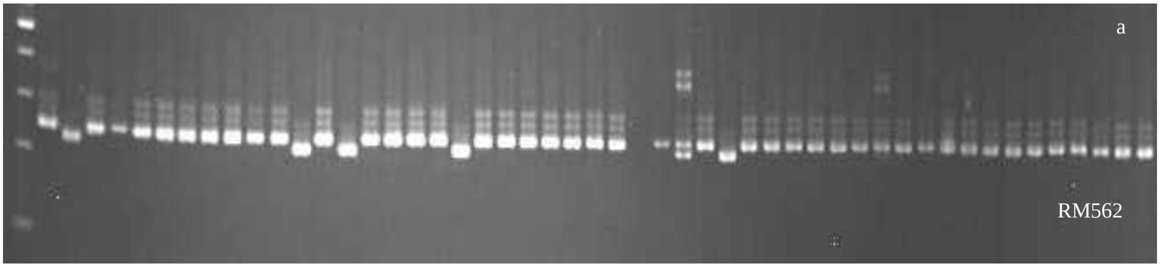

Fig. 9. A partial view of genotyping of BC2F2 population through molecular.

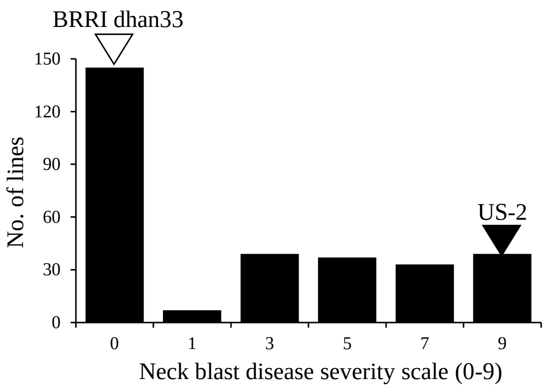

Fig 10. Frequency distribution of disease severity of neck blast resistance in 300 BC1F2 family lines of US2/BRRI dhan33//US2.

Screening of advanced breeding lines against BB disease during T. Aman 2019 and Boro 2019-20

In T Aman 2019, a total of 54 materials and in Boro 2019-20, a total of 37 materials including resistant checks and susceptible checks were screened against bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) pathogen. The experiment was conducted under field conditions using artificial inoculation during T. Aman 2019 and Boro 2019-20 season. Plants were inoculated with a virulent isolate of the major race, BXO97 at maximum tillering stage following leaf clipping method. The disease severity data were recorded at 21 days after inoculation from 10 leaves in each entry. In T Aman 2019, among 54 genotypes including resistant checks and susceptible checks, BR9871-29-1-3-B was found as resistant material and three materials like BR9571-28-2-1-2-1, BR10001-94-2-B and BR(Bio)10376-AC4-1-3) were found as moderately resistant against bacterial blight disease. In Boro19-20, among 37 tested germplasms, two materials like BR(Bio)11447-1-28-14-3 and BR(Bio)11447-3-10-7-1 and four materials like BR8912-12-6-1-1-1-1, BR9669-23-3-2-23, BR9891-17-2-2-23 and BR(Path)12452-BC3-16-19 were found as resistant and moderately resistant respectively against bacterial blight disease.

■ A. Ara, M M Rashid, M A I Khan and M A Latif

DISEASE MANAGEMENT

Control of rice seedling blight disease

Twelve fungicides were evaluated against seedling blight disease in the tray seedling of rice. Seed treatment was done at 0.3% fungicide solution and seedling was raised in trays following the standard tray seedling of rice (TSR) protocol suggested by Plant Pathology Division, BRRI. Among the tested fungicides six fungicides eg, Alix, Azonil. Limostar top, M-zole and tramp were found effective as like as the standard check fungicide Amistar top which produced no infection. Other tested fungicides produced 10.7-46.7% seedling infection along with 53.3% infection in the control treatment.

■ T H Ansari and M Ahmed

Evaluation of effective chemical against sheath blight disease of rice, T. Aman 2019

The experiment was conducted at BRRI HQ, Gazipur and BRRI RS, Rajshahi farm under artificial inoculation condition to determine the efficacy of new fungicides against sheath blight disease. Twenty fungicides with disease control and standard check (Nativo) treatment were tested. Thirty-day-old seedlings of BR11 were transplanted with 20 cm × 15 cm spacing having 2-3 seedlings/hill during T. Aman season. The plot size was 1 m × 1 m with three 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 5 days after inoculation and second at seven days after first spray. Data on relative lesion height (RLH) was taken at dough stage. Among 20, five fungicides such as VAI-Two 35 SC (Azoxystrobin 20%+ Tebuconazole 15%), SR TOP 32.5 SC (Azoxystrobin 20%+ Difeconazole 12.5%), Cropstar 32.5 SC (Azoxystrobin+ Difeconazole), Ulka Plus 35 SC (Azoxystrobin+Tebuconazole) and Admine Top 35 SC (Azoxystrobin 20%+ Tebuconazole 15%SC) (Table. 4) controlled Sheath blight disease successfully (equal or above 80%) in both BRRI, Gazipur and Rajshahi farm.

■ A Ara, M S Miah, A B M A 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 CBD28 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 three 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 2019-20. Among them, only seven fungicides (mostly of tricyclazole group) controlled more than 80% blast disease. These selected fungicides will be evaluated again and then will be recommended to Plant Protection Wing, DAE for registration.

■ M A I Khan, M. Tuhina-Khatun, and M A Latif

Biocontrol of soil diseases associated with rhizosphere of rice (*Oryza Sativa* Subsp. *Japonica*) growing field in Kansai region, Japan

This research focused on in vitro and in vivo biocontrol of two major rice diseases, bacterial leaf blight caused by *Xanthomonus oryzae pv oryzae* (*Xoo*) and sheath blight caused by *Rhizoctonia solani*. Furthermore, the soil of paddy fields in Kansai region, Japan was analyzed for the presence of these pathogens, and their microbial communities were evaluated according to the location and management systems. For biocontrol, the rhizospheric bacteria were isolated and molecularly identified. The results indicated that DAR17225040 and DAR17225017 were 99% similar to *Bacillus aryabhattai and Bacillus megaterium*. The isolated bacteria were able to suppress bacterial leaf blight and sheath blight disease 78% and 86% respectively, under greenhouse conditions**.**

■ H A Dilzahan

Technology dissemination

The Plant Pathology Division used to provide advisory and clinical services to farmers and SAAO and NGO personnel in identifying the diseases along with necessary disease management prescriptions. During the reporting year, 65 (clinical services) samples from farmers' field have been diagnosed and control measures have been advocated. In addition, scientists visited different rice fields across the country with the request of DAE and local representatives.

■ All scientists of Plant Pathology Division

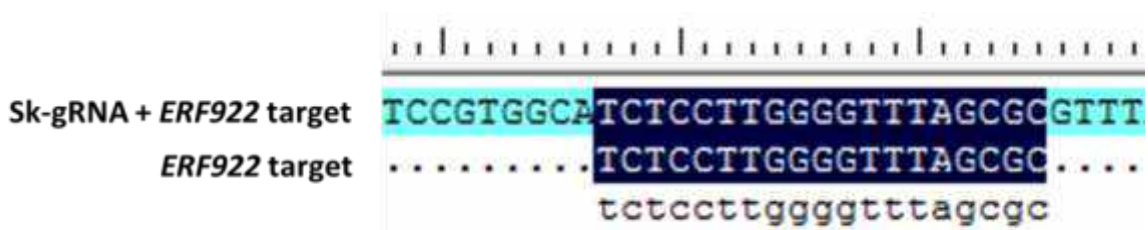

Fig. 11. Alignment of the target site of *ERF922* and the sequence of SK-gRNA ligated with the target site of *ERF922*.

Rice Farming Systems Division

SUMMARY

In four crop cropping system, among the tested cropping patterns the highest rice equivalent yield (26.40 t ha^{-1}) was obtained from Field pea-Mungbean-T. Aus-T. Aman cropping pattern followed by Potato-Sweet gourd-T. Aus-T. Aman cropping pattern (24.47 t ha^{-1}).

In T. Aman season, BRRI dhan87 and BRRI dhan71 yielded significantly higher than BRRI dhan57, whereas in the Boro season, BRRI dhan58 gave significantly higher yeild than BRRI dhan63 with different varietal combination of T. Aman and Boro rice in Boro-Fallow- T. Aman cropping pattern. Supplemental irrigation in T. Aman did not produce any significant yield difference.

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* and IR 15D 1055 yielded significantly higher than the intolerant check (Ciherang-Sub1) under flooding stress.

Four cropping patterns were tested in Madhupur Tract and saline ecosystem and among the evaluated patterns, Watermelon-Fallow-T. Aman yielded relatively higher (23.90 t ha^{-1}) rice equivalent yield which was around 121% more than the existing Boro-Fallow-T. Aman cropping pattern.

In Chattogram hill tract area we introduced T. Aus in Fallow-Fallow- T. Aman cropping pattern in six upazilas. In Aus season average yield of BRRI dhan48 and BRRI dhan82 was 4.43 t ha^{-1}. In T. Aman season, BRRI dhan70, BRRI dhan71, BRRI dhan75, BRRI hybrid dhan6 produced similar yield (4.60 t ha^{-1}).

We incorporated mustard in Boro-Fallow-T. Aman cropping pattern in the plain land of hilly area. Mustard-BRRI dhan84-BRRI dhan70 produced 47% higher REY than the existing check cropping pattern, Mustard-Jonokray-BRRI dhan49.

For fertilizer management of Aus rice in hilly area, row placement of fertilizer around dibbling hole produced more than 1 t ha^{-1} yield advantages over farmers' practice.

Under piloting of cropping pattern technologies programme, among the evaluated cropping patterns BARI Alu32-BJRI tosha pat8-BRRI hybrid dhan6 cropping pattern had relatively higher REY (27.39 t ha^{-1}), which was 171% more yield than the existing cropping pattern Boro-Fallow-T. Aman followed by Mustard-Boro-T. Aman cropping pattern in Kishoreganj. In Khulna, incorporation of Mustard in existing cropping pattern Boro-Fallow-T. Aman increased 28% REY.

CROPPING PATTERN DEVELOPMENT FOR FAVOURABLE ECOSYSTEM

Development of four-crop cropping pattern for favourable irrigated ecosystem in medium highland

The experiment was conducted during 2019-20 at the experimental farm, BRRI HQ, Gazipur to increase total productivity of unit area per year by increasing cropping intensity and to compare the sustainability of four-crop cropping patterns with that of three-crop cropping patterns in terms of soil health and economic profit. The tested cropping patterns were, CP_1= Field pea-Mungben-T. Aus-T. Aman, CP_2= Potato/Pumpkin (Relay)-T. Aus-T. Aman, CP_3= Mustard-Boro-Jute-T. Aman, CP_4= Wheat-T. Aus-T. Aman (ck_1) CP_5= Mustard-Mungbean-T. Aus-T. Aman (ck_2) and CP_6= Potato-Mungbean-T. Aus-T. Aman (ck_3). The experiment was conducted in a RCB design with three replications. Initial soil sample was collected at the beginning of the experiment. Rice variety BRRI dhan28 was used in Boro season in CP_3. BRRI dhan48 was used in T. Aus and BRRI dhan49, BRRI dhan57, BRRI dhan71 and BRRI dhan75 were used in CP_4, CP_6, $CP_{1,2,3}$ and CP_5, respectively for T. Aman season. Potato, field pea, wheat, pumpkin and mustard varieties were Asterix, BARI Motor-3, BARI Gom-30, lalteer and BARI Sarisha-14, respectively. The yield of each crop was converted to REY for comparing the system productivity.

Table 1 presents individual crop yield and REY of respective cropping patterns. Mustard was cultivated under zero tillage condition in CP_3 and yielded 0.65 t ha^{-1} whereas in CP_5 yield was 1.21 t ha^{-1} which was cultivated under conventional method. Field pea was harvested as green pod and yielded 4.88 t ha^{-1}. Wheat and sweet gourd yielded 3.28 t ha^{-1} and 11.9 t ha^{-1}, respectively under respective cropping patterns. Yield of Boro rice was 5.3 t ha^{-1} under Mustard-Boro-Jute-T. Aman cropping pattern (CP_3). Yield of T. Aus and T. Aman rice were ranged from 4.67-4.93 t ha^{-1} and 3.82-5.20 t ha^{-1}, respectively in different cropping patterns. Among the tested cropping patterns, the highest rice equivalent yield (26.40 t ha^{-1}) was obtained from Field pea-Mungbean-T. Aus-T. Aman cropping pattern (CP_1) which was statistically similar to that of Potato Pumpkin (Relay)-T. Aus-T. Aman cropping pattern (CP_2) (24.47 t ha^{-1}). CP_6 produced the rice equivalent yield of 20.69 t ha^{-1} which was statistically lower than that of CP_1 and CP_2 but higher than all the other tested cropping patterns. The REY of CP_4 (13.73 t ha^{-1}) was statistically similar with that of CP_3 (12.08 t ha^{-1}) and CP_5 (16.22 t ha^{-1}). The lowest REY (12.08 t ha^{-1}) was observed in CP_3 as jute was not possible to establish in CP_3.

Table 1. Yield of different crops under four crop cropping pattern experiment, Gazipur, 2019-20.

Treatment	Grain/Tuber/Pod yield (t ha^{-1})									REY (t ha^{-1})
	Mustard	Field pea	Potato	Wheat	Boro	M. bean	S. gourd	T. Aus	T. Aman	
CP_1		4.88				1.16		4.90	5.12	26.40[a]
CP_2			12.0				11.9	4.67	5.2	24.47[a]
CP_3	0.65				5.3			-	4.98	12.08[d]
CP_4				3.28				4.93	4.79	13.73[cd]
CP_5	1.21					0.87		4.80	4.94	16.22[c]
CP_6			13.37			1.25		4.93	3.82	20.69[b]
CV (%)						5.38				
LSD						2.89				

Means with the same letter are not significantly different. Price: Mustard = 50 Tk/kg, Field pea = 45Tk/kg, Potato = 10Tk/kg, Wheat = 22 Tk/kg, Rice = 18 Tk/kg, Mungbean = 65 Tk/kg, Sweet gourd = 12 Tk/kg.

From the economic analysis, it was observed that the highest gross margin was obtained from CP_1 (2, 12,200 Tk/ha) followed by CP_2 (1, 16,160 Tk/ha). CP_5, CP_6 and CP_4 earned the gross margin of 67,560 Tk/ha, 64,120 Tk/ha and 47,740 Tk/ha respectively. The lowest gross margin (30,940 Tk/ha) was obtained from the cropping pattern, CP_3 (Table 2).

Table 2. Economic performance of different cropping patterns, BRRI, Gazipur 2019-20.

Cropping pattern	TVC (000 Tk/ha)	GR (000 Tk/ha)	GM (000 Tk/ha)
CP_1=Field pea-MB-T. Aus-T. Aman	263.0	475.20	212.2
CP_2=Potato\Pumpkin-T. Aus-T. Aman	324.3	440.46	116.16
CP_3=Mustard-Boro-Jute-T. Aman	186.5	217.44	30.94
CP_4=Wheat-T. Aus-T. Aman	199.4	247.14	47.74
CP_5=Mustard-MB-T. Aus-T. Aman	224.4	291.96	67.56
CP_6=Potato-MB-T. Aus-T. Aman	308.3	372.42	64.12

TVC-Total variable cost, GR-Gross return, GM-Gross margin.

Identification of rice variety in Boro-Fallow-T. Aman cropping system for sustainable productivity

The experiment was conducted during 2019-20 at BRRI research field, Gazipur to evaluate the suitability and performance of T. Aman and Boro varieties for sustaining the productivity in Boro-Fallow-T. Aman cropping system under supplemental irrigation in T. Aman. The treatments consisted of ten combinations of T. Aman and

Boro varieties and supplemental irrigation in T. Aman season in RCB design with three replications. In T. Aman season there were three varieties, BRRI dhan87 was used as a moderately long duration variety and BRRI dhan57 and BRRI dhan71 as short duration rice variety. In Boro season, BRRI dhan63 and BRRI dhan58 were transplanted alternately with each treatment combination (Table 3) as follows:-

Land preparation and intercultural operation was done as and when necessary. Fertilizers and pesticides were sprayed as per BRRI recommendation (Adhunik Dhaner Chash). Aman rice was transplanted on 28 July 2019 with 20-25-day-old seedlings while in Boro season transplanting was done on 10 January 2020 with 35-day-old seedling.

The results illustrate that in Aman season there was a significant yield difference among the varieties where BRRI dhan87 produced the highest yield (6.05 t ha^{-1}) and BRRI dhan57 produced the lowest yield (4.05 t ha^{-1}) (Table 3). In Boro season BRRI dhan58 produced significantly higher yield than BRRI dhan63 in all the treatments. The highest yield of BRRI dhan58 was observed, 6.66 t ha^{-1} from T_6 (BRRI dhan71+SI (2-3)-BRRI dhan58) treatment. During Aman 2019 season, no supplemental irrigation was needed due to abundant rainfall. Considering the total rice yield from the pattern, Boro-Fallow-T. Aman, it was found that during 2019-20, T_2 (BRRI dhan87 + SI (2-3)-BRRI dhan58) and T_4 (BRRI dhan87-BRRI dhan58) treatments produced statistically similar yield of 12.43 t ha^{-1} and 12.49 t ha^{-1} respectively which was significantly higher than the other treatments. The lowest yield of rice (9.36 t ha^{-1}) was found from BRRI dhan57-BRRI dhan63 varietal combination under treatment T_9. From the present findings, we conclude that farmers can choose BRRI dhan87 in Aman season with BRRI dhan58 in Boro for obtaining maximum rice yield under Boro-Fallow-T. Aman cropping pattern.

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 3. Yield of different Aman and Boro rice varieties, BRRI, Gazipur, 2019-20.

Varietal combination + supplemental irrigation	T. Aman yield (t ha^{-1})	Boro yield (t ha^{-1})	Total yield (t ha^{-1})
T_1= BRRI dhan87 + SI (2-3)-BRRI dhan63	6.05 a	5.34 b	11.39 bcd
T_2= BRRI dhan87 + SI (2-3)-BRRI dhan58	5.85 a	6.57 a	12.43 a
T_3= BRRI dhan87-BRRI dhan63	6.01 a	5.41 b	11.42 bcd
T_4= BRRI dhan87-BRRI dhan58	6.01 a	6.48 a	12.49 a
T_5= BRRI dhan71 + SI (2-3)-BRRI dhan63	5.91 a	5.42 b	11.33 bcd
T_6= BRRI dhan71 + SI (2-3)-BRRI dhan58	5.47 a	6.66 a	12.13 ab
T_7= BRRI dhan71-BRRI dhan63	5.69 a	5.35 b	11.04 cd
T_8= BRRI dhan71-BRRI dhan58	5.53 a	6.32 a	11.85 abc
T_9= BRRI dhan57-BRRI dhan63	4.05 b	5.31 b	9.36 e
T_{10}= BRRI dhan57-BRRI dhan58	4.18 b	6.44 a	10.62 d
CV (%)	4.80	3.18	6.78

Means with the same letters are not significantly different. SI = Supplemental irrigations

DEVELOPMENT OF CROPPING PATTERN FOR STRESS PRONE AREA

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 2019-20 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 was recorded in both T. Aman and Boro seasons. Among the tested genotypes, Ciherang-Sub1-*AG1-AG2* and IR 15D 1055 yielded significantly higher yield than the intolerant check (Ciherang-Sub1) under flooding stress (Table 4).

Productivity evaluation of different cropping patterns in saline ecosystem

The experiment was conducted at Dhigholia, Dacope and Daulotpur, Khulna during 2019-20 with the four cropping patterns; CP_1: Mustard (BARI Sorisha-14)-Boro (BRRI dhan67)-T. Aman (BRRI dhan76), CP_2: Wheat (BARI Gom-25)-Sesame-T. Aman, CP_3: Watermelon–Fallow-T. Aman, CP_4: Boro-Fallow-T. Aman. Rice equivalent yield was computed at harvesting time. Among the tested cropping patterns, Watermelon-Fallow-T. Aman yielded relatively higher REY (23.90 t ha^{-1}), which was 121% higher than the existing Boro-Fallow-T. Aman cropping pattern followed by Mustard-Boro-T. Aman cropping pattern (Table 5).

Improvement of Boro-Fallow-T. Aman cropping pattern through inclusion of oil seed, pulses and Aus rice

The activity was undertaken at the FSRD site Tengra, Sreepur, Gazipur during 2019-20 to validate different cropping patterns technologies by introducing short duration variety of mustard, mungbean and Aus rice to increase land productivity by introducing new crops in the existing pattern. Two improved patterns viz IP_1: Mustard-Boro-T. Aman, IP_2: Mustard-Mungbean-T. Aus-T. Aman were tested against existing Boro-Fallow-T. Aman cropping pattern. For each new pattern three dispersed farmers were selected. 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

Table 4. Yield (t ha^{-1}) of different rice genotypes under flooding stress in Boro-Fallow-T. Aman cropping pattern, BRRI, Gazipur, 2019-20.

Treatment	T. Aman		Boro	
	Flood	Control	Flood	Control
Ciherang-Sub1-*AG2*	2.71	2.83	3.18	3.31
Ciherang-Sub1-*AG1-AG2*	3.12	3.37	3.83	4.57
IR 15D 1055	3.17	3.35	3.11	3.70
IR 15 D1037	2.89	3.04	2.79	3.85
BR8210-10-3-1-2	1.93	2.28	2.99	4.33
Ciherang-Sub1 (ck)	2.52	2.67	2.67	3.55
KHO (ck)	2.25	2.35	3.10	3.77
$HSD_{(0.05)}$	0.61		0.32	

Table 5. Yield and rice equivalent yield (REY) of different cropping patterns, Khulna, 2019-20.

Treatment	Yield (t ha^{-1})			REY (t ha^{-1})
	Mustard/Wheat	Boro/Sesame	T. Aman	
CP_1: Mustard-Boro-T. Aman	1.10	5.67	5.08	11.80
CP_2: Wheat-Sesame-T. Aman	2.45	-	4.79	8.22
CP_3:Watermelon–Fallow-T. Aman	33 .12	-	5.68	23.90
CP_4: Boro-Fallow-T. Aman	-	5.83	4.94	10.77

Price (Tk/kg): Rice-20/-; Wheat- 28/-; Mustard-45/-, Watermelon-11/-. Note: Sesame was damaged due to heavy rainfall.

mustard and mungbean; BARI sorisha-14 and BARI moog-6 were used, respectively. Recommended management practices were followed for each crop. The yield of each crop was converted to rice equivalent yield (REY) to compare the system productivity.

Table 6 presents individual crop yield and rice equivalent yield of the respective cropping patterns. Mustard yielded 1.22 to 1.26 t ha^{-1} in CP_2 and CP_3. In the existing cropping pattern Boro rice (BRRI dhan28) yield was 4.22 t ha^{-1} whereas it was 5.25 t ha^{-1} for improved pattern (BRRI dhan84). Yield of mungbean was 0.9 t ha^{-1} in CP_3. Aus rice yielded 4.62 t ha^{-1}. T. Aman yield was ranged from 4.16 t ha^{-1} to 5.12 t ha^{-1} in different cropping patterns. Considering REY both the proposed patterns produced higher yield than the existing Boro-Fallow-T. Aman cropping pattern. The highest REY (16.23 t ha^{-1}) was obtained from Mustard-Mungbean-T. Aus-T. Aman cropping pattern and the lowest (8.38 t ha^{-1}) in the farmers existing Boro-Fallow-T. Aman cropping pattern.

From the economic analysis it was observed that the highest gross margin was obtained from CP_3 (64,740 Tk/ha).The gross margin from CP_2 was 54,960 Tk/ha. The lowest gross margin (13640 Tk/ha) was obtained from the cropping pattern CP_1. The CP_3 and CP_2 produced about 374% and 302% higher GM compared to the existing pattern CP_1 (Table 7).

Intensification of single Boro cropping pattern by inclusion of deepwater rice (DWR) in flood prone ecosystem

The area under deepwater ecosystem in the greater Kushtia is not significant. It covers around 12 thousand hectares representing 3% of the net cropped area. Lion-share of the ecosystem is occupied by Boro-Fallow-Fallow cropping pattern. A minor area is under Boro-B. Aman. Other negligible cropping patterns are those where B. Aman crop is followed by some Rabi crops. Demand of more production of food is pushing us for intensification of single Boro area. In this ground, an attempt was made to replace the existing single Boro cropping pattern by Boro-B. Aman pattern. A cropping pattern trial of Boro-B. Aman was conducted at Kumarkahli upazila of Kushtia district. Eighteen farmers were involved in the activity. All the plots were adjacent to each other. Total area of the block was 3.12 hectares. Sowing dates in the seedbed for BRRI dhan29 during Boro season were 20-25 November 2018 which was harvested by the 1st week of May 2019. Deepwater rice was sown during 15-20 May and was harvested on the 30th November 2019. Seeds, fertilizers and pesticides were supplied to the farmers.

Table 8 presents the grain yield and profitability of the cropping patterns. There was no significant yield difference among the plots of Boro crop and also for DW Aman crop. Over all gross return for Boro-Deepwater Aman was around 23% higher than the single Boro cultivation, which was treated as control plot.

Table 6. Yield of different crops under existing and improved cropping patterns, Tengra, Sreepur, Gazipur, 2019-20.

Cropping pattern	Mustard (t ha^{-1})	Boro (t ha^{-1})	Mungbean (t ha^{-1})	T. Aus (t ha^{-1})	T. Aman (t ha^{-1})	REY (t ha^{-1})
Existing Pattern						
CP_1:Boro - Fallow - T. Aman	-	4.22	-	-	4.16	8.38
Improved Pattern						
CP_2: Mustard-Boro-T. Aman	1.22	5.25	-	-	5.12	13.76
CP_3: Mustard-Mungbean-T. Aus-T. Aman	1.26	-	0.9	4.62	4.86	16.23

Market price: Rice@ 18 Tk/kg, Mustard@ 50 Tk/kg and Mungbean@ 65 Tk/kg.

Table 7. Economic performance of different cropping patterns, Tengra, Sreepur, Gazipur, 2019-20.

Cropping pattern	TVC (000 Tk/ha)	GR (000 Tk/ha)	GM (000 Tk/ha)
CP_1:Boro - Fallow - T. Aman	157.2	170.84	13.64
CP_2: Mustard-Boro-T. Aman	212.7	267.66	54.96
CP_3: Mustard-Mungbean-T. Aus-T. Aman	242.4	307.14	64.74

Table 8. Grain yield of Boro and DWR and system productivity of different cropping patterns, 2019-20.

Cropping pattern	Grain yield ($t\ ha^{-1}$)			GR ('000 Tk)	Increase over control (%)
	Boro	Deepwater Aman	Total		
BRRI dhan29-Dudh Raj (average of 11 plots)	8.05	1.75	9.80	173.69	22.98
BRRI dhan29-Digha (average of seven plots)	8.10	1.72	9.82	174.00	23.20
BRRI dhan29-Fallow-Fallow (control) (average of 10 plots)	8.07	-	8.07	141.23	-

Market price: BRRI dhan29= 17.50 Tk/kg; Digha or DudhRaaj= 18.75 Tk/kg

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' fields in Rajasthali and Baghaichhari upazilas in Rangamati district and Dighinala and sadar upazilas of Khagrachhari district during Aus 2019 and Aman 2018. Promising Aus varieties BRRI dhan48 and BRRI dhan82 and T. Aman varieties BRRI dhan49, BRRI dhan70, BRRI dhan71, BRRI dhan75 and BRRI Hybrid dhan6 were tested in the trials. This activity was executed in collaboration with Department of Agricultural Extension (DAE). In the study area farmers adopted BR11 and Babilon in T. Aman season. BRRI provided quality seeds, fertilizers and pesticides while the rest of management was done by the farmers. A total of 24 trials were conducted at six upazilas.

In T. Aus season, the grain yield of BRRI dhan48 ranged from 4.21 to 4.66 $t\ ha^{-1}$ at different upazilas. BRRI dhan82 yielded 4.41 to 4.61 $t\ ha^{-1}$ at different upazilas . In T. Aman season, BRRI dhan75 produced 4.58 to 4.74 $t\ ha^{-1}$ at different locations under Fallow-T. Aus-T. Aman cropping pattern. BRRI dhan70, BRRI dhan71 and BRRI Hybrid dhan6 obtained the average grain yield of 4.49, 4.63 and 4.63 $t\ ha^{-1}$ at different locations. Thus inclusion of Aus rice in existing Fallow-Fallow-T. Aman cropping pattern and using appropriate T. Aman varieties the productivity could be increased significantly.

Improvement of *Jhum* cultivation through the replacement of local rice with the modern Aus rice in hilly areas

Twenty-one trials in *Jhum* cultivation system were conducted in eight upzillas of Bandarban, Rangamati and Khagrachhari districts under Chattogram Hill Tracts agricultural region during Aus 2019. Promising modern rice varieties like BRRI dhan48, BRRI dhan82, BRRI dhan83 and BR26 were evaluated in these trials. This activity was executed in collaboration with DAE. In the study areas local farmers normally cultivated Khamarang, Khalabadia, Badui, Pidi, Ranqui, Mongthongno, Khoborok, Kokro, Churoi, Kanbui, Gallon, Compani, Amedhan, Gunda, Binni, Rangapati etc. which are low yielder. Most of the Jhumia farmers did not use any fertilizer, pesticide or any other improved management practices. BRRI provided quality seeds, fertilizers and pesticides. Management was done by the farmers.

The grain yields of BRRI dhan48 ranged from 3.12 to 3.69 $t\ ha^{-1}$ in Jhum system of different upazilas (Table 9). The higher yield of 3.69 $t\ ha^{-1}$ 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 3.36 to 3.62 $t\ ha^{-1}$ under different upazilas of Bandarban, Rangamati and Khagrachhari districts. The higher yield (3.62 $t\ ha^{-1}$) was observed at Matiranga upazila under Khagrachhari districts where the farmer's local variety Churoi produced 2.21 $t\ ha^{-1}$. BRRI dhan83 yielded 3.22 to 3.79 $t\ ha^{-1}$ under different upazilas of Bandarban, Rangamati and Khagrachhari districts. Irrespective of location and variety, BRRI dhan83 produced higher grain yield at Alikodom (3.79 $t\ ha^{-1}$) where the locally adopted Bordhan produced 2.65 $t\ ha^{-1}$ under *Jhum* cultivation system. The grain yield of BRRI dhan26 ranged from 2.89 to 3.32 $t\ ha^{-1}$ under different upazilas of Bandarban and Rangamati districts. The higher grain of BRRI dhan26 at Rajosthali upazila of Rangamati district was 3.32 $t\ ha^{-1}$ where the locally adopted Khoborok produced 2.34 $t\ ha^{-1}$. Among the local varieties, higher grain yield of 3.27 $t\ ha^{-1}$ was obtained from Ranqui followed by Mongthongno (3.12 $t\ ha^{-1}$) and Kanbui (3.04 $t\ ha^{-1}$) at Rowangchhari upazila of Bandarban district.

Table 9. Yield of Aus rice under *Jhum* cultivation, Chattogram Hill Tract, Aus 2019.

Upazila	HYV	Grain yield (t ha^{-1})	Local variety	Grain yield (t ha^{-1})
Baghaichhari, Rangamati	BRRI dhan48	3.64	Khamarang	2.27
Khagrachhari sadar	BRRI dhan48	3.51	Khalabadia	2.13
Matiranga, Khagrachhari	BRRI dhan48	3.32	Badui	2.20
Alikodom, Bandarban	BRRI dhan48	3.69	Bordhan	2.33
Thanchi, Bandarban	BRRI dhan48	3.12	Beti	2.10
Baghaichhari, Rangamati	BRRI dhan82	3.51	Khamarang	2.17
Khagrachhari sadar	BRRI dhan82	3.47	Khalabadia	1.82
Matiranga, Khagrachhari	BRRI dhan82	3.62	Churoi	2.21
Rowangchhari, Bandarban	BRRI dhan82	3.36	Kanbui	3.04
Alikodom, Bandarban	BRRI dhan82	3.54	Bordhan	2.23
Baghaichhari, Rangamati	BRRI dhan83	3.38	Amedhan	2.10
Thanchi, Bandarban	BRRI dhan83	3.42	Beti	1.93
Alikodom, Bandarban	BRRI dhan83	3.79	Bordhan	2.65
Rowangchhari, Bandarban	BRRI dhan83	3.48	Ranqui	2.19
Khagrachhari sadar	BRRI dhan83	3.22	Binni	1.88
Matiranga, Khagrachhari	BRRI dhan83	3.56	Gallon	2.27
Alikodom, Bandarban	BRRI dhan26	3.11	Bordhan	3.12
Rowangchhari, Bandarban	BRRI dhan26	2.89	Mongthongno	3.12
Rajostholi, Rangamati	BRRI dhan26	3.32	Khoborok	2.34
Thanchi, Bandarban	BRRI dhan26	3.01	Company	2.36
Baghaichhari, Rangamati	BRRI dhan26	3.27	Kokro	2.88

Inclusion of mustard in Boro-Fallow-T. Aman cropping pattern in valley of hilly areas

The study was conducted in six farmer's fields of Rajosthali upazila of Rangamati district during 2018-19. 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-

CP_1= BRRI dhan70-Mustard- BRRI dhan88, CP_2= BRRI dhan71- Mustard-BRRI dhan88, CP_3=BRRI dhan71-Mustard-BRRI dhan84, CP_4= BRRI dhan70-Mustard-BRRI dhan84, CP_5= BRRI dhan70-Mustard- BRRi dhan88, CP_6=BRRI dhan71-Mustard-Japanese Black Rice, CP_7= BRRI dhan49- Fallow- BRRI dhan28, CP_8= BRRI dhan49- Mustard- Jonokray.

In T. Aman season, BRRI dhan49, BRRI dhan70, BRRI dhan71 and BRRI hybrid dhan6 were evaluated in the trials. Mustard (BARI Shorisha 14) was a transition period crop. In Boro season, BRRI dhan74, BRRI dhan81, BRRI dhan86 and BRRI dhan89 were tested in the trials. This activity was executed in collaboration with DAE. In the study area BRRI dhan49 in T. Aman season, BRRI dhan28 and Jonokrak (local) in Boro season were used as check. BRRI provided quality seeds, fertilizers and pesticides while the rest of the management practices were done by the farmers. The yield of mustard was converted to REY for comparing the system productivity.

Individual crop yield and rice equivalent yield (REY) of respective cropping patterns are presented in (Table 5). In T. Aman season, grain yields of BRRI dhan70 ranged from 3.22 to 3.41 t ha^{-1} in diffetrent farmers' fields under Mustard-Boro-T. Aman cropping pattern. The grain yields of BRRI dhan71 and BRRI dhan49 ranged from 3.44 to 3.69 t ha^{-1} and 3.27 to 3.36 t ha^{-1} under Mustard-Boro-T. Aman and Boro-Fallow-T. Aman cropping pattern respectively. In Boro season, BRRI dhan88 gave 5.48 and 6.65 t ha^{-1} under respective cropping patterns. The grain yields of BRRI dhan84 ranged from 5.50 to 6.1 t ha^{-1} under Mustard-Boro-T. Aman cropping patterns. BRRI dhan86 yielded 6.1 to 6.4 t ha^{-1} where the locally adopted Jonokary and BRRI dhan28 yielded 5.2 and 5.6 t ha^{-1} respectively. BRRI dhan88 showed apparently better performance among the tested varieties in the trials. The REY obtained from the pattern CP1, CP2, CP3, CP4, CP5, CP6, CP7 and CP8 were 10.16, 10.67,10.57, 11.18, 11.14, 8.56 and 8.87 t ha^{-1} respectively (Table 10). The higher REY (11.76 t ha^{-1}) was obtained from the pattern CP_2 followed by the pattern CP_5 (11.15 t ha^{-1}). Considering these rice equivalent yields, it may be concluded that productivity of the existing pattern could be increased through the inclusion of mustard in between T. Aman and Boro rice, which also help to ensure crop diversity and food security.

Table 10. Yield and REY of different crops in Mustard-Boro-T. Aman, cropping pattern 2019-20.

Cropping pattern	T. Aman	Yield (t ha^{-1})		REY (t ha^{-1})
		Mustard	Boro	
CP1-T. Aman-Mustard-Boro	3.32	0.68	5.48	10.16
CP2-T. Aman-Mustard-Boro	3.69	0.71	6.65	11.76
CP3-T. Aman-Mustard-Boro	3.51	0.53	6.10	10.67
CP4-T. Aman-Mustard-Boro	3.41	0.83	5.50	10.57
CP5-T. Aman-Mustard-Boro	3.22	0.63	6.70	11.18
CP6-T. Aman-Mustard-Boro	3.44	0.75	6.2	11.14
CP7-T. Aman-Fallow- Boro (ck 1)	3.36	-	5.2	8.56
CP8-T. Aman-Fallow- Boro (ck 2)	3.27	-	5.6	8.87

Fertilizer management in HYV Aus rice in Jhum cultivation

Field experiments were conducted in *Jhum* system at Rajasthali, Rangamati and Rowangchhari, Bandarban to develop a suitable method of fertilizer application in HYV Aus rice in 2019. Four nitrogen (N) treatments were: 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=Basal broadcasting+half urea top dressing at tiller initiation stage and maximum tillering stage in two splits.

Promising modern rice varieties like BRRI dhan48 and BRRI dhan83 were used in the trials. Urea, TSP and MoP were applied as a source of N, P and K respectively and at the rate 60-10-40 kg/ha. Normal cultural practices including weeding and insecticides spray were done as and when necessary. The crop was infested with some common weeds and controlled by uprooting. There were some incidence of insect attack especially rice hispa and rice stem borer, which were controlled by spraying Diazinon and Malathion. The seeds of rice were sown by dibbing method with the help of *da* and were sown directly on the soil in the month of May 2019. The rice crops were harvested at maturity in September 2019.

The mean grain yield of BRRI dhan48 in Jhum system ranged from 2.19 to 3.51 t ha^{-1} under different treatments (Table 11). At Rajosthali upazila T_3 produced the higher yield (3.36 t ha^{-1}) followed by the treatment T_4 (3.25 t ha^{-1}). The lowest grain yield (2.03 t ha^{-1}) was observed in T_1. At Rowangchhari upazila, BRRI dhan48 yielded 2.43 to 3.59 t ha^{-1} and T_1 produced the lowest yield (2.43 t ha^{-1}). At Alikokom upazila the grain yield of BRRI dhan48 varied from 2.11 to 3.58 t ha^{-1} under different treatments. The higher grain yield was obtained from T_3 (3.58 t ha^{-1}) followed by the T_4 (3.46 t ha^{-1}). The lowest yield was in T_1 (2.11 t ha^{-1}). The mean grain yield of BRRI dhan83 ranged from 2.15 to 3.61 t ha^{-1}. At Rajosthali the grain yield of BRRI dhan83 varied from 2.19 to 3.54

Table 11. Yield of rice under different fertilizer application methods in *Jhum* cultivation, Chattogram Hill Tract, 2019.

Treatment	Grain yield (t ha^{-1})				Mean
	Variety	Rajasthali	Rowangchhari	Alikodom	
T_1	BRRI dhan48	2.03	2.43	2.11	2.19
T_2	BRRI dhan48	3.12	3.47	3.27	3.28
T_3	BRRI dhan48	3.36	3.59	3.58	3.51
T_4	BRRI dhan48	3.25	3.57	3.46	3.43
T_1	BRRI dhan83	2.19	2.37	1.89	2.15
T_2	BRRI dhan83	3.23	3.55	3.38	3.39
T_3	BRRI dhan83	3.54	3.68	3.62	3.61
T_4	BRRI dhan83	3.43	3.61	3.63	3.56

t ha^{-1} and the higher yield was obtained from the treatment T_3 (3.54 t ha^{-1}). At Rowangchhari, the higher yield of BRRI dhan83 was observed T_3 (3.68 t ha^{-1}) followed by T_4 (3.6 t ha^{-1}). At Alikodom BRRI dhan83 yielded 1.89 to 3.63 t ha^{-1} and T_1 gave the lowest yield (1.89 t ha^{-1}). T_3 and T_4 produced the grain yields of 3.62 t ha^{-1} and 3.63 t ha^{-1} respectively. Irrespective of location and variety, T_3 performed better among all the treatments. Therefore, row placement might be an effective option for effective fertilizer management in Jhum system.

DEVELOPMENT OF AGROFORESTRY SYSTEM

Screening of exotic date palm (*phoenix dactylifera*) genotypes for agro-forestry in the drought-prone ecosystem

Good quality date palm has special utility in our country and is totally imported from exotic source. Exotic date palm varieties can be introduced and evaluated in our local situation. In botanical classification, date palm belongs to *Phoenix* genus having several species. Among them, *Phoenix dactylifera* is the most important elite species that is commercially cultivated for fruit production. *Phoenix sylvestris* is a wild species and obviously it is one of the closest relatives *Phoenix dactylifera*. *Phoenix sylvestris*is readily available in Bangladesh, and is grown for juice and *gur* production. Abundance of wild relatives of a plant species indicates the possibility of its well adaptation. The north-western part of the country is comparatively dry. This region holds a tremendous potentiality for it. A research initiative has been under taken at Mujibnagar Complex for the development of elite date palm genotype suitable for Bangladesh.

Collected seeds of 10 varieties of *P. dactylifera* were sown in nursery bed in 2013. Six-month-old seedlings were transplanted in 3m×3m spacing. Two orchards were established, one at BRRI, Gazipur with 500 saplings and the other one at Mujibnagar Comolex, Mujibnagar, Meherpur with 1100 saplings. A regular irrigation and fertilizer and weed management schedule was followed. Suckers of selected plants (true-to-type) will be used for further propagation and field plantation.

Among the plant population 195 male and 30 female plants have been identified. Therefore, up to date ratio of female plants is approximately 15%. Other plants are in vegetative stage and yet to be identified (male or female). As date palm is a dioecious plant and the population derived from sexual propagation all the plants are of segregated nature. Shape, size, colour and taste of fruits and other phenotypic characters are different from plant to plant. Plants of homogeneous nature will be characterized as a group. Each group will be recognized as a variety.

Performance of different cropping patterns for year-round vegetable production under agro-forestry systems with exotic date palm (*P. dactylifera*)

The canopy structure of date palm is of eco-friendly type which marginally affects the growth and yield of field crops. Integrated gardening of date palm with different field crops may enhance the total productivity of the land. Some crops are well-grown under the partial shade of tree plants. Some may be cultivated in marginal and less fertile land. Several crops can tolerate a wide range of stresses. In addition, the area is connected with other parts of the country by smooth road transport which facilitates vegetable marketing. In this ground we designed some cropping sequences of seasonal vegetables to fulfill following objectives.

Six cropping patterns, composed of vegetables, along with one control plot were used as seven treatments of the experiment. Among the six cropping patterns Pumkin-Mukhikachu produced the highest gross margin of 143.86 thousand taka per hectare (Table 12). It was followed by Carrot-Mukhikachu (143.50 thousand taka). There was no significant difference between the GM of these two patterns. The GM of these two cropping patterns were significantly higher than the others. The LSD value for GM was 17.32. The lowest GM (74.15 thousand taka) was from Pumkin-Okra.

Table 12. Productivity and profitability of year-round vegetables growing cropping patterns under date palm agro-forestry systems, 2019-20.

Cropping pattern (intercropping with date palm)	Economic yield of crops (t ha^{-1})			Cost and return of the pattern ('000Tk/ha)		
	1st	2nd		GR	TVC	GM
T_1 = Carrot-Red amaranth-Okra	7.46	6.41	8.33	177.60	65.23	112.37
T_2 = Carrot-Okra	7.50	9.09	-	132.72	45.64	87.08
T_3 = Carrot-Mukhikachu	7.15	12.11	-	238.85	95.35	143.50
T_4 = Pumpkin-Okra	11.24	8.34	-	134.16	60.01	74.15
T_5 = Pumpkin-Mukhikachu	11.25	12.84	-	260.10	116.24	143.86
T_6 = Fallow-Mukhikachu	-	13.65	-	204.75	86.67	118.08
T_7 = Sole (no crop with date palm)	-	-	-	-	-	-
LSD						17.32

Price of the product (Tk/kg): Carrot= 8.00; Red amaranth= 8.00; Okra= 8.00; Pumpkin= 6.00; Mukhikachu = 15.00.

Evaluation of different rice-based cropping patterns under agro-forestry systems with exotic date palm (*Phoenix dactylifera*)

Cropping systems of Bangladesh are obviously rice-based. Local date trees *(Phoenix sylvestris*) are grown on elevated borders of rice land in different areas of Bangladesh. The canopy structure of date palm is of eco-friendly type which marginally affects the growth and yield of field crops. A long time like 10-12 years is required for the full growth and fruiting of dates. During this long time farmers can grow some crops in the partial shade of the garden. A rainfed rice crop may be harvested during wet season. Considering these points several rice-based cropping patterns are designed for exploring their potential. Six rice-based cropping patterns along with one control plot were used as seven treatments of the experiment. All field crops were grown in between the two rows of date palm established at 3 m distance.

Among the six cropping patterns DS Aman (BRRI dhan71) Pumpkin produced the highest gross margin of 67.75 thousand taka per hectare which was significantly higher than all other cropping patterns (Table 13). It was followed by DS Aman (BRRI dhan71)-Chilli (57.93 thousand taka). The LSD value for GM was 8.13. The lowest GM (29.42 thousand taka) was from DS Aman (BRRI dhan71)-Barley.

Evaluation of different year-round fodder production under agro-forestry system with exotic date palm (*Phoenix dactylifera*)

Mujibnagar and its surrounding area are characterized by the abundance of goat, sheep and cattle farming. However, no grazing land is available over there. People grow fodder crops on their valuable crop land. Farmers are used to purchase green fodder from open market. So, the costing of livestock farming is high enough. In general fodder crops are tolerant to different stresses like drought, shade water stagnation etc.

Table 13. Productivity and gross return of rice-based cropping patterns under date palm agro-forestry systems, 2019-20.

Cropping pattern (intercropping with date palm)	Economic yield of crops (t ha^{-1})		Cost and return of the pattern ('000Tk ha^{-1})		
	1st	2nd	GR	TVC	GM
T_1 = DS Aman (BRRI dhan71)-Chilli	5.50	2.05	113.25	55.32	57.93
T_2 = DS Aman (BRRI dhan71)-Sunflower	1.59	1.95	76.95	21.34	55.61
T_3 = DS Aman (BRRI dhan71)-Pumpkin	11.25	2.04	98.10	30.35	67.75
T_4 = DS Aman (BRRI dhan71)-Barley	1.25	2.11	50.40	20.98	29.42
T_5 = DS Aman (BRRI dhan71)-Grasspea	1.15	1.99	58.60	20.11	38.49
T_6 = DS Aus-Blackgram	2.04	0.89	66.20	20.65	45.55
T_7 = Sole (no crop with date palm)	-	-	-	-	-
LSD					8.13

Price of the product (Tk/kg): Rice= 15; Chilli= 15; Pumpkin= 6; Barley= 15; Sunflower = 30; Grasspea= 25; Blackgram= 40.

Considering the aforesaid dimensions, some cropping sequences have been designed with the combinations of winter and summer season fodder crops for the agro-forestry systems in date palm orchard.

Six cropping patterns, composed of fodder crops, along with one control plot were used as seven treatments of the experiment. All fodder crops were grown in between the two rows of date palm established at 3 m distance. Among the six cropping patterns of different green fodder Cowpea-Maize produced the highest gross margin of 58.92 thousand taka per hectare (Table 14). This figure was significantly higher than all other GM values. It was followed by Oat-Maize (47.67 thousand taka). The lowest GM (27.35 thousand taka) was from Triticale-*Bhura*.

Performance of different spices crops in various cropping patterns under agro-forestry system with exotic date palm (*P. Dactylifera*)

The people of south Asia are fond of spicy curry along with main dishes. Demand of spices crops are increasing for their taste, flavour, attractive colour and medicinal values. Sometimes Bangladesh imports various spices. Because of population pressure agricultural land is mainly occupied by rice and also by other commercially important crops. Different spice crops can grow in partial shade of tree crops. To capture the maximum output of the land some cropping patterns with spices crops have been proposed. Six cropping patterns composed of different spices crops, along with one control plot were used as seven treatments of the experiment. All spices crops were grown in between the two rows of date palm established at 3 m distance.

Among the six cropping patterns Fallow-Turmeric obtained the highest gross margin of 184.45 thousand taka per hectare (Table 15). It was followed by Chilli-Turmeric (180.51 thousand taka) and Onion-Turmeric (171.25 thousand taka). There was no significant difference among the GM of these three patterns. The GM of these three cropping patterns was significantly higher than the others. The lowest GM (97.45 thousand taka) was earned from Fallow-Ginger.

Table 14. Productivity and profitablity of different cropping patterns of fodder crops under date palm agro-forestry systems, 2019-20.

Cropping pattern (intercropping with date palm)	Green fodder yield of crops (t ha^{-1})		Cost and return of the pattern ('000Tk/ ha)		
	1st	2nd	GR	TVC	GM
T_1 = Triticale-Maize	6.50	12.05	46.38	5.64	40.74
T_2 = Oat-Maize	9.68	11.95	54.08	6.41	47.67
T_3 = Cowpea-Maize	12.35	13.85	65.50	6.58	58.92
T_4 = Triticale-*Bhura*	6.55	6.25	32.00	4.65	27.35
T_5 = Oat-*Bhura*	9.68	6.15	39.58	4.02	35.56
T_6 = Cowpea-*Bhura*	12.35	6.47	47.05	4.35	42.70
T_7 = Sole (no crop with date palm)	-	-	-	-	-
LSD					7.29

Price of the product (Tk/kg): Green fodder= 2.50.

Table 15. Productivity and gross return of different cropping patterns of spices crops under date palm agro-forestry systems, 2019-20

Cropping pattern (intercropping with date palm)	Economic yield of crops (t ha^{-1})		Cost and return of the pattern ('000Tk/ ha)		
	1st	2nd	GR	TVC	GM
T_1 = Chilli-Ginger	5.42	6.05	202.30	95.24	107.06
T_2 = Chilli-Turmeric	5.26	12.95	273.15	92.64	180.51
T_3 = Onion-Ginger	14.25	6.85	208.25	100.29	107.96
T_4 = Onion-Turmeric	15.07	13.05	271.10	99.85	171.25
T_5 = Fallow-Ginger	-	8.14	162.80	65.35	97.45
T_6 = Fallow-Turmeric	-	16.47	247.05	62.60	184.45
T_7 = Sole (no crop with date palm)	-	-	-	-	-
LSD					16.92

Price of the product (Tk/kg): Chilli= 15.00; Turmeric= 15.00; Ginger= 20.00; Onion= 5.00.

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 increase the farm productivity through different cropping pattern technology. BRRI and Bangladesh Agricultural Research Institute (BARI) have already developed some potential crop varieties, improved cropping patterns and management technologies as well. Among our evaluated cropping patterns BARI Alu32-BJRI tosha pat8-BRRI hybrid dhan6 CP had relatively higher REY (27.39 t ha^{-1}), 171% more yield than the existing CP, Boro-Fallow-T. Aman followed by Mustard-Boro-T. Aman CP. In Khulna, introduction of Mustard in existing CP, Boro-Fallow-T. Aman increased 28% REY. Aside from this from the Boro-2019-20 we started the similar programme with assistance of Kushtia and Rajshahi regional stations in those areas.

INTEGRATED FARMING SYSTEM RESEARCH AND DEVELOPMENT

Integrated farming system research and development for livelihood improvement in the plain land ecosystem

Rice Farming Systems Division of BRRI has been studying farming systems research and development under the coordinated sub-project entitled “Integrated Farming Research and Development for Livelihood Improvement in the Plain Land Ecosystem” at Tengra village, Sreepur, Gazipur from February 2018. Site characterization for the FSR and Development site was done by baseline survey, direct field observation and review of the literature to identify problems for development of packages of technology/agronomic practices and technology validation and intervention. On the basis of problems identified in baseline survey and site characterization, in total 18 activities were undertaken and continued during last two years (Feb. 2018-Jan. 2020) under homestead production system, crops and cropping system, livestock system, fisheries system and

Table 16. Yield and REY of different cropping patterns in Kishoreganj and Khulna 2019-20.

Location and CP	Yield (t ha^{-1})							REY (t ha^{-1})
Kishoreganj	Mustard	Potato	Corn	Black gram	Jute	Boro	T. Aman	
Existing CP- BRRI dhan28-F-BRRI dhan72	-	-	-	-	-	5.98	4.09	10.07
Improved CP								
BARISharisha14-BRRI dhan89/92/HBD5-BRRI dhan87	1.48					6.65	5.89	15.87
BARIAlu32-BJRI tosha pat8-BRRI hybrid dhan6	-	18.44			2.81		6.14	27.39
BARI sharisha14-BARI hybrid bhutta9+BARI Mash1-BRRI dhan72	1.53		7.12	0.67			4.97	15.78
Khulna								
Existing CP- BRRI dhan28-F-BR23	-	-	-	-	-	6.04	5.08	11.12
Improved CP: BARI shorisha14-BRRI Dhan 67-BRRI dhan87	1.12	-	-	-	-	6.12	5.62	14.26

Price (Tk/kg): Rice-20/-; Black gram- 50/-; Mustard-45/-; Potato-10/-; Corn-16/-; Jute- 50/-

plantation system. In total 12 cooperator farm families, four from each category of marginal (0.021-0.2 ha), small (0.21-1 ha), and medium (1.01-3 ha) were selected for intervening farming systems technologies. In crop component, high yielding newly released Aus varieties were introduced in Boro-Fallow-T. Aman and Fallow-Fallow-T. Aman cropping pattern in that region. On-farm demonstrations on newly released BRRI varieties are going on during Aus, Aman and Boro season. Improvement of the existing cropping system through replacement of rice variety and non-rice crops is also going on. In livestock component, turkey rearing under scavenging system seems to be a promising option to increase farmers' income. Pigeon and goat rearing is going on to increase farm income. Homestead productivity was also increased. On the other hand, farm income as well as consumption of vegetables and livestock products of the farmers' increased significantly. Semi aquatic production system of vegetables, fruits and fish in the derelict pond was highly profitable and farmers are very much interested to this new technology. Other activities like drumstick plantation, utilization of fallow land under orchard, spraying of fruit trees is in progress. Fruit sapling distribution, chewing type sugarcane cultivation at homestead, palmyra seed sowing etc. were also done.

Agricultural Economics Division

SUMMARY

Preferences and adoption of a rice variety depends on different agro-climatic, sociocultural and geographical factors. Salinity and pest infestation are the major thrust in the south coastal region of Bangladesh. Higher yield potential associated with shorter growth duration, slender to medium grain size, biotic and abiotic stress resistances are the expected essential traits of the stakeholders of rice value chain in this region. Therefore, breeders must consider those traits during the process of variety development for the saline ecosystem of Bangladesh.

The health risk management practices revealed that the migrant labourers, maintained social distance from (i) dwellers of local inhabitants, and each other while working in the fields. Labourers wore masks in the vehicles, during working to the fields and going to market places for buying essentials. However, they could not adopt the social distance properly while staying at the accommodation. Besides, they did not wear masks always while harvesting rice because of hot weather; they did not wash hands frequently in the rice fields due to unavailability of water in the crop fields.

Although, Boro rice escaped from the adverse consequences of Amphan as the crop was mostly harvested before it struck the crop; however, yield loss of standing Boro crop was about 2.5 - 5 t/ha in some villages. The Aus area decreased about 38-60% of the target area due to mainly damage of seedlings in the nursery and stagnant water in the fields. Besides, the yield of the Aus rice crop might be lower (7-20%) compared to last years' yield; because of (i) delay transplanting (ii) inadequate fertilizer application and weeding due to lack of money. Besides, T. Aman yield may decrease about 0 – 35% compared to normal seasonal conditions owing to (i) delay transplanting (ii) application of less fertilizers (iii) increased area of local cultivars. Ensuring easy access to bank credit at a lower interest rate, providing inputs and cash supports to the small and marginal farmers and finally reduced fertilizer prices may ensure a better harvest of upcoming T. Aman.

The availability of wage workers in the *haor* areas for harvesting Boro rice was adequate in 2020. The contributions of migrant labourers was 74 – 80% in harvesting Boro rice in 2019, which decreased to 60 – 69% in 2020. The contributions of combine harvesters and reapers were 6, 7 and 9% in Sunamganj, Kishoreganj and Netrakona, respectively. The cost of harvesting Boro rice by combine harvesters included the wage of manual carrying the grain and straw from fields to home was 31 – 39% lower than that of manual operations. Per acre yield of BRRI dhan28, BRRI dhan29 and hybrid were 69-82%, 20-33% and 20-30% higher respectively in 2020 compared to 2019 due to the best seasonal weather conditions in 2020.

Jhum covered 16% cultivated area of hilly region of Bangladesh in 2019. In Boro season, more than 55% areas were devoted to BRRI varieties; where BRRI dhan28 occupied the highest areas followed by BRRI dhan29. In Aman season, about 77% areas were covered by BRRI varieties where BRRI dhan49 ranked first position followed by BRRI dhan11. Average yield of BRRI varieties in Boro season was 5.33 t ha^{-1} whereas in Aman season it was 4.46 t ha^{-1}. Rice cultivation was found profitable in cash cost basis but not in full cost basis. Higher production cost, lack of institutional credit, poor market infrastructure and higher land rent were reported as major problems in the study areas. Increased subsidized irrigation facilities, adequate institutional credit facilities, infrastructure development etc could be probable solutions of the existing problems in the hilly areas.

Calibrating with the base parameters and public cost for rice research (BRRI and BARC), the IRR of the post-1990s BRRI varieties R and D is Tk 56 for the period of 1990-2018 and gave returns on average of Tk 2 per year from the date of investment. The IRR of the post-1990s BRRI varieties R and D is Tk 52 for the period 1990-2018 when research, extension and private expenditure (IRRI) were taken into consideration. Due to adoption of the post-1990s BRRI rice varieties, per year saving of import expenditure of Tk 39,684 million for rice could be saved.

FARMERS' VARIETAL PREFERENCES AND PRODUCT PROFILE OF RICE IN SALINE ECOSYSTEM OF BANGLADESH

Salinity is a devastating abiotic constraint to rice production in the southwest coastal region of

Bangladesh (Hague, 2006). About 1.01 million hectares of land in this region consists of 19 districts frequently affected by salinity (SRDI, 2010). In T. Aman season, salinity is not a serious problem because in this season rice is cultivated mainly depending on rainfall but in Boro season, especially at early vegetative and reproductive stages are severely affected by the different degrees of soil and water salinity ranging from 10-22 dS/m (Jahan *et al.*, 2018). So, this study delineated the farmers' preferences for product profiles that will help to develop future rice varieties in the coastal saline region of Bangladesh.

To address this issue, Asasuni upazila in Satkhira and Koyra upazila in Khulna districts were selected purposively during the reporting year 2019-20. Sixty farmers were chosen randomly for direct interview in each season. Four focus group discussions (FGDs) were conducted for capturing the collective understanding on varietal preferences in this area.

Most of the farmers of Satkhira and Khulna districts cultivated BRRI dhan67, BRRI dhan28, *Jamaibabu*, Binadhan-8, Binadhan-10, SL-8H and Tej during Boro season. Among these varieties, BRRI dhan67 was the most preferred variety due to moderately salt tolerance, higher yield potential, medium slender grain size, good taste to eat and non-sticky texture. On the other hand, farmers cultivated BR10, BR11, BR23, BRRI dhan30, and BRRI dhan49, Binadhan-7, *Jaibalam*, *Guti Swarna*, *Kasra*, *Sadamota* and *Rani Salute* in T. Aman season (Table 1). Among these varieties, BR10, BR23 and BRRI dhan30 were the most preferred varieties due to higher yield potential, less lodging tendency at maturity stage, shorter growth duration than local varieties, less susceptibility to major diseases and insects, good taste to eat and higher market demand.

Product profiles have been assessed based on four traits group namely basic, range, future value added and game changing ability. Benchmark variety is the variety that farmers want to replace with their preferred traits. BRRI dhan47 was the benchmark variety as it was the most preferred cultivar previously in this region. But due to some constraints, the farmers want to shift this variety. It was found from the survey that the existing traits of the benchmark variety yield were as like 5.73 t ha^{-1}, medium bold grain, 26.1% amylose, higher shattering problem, 6-8 ds/m saline-tolerant in the whole life cycle, 152 days growth duration, 105 cm plant height, 6-7 numbers per hill tiller, 60-65 percent head rice, susceptible to pest resistance and less than 160 number of filled grains per panicle. Farmers in the study areas want to replace the weakness of the benchmark variety with the following traits as: 10% higher yield than 5.73 t ha^{-1}, medium slender type grain, less than 60% shattering reduction, 12-14 dS/m saline tolerant capacity in seedling stages and 8-10 dS/m saline tolerant in whole life cycle, moderate growth duration (<145 days), higher number of tillers (10-12 no./hill), greater than 65 percent head rice, pest resistance and higher number of filled grain in the panicle (Table 2).

Table 1. Varietal choice among farmers in saline stress prone environments of Bangladesh.

T.Aman season		Boro season	
Satkhira	Khulna	Satkhira	Khulna
BRRI dhan49	BR23	BRRI dhan67	BRRI dhan28
BR10	BR10	BRRI dhan28	BRRI dhan67
BR23	BRRI dhan30	*Jamaibabu*	Binadhan-10
BRRI dhan30	BR11	BRRI dhan50	BRRI dhan55
GutiSwarna	*Jaibalam*	*Miniket*	BRRI dhan61
Binadhan-7	BRRI dhan49	Binadhan-10	Binadhan-8
BR11	*Morich sail*	Binadhan-8	Sinjenta-1201
Jamaibabu	*Kasra*	SL-8H	SL-8H
Jaibalam	*Sadamota*	Tej	Aloran
BRRI dhan39	*Rani salute*	Shakti-2	BR26

Source: Prepared by authors' based on data from field survey, 2019-20.

Table 2. Product profile for Boro season in saline ecosystem of Bangladesh.

Target environment: Saline ecosystem		Benchmark variety: BRRI dhan47		
Season: Boro				
Traits	Trait specification	Existing traits	Expected traits	Number of available materials (Gene/QTL/advanced line)
Basic	Yield (ton/ha)	5.73	>10%	
	Grain size and shape	MB	MS	
	Amylose (%)	26.1	26.1	
	Shattering reduction (%)	High shattering problem	>60	
	Salinity tolerant: Seedling stage (ds/m)	10-12	12-14	
	Salinity tolerant: Whole life cycle (ds/m)	6-8	8-10*	
Range	Growth duration (days)	152	<145	
	Plant height (cm)	105	105	
	Tillering (no./hill)	6-7	10-12	
	Head Rice (%)	60-65	>65	
Future value added	Disease resistance	None	BB, Brown spot	
	Insect resistance	None	Stem borer	
Game changing	Filled grains panicle^{-1}	<160	>200	

Note: MB, medium bold; MS, medium slender; QTL, Quantitative trait locus; BB, Bacterial blight. *Should tolerate 14-16 ds/m saline at 21 days continuously in booting stage and yield reduction not more than 20% than normal condition. Source: Prepared by authors based on data from field survey 2019-20.

Table 3 presents the farmers preferred product profile for T. Aman season in the saline ecosystem of Bangladesh. The benchmark variety was BRRI dhan41 reported by the farmers. The existing traits of the benchmark variety were 4.5 t ha^{-1} yield, long bold grain size and shape, 24.6% amylose, 6 dS/m salt tolerant in the whole life cycle, 148 days growth duration, 115 cm plant height, less than 150 number of filled grains per panicle, and no pest resistance capacity. Most of the farmers reported that the expected traits of the benchmark variety will be 10% higher yield than the existing benchmark variety, medium slender grain size and shape, greater than 25% amylose, 10-12 dS/m salinity tolerant capacity in the seedling stage, 125-135 days growth duration, more number of tillers (10 no. /hill), higher filled grain per panicle (180 no.), and pest (sheath blight and BPH) resistance.

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MIGRANT WAGE WORKERS ADAPTATION TO HEALTH RISK OF COVID-19 IN *HAOR* AREAS OF BANGLADESH

The rice cultivation in the *haor* areas frequently affected by early flash floods due to heavy rainfalls and on rushes of water from the upstream. The flash flood is a potential threat to the food security of *haor* people because Boro rice is only the rice crop cultivated in the area. Therefore, *haor* farmers employed a large number of migrant labourers to expedite the rice harvesting to escape from unexpected crop loss due to flash floods. In the current year, Bangladesh government took a very timely policy decision by providing approval for vehicle movement for transporting off-farm wage workers to the *haor* areas for facilitating the Boro rice harvesting subject to maintaining social distance and health-protective measures to eliminate the risk of transmission of the COVID-19. Thus, the present study aimed to delineate migrant labourers' health risk management strategies to COVID-19.

Netrakona, Kishoreganj and Sunamganj districts were selected purposively for the study because higher number of wage workers migrated to these areas. Online telephonic interview was conducted during the fourth week of April to the first week of May 2020 for collecting necessary information from the purposively selected 90 labour leaders and 90 farmers of 90 villages (Table 4).

Health risk management strategies: Social distance and food intake

Maintaining social distance and having a healthy diet for increasing body immunity are the most vital health risk management strategies to alleviate the transmission of the COVID-19. Table 5 presents the social distance status of the migrant labourers in the vehicles while travelling to *haor* areas. Trucks, engine boats and pickup vans were used for transporting labourers. Some labourers used bus travelling to *haor* areas from their residence. Besides, battery and CNG operated auto-rickshaw and motorbikes also were used for transporting the labourers. Some of the labourers walk on feet to reach the destination (Table 5). The labour leaders in the telephone interview said that majority of them wore mask but could not maintain a social distance in the vehicles for combating the transmission of the COVID-19 from each other.

Table 3. Product profile for T. Aman season in saline ecosystem of Bangladesh.

Target environment: Saline ecosystem			Benchmark variety: BRRI dhan41		
Season: T.Aman					
Traits	Trait specification		Existing trait	Expected trait	Number of available materials (Gene/QTL/ advanced line)
Basic	Yield (ton/ha)		4.5	>10%	
	Grain size and shape		LB	MS	
	Amylose (%)		24.6	>25	
	Salinity tolerant	Seedling stage (dS/m)	8	10-12	
		Whole life cycle (dS/m)	6	6-8	
Range	Growth duration (days)		148	125-135	
	Plant height (cm)		115	115-120	
	Tillering (no./hill)		6-7	10	
	Head Rice (%)		60-65	>65	
	Filled grains panicle^{-1}		<150	150-180	
Future value added	Disease resistance		None	Sheath Blight, BLB	
	Insect resistance		None	BPH, Gall midge	

Note: LB, Long bold; MS, Medium slender, BLB, Bacterial leaf blight; BPH, Brown plant hopper. Source: Prepared by authors based on data from field survey 2019-20.

Table 4. Study locations and distribution of sample in the *haor* areas in Bangladesh.

District	Upazila	Number of labour leaders	Number of total labour	Number of farmers
Sunamganj		60	1,294	60
	Jamalganj	20	503	20
	Jagannathpur	10	106	10
	Derai	20	408	20
	Dharmapasha	10	277	10
Netrokona		15	311	15
	Mohonganj	5	106	5
	Kaliajuri	5	125	5
	Modon	5	80	5
Kishoreganj		15	436	15
	Nikli	5	99	5
	Mithamain	5	154	5
	Itna	5	183	5
Total		90	2,041	90

Table 5. Social distance status at transportation vehicles of migrant labour in *haor* areas of Bangladesh.

Mode of transportation	Kishoreganj		Netrokona		Sunamganj	
	% of total migrant group	Maintain social distance (yes/no)	% of total migrant group	Maintain social distance (yes/no)	% of total migrant group	Maintain social distance (yes/no)
Pickup van	22	No	40	No	25	No
Truck	19	No	47	No	23	No
Engine boat	52	No			18	No
Auto rickshaw	7	No	13	No	11	No
Bus					18	No
Motorbike					5	No
Total	100		100		100	

Table 6 presents the status of social distance at the accommodation and fields, and food intake of the migrant labourer in the *haor* areas. The wage workers in the interview said that they were requested to maintain social distance from the community people during staying in the village. The villagers were advised to construct a temporary accommodation system in an isolated place from the residential areas of the villages. It was observed that the majority of labour groups (63–86%) stayed in the tents. On average, about 27% of migrant groups in Kishoreganj lived in the engine boats that they used for travelling to the *haor*. Besides, some stayed in the schools in all the locations. In Sunamganj, a few stayed at a tent in the home-yard or at their guest room outside the house. It was observed that the migrant Boro harvest labourers maintained social distance from the dwellers. However, most labour groups (85–93%) could not maintain social distance properly while they were staying in their accommodation because they had to live 14–26 and 10–12 persons in a tent or boat and a room respectively. Most workers were fully aware of COVID–19 issue because DAE personnel briefed them about the issue before they left for *haor* areas for harvesting Boro rice. Therefore, most of the group members (89–93%) properly maintain social distance while harvesting rice in the fields and carrying out from the fields (Table 6).

Table 6. Social distance status at accommodation and food sources of the migrant labour in the *haor* areas in Bangladesh.

Risk management strategies	Sunamganj (n=120)	Kishoreganj (n=30)	Netrokona (n=30)
Accommodation (%) : Tent	81	53	86
: School	12	20	14
:Boat		27	–
: Farmers' house	7	–	–
Number of persons live in a tent and boat	14	26	17
Number of persons live in a room	12	11	10
Maintain social distance at accommodation (%)	15	7	7
Do not maintain social distance at accommodation (%)	85	93	93
Maintain social distance while harvesting the rice (%)	10	93	73
Do not maintain social distance while harvesting rice (%)	–	7	27
Source of foods (%): Cooked by themselves	85	93	93
Farmers	15	7	7

Source: Telephone survey 2020; Note: Out of total respondents (n) of each location, half are labour leaders and the rest are farmers

Most of the wage workers reported that they had bought commodities including rice, potatoes, pulses, edible oil and spices on debt from local shopkeepers for cooking foods themselves. Besides, each group hired a cook for cooking food for them. Most of the labour groups (85–93%) lived on the food they cooked by themselves (Table 3). A few labour groups lived on food provided by landlord farmers, but the meals served outside of the farmers' place, including the fields to maintain social distance from the village dwellers.

Sanitization status

Most of the wage workers were aware of the importance of sanitization, however, they were not able to maintain all the customs of sanitization always because of some practical reasons. Firstly, they should stay at home, but they went out for maintaining livelihood. Secondly, although most migrant labourers have the mask, they cannot bear with wearing the mask while harvesting rice because of hot and humid condition in the summer period (Table 7). Thirdly, the most wage worker leaders in the interviews reported that they could not wash hands frequently while harvesting rice because of the unavailability of water in the rice fields.

They said that there was water in the canals and rivers adjacent to their accommodation, and they washed hands before and after having meals, and after finishing work at their accommodation. Some of the labour leaders mentioned that they had been drinking raw tea with spices in the morning and evening to improve their immunity for protecting from the COVID-19 infestation. The wage workers migrated mainly from Pabna, Tangail, Sirajganj, Mymensingh, Sylhet, Manikganj and non-*haor* areas of Sunamganj for harvesting Boro rice. The health risk management practices of migrant labourer, including maintaining social distance from (i) village dwellers where the number of migrated people is higher, and each other while harvesting rice in the fields. Besides, the labourers wore masks in the vehicles, walking out to crop fields for harvesting rice and going to market places for buying essentials. However, they could not adopt the social distance properly while staying at the accommodation. Besides, they could not wear masks always while harvesting rice because of hot weather and they could not wash hands frequently in the rice fields because of the unavailability of water in the crop fields.

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IMPACTS OF SUPER CYCLONE AMPHAN AND FARMERS' ADAPTATION IN SOUTHERN COASTAL BANGLADESH

Bangladesh will require about 44.6 MT of clean rice for 215.4 million people by 2050 to ensure food security (Kabir *et al*, 2015). A large number of studies anticipated that climate variability and natural calamities might be quite frequent and intense in the future, particularly in the coastal areas of Bangladesh (MoEF, 2009, Yu et al., 2010, WB, 2013). Extreme weather events have been quite frequent in the country, for instance a very damaging tropical cyclone Bulbul struck the coastal Bangladesh in November 2019, causing storm surge, heavy rains, and flash floods across the areas. Again, a super cyclone struck the Bangladesh coast on 22 May 2020 that also caused widespread

Table 7. Sanitization status of the migrant labourers in the *haor* areas in Bangladesh.

Risk management strategies	Sunamganj (n=120)	Kishoreganj (n=30)	Netrokona (n=30)
Wear a mask while in the marketplace (%)	100	100	100
Not wear a mask while harvesting rice (%)	100	100	100
Not adequate hand washing facilities in rice fields (%)	100	100	100
Adequate water for hand washing at accommodation (%)	98	100	100
How often do they wash their hands: Seldom (%)	100	100	100
Drink raw tea with spices (%)	16	23	18

Source: Telephone survey 2020; Note: Out of total respondents (n) of each location, half are labour leaders and the rest are farmers.

damage of rice and non-rice crops across 26 districts in coastal and north-western regions of the country. Thus, the present study evaluated the impacts of cyclone Amphan on rice farming and livelihoods of the coastal dwellers in Bangladesh with the following specific objectives to-

(i) Delineate the impact of Amphan on rice farming and livelihoods of coastal households;

(ii) Delineate farmers' suggestions for increasing crops production and adaptive capacity.

Four southern coastal districts namely Satkhira, Khulna, Bagherhat and Patuakhali were selected purposively for the study because those were the most affected areas among 26 districts that were hit by the super cyclone Amphan (Table 8). Seriously affected seven upazilas by Amphan were then purposively selected from the particular district. Thereafter, two villages were selected from each upazila where arable areas were intensively used for (i) rice and non-rice cropping and (ii) shrimp/prawn farming. Secondly, six key informant farmers were selected from each village for online interview with the mobile phone.

Impact of Amphan on Boro rice

The respondents reported that Boro rice in most coastal locations was not affected much as the crop mostly harvested before the super cyclone Amphan. Fig. 1(a) and 1(b) shows the yield loss due to Amphan affected Boro areas was 0.5 to 5 t/ha in the study villages as the crop in the area was inundated for 5-10 days.

The key informants said that not only they incurred yield loss of Boro rice in the affected areas, but also the quality of the grain deteriorated substantially so that the grain has no market demand. They also mentioned that even the affected grain might not be possible for family consumption due to odour of cooked rice.

Fig. 1 (a) Submerged Boro rice, Morrelganj (Khan May 2020).

Fig. 1 (b) Submerged Aus nursery, Morrelganj (Rahman May 2020).

Table 8. Impact of Amphan on performance of Boro rice in southern coastal Bangladesh.

District	Upazila	% of total Boro area affected by Amphan (%)	Grain yield loss (t ha^{-1})
Satkhira	Shyamnagar	3 – 5	0.5 - 4.5
	Ashashuni	3 – 5	1 - 4.5
Khulna	Koyra	8 – 10	5 - 5.5
Bagherhat	Morrelganj	13 – 15	2-2.5
	Kachua	5 – 10	0.5 0.8
Patuakhali	Bauphal	10 – 13	1.0-1.5

Note: HH= Households

Impact of Amphan on Aus rice

Aus cultivated area was about 20-30% of total arable land in the case study villages except Mirzaganj where 65-70% of the total cultivable area was under Aus rice. Few areas of Aus rice which was transplanted before Amphan was damaged that mostly due to inundation. Besides, the seedlings in the nursery bed also wilted because of inundation. Thus, the total achievement of Aus cultivation was 38-60% of the total targeted area in the study villages. Besides, Aus cultivation was zero in Koyra and Kashimari village in Shyamnagar due to inundation which was caused from broken embankment. The key informants reported that cultivation of Aus area not only decreased considerably, but the yield of the rice crop might also be decreased slightly due to farmers' inability to invest in farm activities. Farmers projected that the grain yield of Aus in the current year might be 7-20% lower than the performance in last year. Farmers' income was affected and decreased mainly due to crops loss and damage of other farm enterprises like fish and shrimp by cyclone Amphan. On the other hand, farm income was also affected due to decreased off/non-farm income because of countrywide lockdown which was imposed for the out breaking of COVID-19 virus (Table 9).

Impact of Amphan on T. Aman rice

The respondents projected that grain yield of T. Aman in the current year may decrease about 10 – 20% in comparison to normal seasonal condition. The yield may decrease due to (i) delay transplanting for lack of cash to hire power tiller/tractor and labour, (ii) application of less fertilizers and (iii) increasing area of local cultivars as it needs less fertilizers (Table 10).

Table 9. Impact of Amphan in the achievement of Aus area in southern coastal Bangladesh.

District	Upazila	Area decreased (% of target area)	Projected yield loss (t ha^{-1})	Reasons of yield decrease			
				Delay TP (yes/no)	Apply less fertilizer and pesticides (yes/no)	Inadequate weeding (yes/no)	Increase adoption of LVs and HH seed (yes/no)
Satkhira	Shyamnagar	40-100	10-15	Yes	Yes	Yes	No
	Ashashuni	100	-	-	-	-	-
Khulna	Koyra	100	-	-	-	-	-
Bagherhat	Morrelganj	50-60	10-15	Yes	Yes	Yes	Yes
	Kachua	40-49	10-12	Yes	Yes	Yes	No
Patuakhali	Mirzaganj	43-47	15-20	Yes	No	Yes	No
	Bauphal	38-50	7-12	Yes	Yes	Yes	No

Note: HH= Households, Note: Reason for area decrease, seedling damage (5-8%) and lack of money for tillage and purchasing fertilizer, 90% seedling was damaged in the nursery.

Table 10. Impact of Ampahn and COVID-19 on performance of Aman in southern coastal Bangladesh.

District	Upazila	Grain yield (mound/ acre) in 2018	Projected yield decreased in 2020 compared to 2018 (%)	Reasons of yield decrease			
				Delay TP (yes/ no)	Apply less fertilizer and pesticides (yes/no)	Inadequate weeding (yes/no)	Increase adoption of LVs and HH seed
Satkhira	Shyamnagar	29-35	30	Yes	Yes	Yes	Yes
	Ashashuni	40 - 43	10	Yes	Yes	Yes	No
Khulna	Koyra	40-44	30	Yes	Yes	No	Yes
Bagherhat	Morrelganj	43-46	15	Yes	Yes	Yes	Yes
	Kachua	42-43	15	No	Yes	Yes	Yes
Patuakhali	Mirzaganj	40-44	10	Yes	Yes	Yes	No
	Bauphal	46	15	Yes	Yes	Yes	No

Note: HH= Households, the projected performance of T. Aman in 2020 was compared with the performance of the rice crop in 2018 as the performance of T. Aman was substantially affected by cyclone Bulbul in 2019.

BIOPHYSICAL AND MARKET PERFORMANCE OF BORO RICE IN *HAOR* AREA IN BANGLADESH

Haors are low-lying wetland areas in north-eastern and north-central parts of Bangladesh. It plays a vital role in the economy through (i) providing about 18% of total Boro production (BBS, 2018), and (ii) generating employment opportunities for off-farm wage workers. On average, total *haor* districts and haors cover about 19% and 9% of total Boro rice areas in the country respectively (BBS 2018). Though, harvesting time of this crop is about one month earlier in *haor* than other areas but it frequently get affected by early flash floods due to heavy rainfalls and on rushes of water from the upstream Meghalaya hills in India. Therefore, the *haor* farmers employ a large number of migrant labourers to expedite the rice harvesting to escape from unexpected crop loss due to flash floods. Thus, the present study aims to delineate (i) availability status and contribution of wage workers and power harvester in harvesting Boro rice, (ii) the cost of harvesting Boro rice under manual and mechanical operation and (iii) biophysical and market performance of Boro cultivars.

Netrakona, Kishoreganj and Sunamganj districts were selected for the study. The online interview using a mobile phone was conducted during the last week of April to the first week of May 2020 for collecting data from the purposively selected 90 labour leaders and 90 farmers of 90 villages of the selected *haor* districts. A descriptive and inferential analysis i.e. a two-sample t-test was carried out using software programme STATA15 to assess if there was any significant variations in the mean yield and prices of Boro rice among the studied locations.

Availability of labourers and harvesters for harvesting Boro

Both the farmers and labour leaders said that the availability of wage workers for harvesting Boro rice in the current year was higher than the requirement. It was because of (i) most non–farm wage workers went back home from cities and towns due to lockdown and they were ready to work as farm workers.

The estimated area allocation per combine harvester for Boro season in the *haor* districts was in the range between 1185-2843 ha. However, the average capacity of a combine harvester in a season is 30 – 35 ha (Islam, 2018) indicating that the availability of combine harvesters was inadequate for harvesting the Boro rice by machines (Table 11).

Contribution of labourers and harvesters for harvesting Boro rice

The contribution of migrant labourers for harvesting Boro rice was about 74–80% of the total Boro area in 2019, which decreased to 60–69% in 2020. Farmers reported that the contribution of migrant labourers in 2020 was lower due to higher participation of local non–farm wage workers in harvesting period. Most farmers mentioned that the availability of power harvester was not sufficient and overall contribution of the combine harvesters was low (6–9%) due to lack of proper roads for movement and wet soil in the middle of *haor* which is not suitable for power harvester operation as well (Table 12).

Table 11. Mechanization scenarios for harvesting rice in the *haor* Districts of Bangladesh.

Item	Habiganj	Moulovibazar	Brahmanbaria	Kishoreganj	Sylhel	Netrakona	Sunamganj	All
Total combine harvester (no.)	57	44	39	88	68	102	142	540
New combine harvester (no.)	22	5	17	40	11	53	44	192
Estimated area per harvester (ha)	2,105	1,240	2,843	1,894	1,185	1,809	1,544	1,734
Total reaper (No.)	195	124	20	99	173	25	213	849
New reaper (No.)	33	3	3	13	2	1	10	65
Estimated reaper (ha)	615	440	5544	1684	466	7381	1030	1103

Source: DAE, 2020.

Table 12. Representation of manual labour and power harvesting of Boro rice in the *haor* areas of Bangladesh.

Item	Sunamganj (n=120)	Kishoreganj (n=30)	Netrakona (n=30)
Total Boro area in 2020 harvested by:			
Local labourer (% of total area)	30	28	37
Migrant labourer (% of total area)	66	69	60
Harvesters and reapers (% of total area)	6	7	9
Total Boro area in 2019 harvested by:			
Local labourer (% of total area)	18	15	20
Migrant labourer (% of total area)	78	80	74
Harvester and reapers (% of total area)	4	5	6

Source: Telephone survey 2020; Note: Out of total respondents (n) of each location, half are labour leaders and the rest are farmers.

Boro harvesting cost

The cost of harvesting Boro rice (BDT 6,309-6,944/acre) by combine harvester was 31-39% lower than manual harvesting and carrying, including the cost of threshing by power thresher. Per acre cost of Boro harvesting by reaper was 12-18% lower than the manual Boro harvesting and carrying, including threshing by power thresher. Moreover, mechanical harvesting reduces the harvesting time largely, which facilitates to escape from damage of rice by flash-floods. The opportunity cost of the straw of Boro rice was BDT 2,500-3000 per acre (Table 13).

The average price of Boro paddy in the third week of April in Kishoreganj was significantly higher at the 1% level of probability than in Sunnamganj. The average price in the fourth week of April in Kishoreganj was higher at the 5% level of significance than in Sunnamganj (Table 14). The average price of Boro rice in the third week of April in Kishoreganj was significantly higher at the 10% level of probability than in Netrakona. On the other hand, there was no significant variation in the mean price of Boro rice in the fourth week of April between Kishoreganj and Netrakona (Table 14).

Table 13. Boro harvesting, carrying and threshing cost under different basis of payment for labour and machine in the *haor* areas in Bangladesh.

Payment charge	Sunamganj (n=120)	Kishoreganj (n=30)	Netrakona (n=30)
Combine harvester (BDT/acre)	6,309	6,944	6,542
Harvesting and threshing	4,659	5,294	5,102
Carrying straw and grain manually	2,200	2,200	1,920
Reaper (BDT/acre):	7,442	7,865	7,635
Harvesting	4,067	4,250	4,220
Carrying manually	1,750	1,690	1,740
Power thresher	1,625 (2.5 mound)	1,925 (2.75 mound)	1,675 (2.5 mound)
Labour cash contract and power thresher (BDT/acre):	8,150	9,474	8,583
Cash contract: Harvesting and carrying	6,525	7,549	6,908
Power thresher	1,625	1,925	1,675
Labour paddy share and power thresher (BDT/acre):	8,765	9,205	8,644
Paddy share (mound/acre)	10.5 (BDT 7,140)	10.4 (BDT 7,280)	10.1 (BDT 69,69)
Power thresher	1,625	1,925	1,675
Daily wage Labour and power thresher: BDT/man–days:	8,305	8,605	7,915
Daily wage	550 (BDT 6,680)	550 (BDT 6,680)	520 (BDT 6,240)
Power thresher	1,625	1,925	1,675

Source: Telephone survey 2020.

Table 14. Price of wet Boro rice for the last two weeks in *haor* areas of Bangladesh.

Item	Sunamganj (n=120)	Kishoreganj (n=30)	Netrakona (n=30)
Price in third week of April (BDT/mound)	706	783	750
Price in fourth week of April (BDT/mound)	683	729	687

Source: Telephone survey, 2020; Note: Out of total respondents (n) of each location, half are labour leaders and the rest are farmers. 1 mound= 40 kg, the wet of 40 kg wet rice decreased to in the range between 33–35 kg after drying.

Biophysical and market performance of Boro rice

The average yield of BRRI dhan28 in the *haor* areas in 2020 was 69–82% higher than that of 2019. Similarly, per acre yield of BRRI dhan29 and hybrid was also (20–33% and 20–30% respectively) in 2020 than that of 2019 (Table 15). Farmers reported that the best seasonal weather condition in terms of less infestation of pests and diseases were the vital factor for the higher grain yield in 2020.

Tables 16 and 17 present the mean test results of the price of Boro paddy in the third and fourth week of April between Kishoreganj and Sunamganj and between Kishoreganj and Netrakona. The mean price in the fourth week of April in Kishoreganj was significantly higher at the 5% level of probability than in Sunnamganj (Table 16). On the other hand, there was no significant variation in the mean price of Boro rice in the fourth week of April between Kishoreganj and Netrakona (Table 17).

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Table 15. Mean test of biophysical performance of major Boro cultivars in haor areas between 2019 and 2020.

Variety grown	Kishoreganj		Mean diff (t test)	Sunamganj		Mean diff (t test)	Netrakona		Mean diff (t test)
	Yield (mound/acre)			Yield (mound/acre)			Yield (mound/acre)		
	2019	2020		2019	2020		2019	2020	
BRRI dhan28	33.600	57.533	-23.933***	32.320	53.733	-21.412***	32.667	59.600	-26.933***
BRRI dhan29	53.533	64.600	-11.067***	47.768	64.122	-16.354***	54.867	66.000	-11.733***
Hybrid	56.467	73.067	-16.600***	58.200	69.922	-11.722***	60.067	72.467	-12.400***
Sample size	15	15		60	60		15	15	

Note: ***p< 0.01 percent level of probability, 1 Mound= 40 kg, the yield was estimated based on 10-14% moisture contain.

Table 16. Mean test of Boro rice price between Kishoreganj and Sunamganj in the third and fourth week of April 2020.

Item	Kishoreganj	Sunamganj	Mean diff (t test)	Kishoreganj	Sunamganj	Mean diff (t test)
	3rd week	3rd week		4th week	4th week	
Group mean	783.333	706.182	77.152***	728.667	683.455	45.212**
Sample	15	55		15	55	

Notes: ***p <0.01, **p < 0.05 percent level of probability.

Table 17. Mean test of Boro rice price between Kishoreganj and Netrakona in the third and fourth week of April 2020.

Item	Kishoreganj	Netrakona	Mean diff (t test)	Kishoreganj	Netrakona	Mean diff (t test)
	3rd week	3rd week		4th week	4th week	
Group mean	783.333	750.00	33.333*	728.667	686.667	42.00^{NS}
Sample	15	15		15	15	

Notes: *p < 0.1 percent level of probability. NS = Not significant.

RICE PRODUCTION SCENARIO OF HILLY AREAS IN BANGLADESH

Total area of three hilly districts is 13295 sq.km (10% of the country) of which, nearly 77% are hill and 3% are undulating bumpy and only 20% are plain land (valley) available for crop production. All types of modern rice can be grown in the valley. As increased population created pressure on land, time interval of cultivating *Jhum* land reduced from 10-12 years to 2-3 years but yet hilly areas are in still food deficit. *Jhum* areas declining due to cultivation of fruits, cash crops and afforestation. The present study has been conducted with the following objectives to:

- Find out the adoption level of different rice varieties and reasons of adoption
- Analyze profitability of rice production
- Find out major problems of rice production in hilly areas

The study was conducted in eight upazilas of three hilly districts during 2019-20. In total 1500 famers were interviewed with structured questionnaire. Data were also collected from retailers and wholesalers of rice markets in three districts. Eight FGDs were conducted to collect and validate the information from different stakeholders. Simple tabular form was applied to analyze the data.

Rice areas in hilly districts

Total rice area were 1,01,329 ha and *Jhum* area were around 16% in hilly districts during 2019. Largest area was covered by T. Aman (43.84%) followed by Boro (32.34%). Khagrachari district alone covered 41,263 ha which is the highest among the three district.

Adoption of Boro varieties in the hilly areas

Among the BRRI varieties, BRRI dhan28 occupied the highest area (20.33%) followed by BRRI dhan29 and BRRI dhan58. More than 55% areas were covered by BRRI varieties though hybrid rice covered more than 38% areas in the studied locations. All types of farmers chose hybrid rice because of higher yield (Table 18).

Adoption of Aman varieties in the hilly areas

In the study locations, around 70% areas were under BRRI varieties and BRRI dhan49 ranked the first position while BRRI dhan11 ranked second position. More areas (28.11%) were also covered by other MVs like *Pajam*, *Chakka panja*, *Sada panja* etc. These varieties were preferred by the famers because of good taste, drought tolerance ability and low input requirement (Table 19).

Yield of Boro rice

Average yield of BRRI variety was 5.33 t ha^{-1} and hybrid rice was 6.30 t/ha. BRRI dhan58 produced higher yield (5.54 t/ha) followed by BRRI dhan29. In some areas, there were the shortage of irrigation water during flowering stage that hampered the yield (Table 20).

Yield of Aman rice

Average yield of Aman rice was 4.37 t ha^{-1} and average yield of BRRI variety was 4.46 t ha^{-1}. BRRI dhan33 produced higher yield (4.58 t ha^{-1}) because it was transplanted early in the more fertile land (Table 21).

Table 18. Adoption rate (%) of Boro rice varieties in the hilly districts.

Variety	Bandarban	Khagrachori	Rangamati	Average
All BRRI	53.57	51.84	55.93	55.03
BRRI dhan28	9.17	16.85	24.57	20.23
BRRI dhan29	0.29	3.89	18.26	12.76
BRRI dhan58	20.91	11.66	5.75	9.89
Other BRRI	16.47	19.44	3.75	8.09
Hybrid	42.76	45.57	35.56	38.10
OMVs	3.67	2.59	8.51	6.86
Total	100.00	100.00	100.00	100.00

Table 19. Adoption rate (%) of T. Aman rice varieties in the hilly districts.

Variety	Bandarban	Khagrachori	Rangamati	Average
All BRRI	71.99	72.78	67.20	69.65
BR11	11.42	30.15	12.50	15.02
BRRI dhan33	11.89	4.44	0.07	4.59
BRRI dhan39	1.82	0.45	6.12	3.82
BRRI dhan49	23.05	25.37	21.76	22.76
BRRI dhan51	0.00	0.00	4.82	2.49
Other BRRI	23.81	12.37	14.91	17.36
Hybrid	5.00	0.00	0.00	1.61
OMVs	22.34	27.22	32.00	28.11
LVs	0.68	0.00	0.80	0.63
Total	100.00	100.00	100.00	100.00

Table 20. Yield (t ha^{-1}) of Boro season rice varieties in the hilly districts.

Varieties name	Bandarban	Khagrachori	Rangamati	Average
Average BRRI	5.60	5.71	4.69	5.33
BRRI dhan28	5.21	5.76	4.51	5.16
BRRI dhan29	5.43	5.09	5.21	5.25
BRRI dhan58	6.20	6.00	4.43	5.54
Other BRRI	5.45	5.24	5.21	5.30
Hybrid	6.60	6.56	5.73	6.30
OMVs	5.15	4.30	4.82	4.76
Average	6.04	5.84	5.04	5.64

Table 21. Yield of Aman (t ha^{-1}) rice varieties in the hilly districts.

Varieties name	Bandarban	Khagrachori	Rangamati	Average
Average BRRI	4.92	4.39	4.15	4.46
BR11	4.95	4.27	4.24	4.43
BRRI dhan33	4.85	4.92	4.94	4.58
BRRI dhan39	4.81	4.63	4.44	4.50
BRRI dhan49	4.86	4.36	4.12	4.42
BRRI dhan51	-	-	3.81	3.81
Other BRRI	5.01	4.49	3.88	4.46
Hybrid	5.96	-	-	5.96
OMVs	4.73	4.29	3.71	4.10
LVs	4.08		2.84	3.40
Average	4.91	4.36	4.01	4.37

Profitability of rice production in the hilly districts

Table 22 presents the profitability of rice production in the hilly districts. On cash cost basis, Boro rice production was profitable but on full cost basis, it was a losing concern. Aman rice production was not profitable due to lower price of paddy and higher cost for land rent. But on cash cost basis, Aman was profitable due to higher involvement of family labor. In the hilly districts, involvement of family labours were higher in rice production activities. Like other areas of Bangladesh, price of paddy was lower in the study locations (Table 22).

Problems of rice production in the hilly districts

Table 23 delineates the problems of rice production in the hilly districts**.** Higher irrigation and tillage cost was the major cost of rice production in the hilly areas. Lower price of paddy also discouraged surplus rice production. Tenant farmers had to depend on NGOs for credit to apply inputs.

Table 22. Profitability of rice production in the hilly districts.

Total costs (BDT/ha)	Boro			Aman		
	Rangamati	Khagrachori	Bandarban	Rangamati	Khagrachori	Bandarban
Total variable costs (BDT/ha)	105589	105156	112782	81455.47	78810.58	95036.47
Total fixed cost (BDT/ha)	60160.78	62965.08	76031	39318.25	39053.33	39865.00
Yield (kg/ha)	45428	42191	36751	42137.22	39757.25	55171.47
Market value of paddy (BDT/ha)	5314	5228.28	5715.7	4317.59	4033.17	4432.00
Market value of straw (BDT/ha)	80773	84855	89051	61827.89	63603.09	64662.88
Gross benefit (BDT/ha)	11000	12000	15000	10500.00	11000.00	12000.00
Gross margin (BDT/ha)	91773	96855	104051	72327.89	74603.09	76662.88
Net return (BDT/ha)	31612	33890	28020	33009.64	35549.76	36797.88
Unit price of grain (BDT/kg)	-13816	-8301	-8731	-9127.58	-4207.49	-18373.59
Unit cost of production (BDT/kg)	15.2	16.23	15.58	14.32	15.77	14.59
BCR (cash cost basis)	19.87	20.11	19.73	18.87	19.54	21.44
BCR (full cost basis)	1.53	1.54	1.37	1.84	1.91	1.92
Total costs (BDT/ha)	105589	105156	112782	0.89	0.95	0.81

Table 23. Problems of rice production in the hilly districts.

Problem	Farmers opined (%)			All districts
	Khagrachari	Rangamati	Banderban	
Higher irrigation cost	100.00	100.00	100.00	100.00
Higher tillage cost	100.00	100.00	100.00	100.00
Lack of institutional credit for tenant farmers	100.00	100.00	100.00	100.00
Dependence on NGOs for credit	50.00	50.00	45.00	48.33
Advance selling of output	-	-	30.00	10.00
Exploited by local *Faria* syndicate	70.00	75.00	70.00	71.66
Lack of local paddy market	80.00	90.00	80.00	83.33
Higher carrying cost of paddy	100.00	100.00	100.00	100.00
Lower price of rice	100.00	100.00	100.00	100.00
Higher land rent for tenant	100.00	100.00	100.00	100.00
High cost of fertilizers	100.00	100.00	100.00	100.00
Higher cost incurred for input carrying	100.00	100.00	100.00	100.00
Dependence on rainfall affect yield	90.00	90.00	90.00	90.00

Suggestions to solve the problems

Increased subsidized irrigation and tillage equipment, extended institutional credit facilities, subsidy in diesel, strengthening the monitoring activities to ensure fair paddy price for the farmers etc were reported as probable measures for the solution of existing hitches.

RETURN TO RESEARCH INVESTMENT OF THE POST-1990S BRRI VARIETIES AND TECHNOLOGIES IN BANGLADESH

Major rice policies have been implemented by the government to increase production and to reduce imports. The government allocated sufficient investment in rice research and extension to improve yield and reduce the costs of rice production in the long run. Bangladesh agricultural research system is a key component of a high investment/high growth strategy in agriculture. BRRI leads the targeted breeding activities well in Bangladesh’s diverse environments. In the future, agricultural research will be the major driving force for increasing agricultural productivity and production on a sustained basis. The present study was undertaken with following objectives to :

- ✓ Estimate the economic rates of return to research and extension investment in post 1990 rice technologies
- ✓ Determine the foreign exchange savings and earnings, and
- ✓ Provide information to policy makers, donor agencies and researchers about the research and extension contribution of rice technologies

Methods and model. Economic surplus approach has been used to measure the changes in economic welfare emanated from technological interventions (Alston *et al.* 1995, Currie *et al.* 1971). The components of economic surplus are consumers' and producers' surplus resulting from a shift in the supply curve, caused by an increase in productivity. The Akino and Hayami (1975) approximation formulas which is suitable for closed and small open economy like Bangladesh was applied for calibration of social welfare of the post-1990s BRRI rice varieties and technologies.

Yield Advantage:

$$1-(Y_{pre-1990}/Y_{post-1990t})$$

where,

$Y_{post-1990}$= yield of post-1990s rice varieties in year t, and $Y_{pre-1990}$= yield of pre-1990 rice varieties that had been grown in the past.

The supply shifter k :

$$\sum_{i=1}^{n}[1-(Y_{pre-1990}/Y_{post-1990t})]\times A_{post-1990t}$$

Where; $Y_{post-1990t}$ = yield of the post-1990s rice varieties in year t.

$Y_{pre-1990}$ = the yield of average pre-1990 varieties that had been cultivated in the past and that would still be grown if no new varieties had been developed.

$A_{post-1990t}$ = the proportion of the total area sown to post-1990s rice variety i in year t. n = the number of improved varieties.

The most powerful method of expressing the relationship between the total discounted costs and benefits is the internal rate of return (IRR).

$$IRR = \sum_{t=0}^{T} C_t/(1+r_i)^t = \sum_{t=0}^{T} B_t/(1+r_i)^t$$

where,

r_i = internal rate of interest;

C_t = total research costs in year t;

B_t = total benefits in year t; and

T = year in which the research ceases to produce benefits.

The present value of net benefits (NPVB) indicated the amount of total funds returned from the investment in research and extension.

$$NPVB = \sum_{t=1}(\Delta TS_t - C_t) / (1+r_i)^t$$

where, C_t = total research costs in year t;

ΔTS_t = total surplus in year t; r = the discount rate, and n = the time horizon over which the benefits of the investments are realized.

Required data. BRRI varieties which were released before 1990 defined as pre-1990s and those after 1990 treated as post-1990s. Other than BRRI varieties were classified as local and other MVs based on variety type. Local rice varieties are those traditionally cultivated over the years. Other MVs which were developed by other than BRRI. Yield advantage and replacement among them were compared.

The adoption profile of rice varieties over the years was adopted from different annual report of Bangladesh Rice Research Institute (BRRI. The costs incurred in the past years for rice research were collected from DAE, BARC, BRRI and IRRI. Year-wise area, production and yield were collected from BBS and DAE. Year-wise quantity and price of imported rice from Food and Agriculture Organization statistics (FAOSTAT) and FOB (Free On Board) price of rice from BBS. Consumer price index (CPI) (1980-2018) was collected from various issues of the Bangladesh Bureau of Statistics (BBS).

Results. The post-1990s varieties in Aus season have no coverage in 1990 and tremendously went up to 64 percent in 2018. Area shifting to them still continues. Area under pre-1990s BRRI MVs, other MVs and local (50 percent) after 1990 were in declining trend and went down to 6 percent in 2018.

Total percent area under post-1990s varieties in T. Aman is about 1 percent in 1997 and surprisingly increased to 42 percent in 2018. Area under pre-1990s BRRI MVs, other MVs and local is 57 percent and radically decreased to 12 percent in 2018

Area under the post-1990s varieties in Boro season is 2 percent in 1994 and rapidly increased to 67 percent in 2018. Area under pre-1990 BRRI MVs, other MVs and local is 60 percent and drastically decreased to 2 percent in 2018.

The supply shifter is estimated to be 2% in 1992 (2% more production) due to the adoption of post-1990s BRRI rice varieties and continuously increased to 16% in 2018 (16% more production) in Aus season. Similarly T. Aman season received supply shifter of 6% in 1997 and 16% in 2018. About 2% more in 1994 and 17% more rice production in 2018 respectively were obtained with adoption of the post-1990s BRRI varieties in Boro season.

Calibrating with the base parameters and only public research cost (BRRI and BARC), the IRR to the post-1990s BRRI varieties R&D is tk. 56 for the period 1990-2018 and produced returns on an average tk. 2 per year from the date of investment. The benefit-cost ratio (BCR) is estimated at 10.09, implying that one taka investment generated tk. 10.09 taka over the period. The IRR to the post-1990s BRRI varieties R&D (Research and development) is tk. 52 for the period 1990-2018 when research, extension and private expenditure from International Rice Research Institute (IRRI) were taken into consideration. The benefit-cost ratio (BCR) under this situation is estimated at tk.9.000. Due to adoption of the post-1990s BRRI rice varieties, per year saving of import expenditure of tk. 39684 million for rice could be saved. Therefore, Bangladesh has to make more investment in rice research and emphasize on quality rice production.

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SUMMARY

Among T. Aman varieties, BRRI dhan49, BRRI dhan79 and BRRI dhan87 were found stable, while BR3, BR5, BRRI dhan25, BRRI dhan33, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan46, BRRI dhan56, BRRI dhan57, BRRI dhan70, BRRI dhan76 and BRRI dhan77 appeared to be below average stable. BR 4, BR10, BR 11, BR 22, BR23, BR25, 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 dhan76, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI hybrid dhan4 and BRRI hybrid dhan6 were found having average stability among T. Aman varieties. BRRI dhan34 and BRRI dhan62 were found as unstable varieties where no stable variety was found in T. Aman season.

BRRI dhan30 (G8) recorded the highest average grain yield among long duration varieties, and BRRI dhan49 (G21) was the most stable genotype with above-average yield in medium duration where BRRI dhan87, BRRI hybrid dhan6 (G42), BRRI dhan72 (G37), and BRRI hybrid dhan4 (G41) 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 environment was BR10 (G4) and BRRI dhan30 (G8) for first; BR22 (G6) and BR23 (G7) for another mega environment. In medium duration, the biplot grouped the test locations into three mega-environments and BRRI dhan49 (G21) was the winning genotype in the first mega-environment while BRRI dhan79 (G27) was the winner in the second and BRRI dhan54 (G24) was the winner in the last mega-environment. Also, three mega-environments were identified in short duration, BRRI dhan87 (G40), BRRI dhan72 (G37) and BRRI dhan66 (G35) being the winning genotypes for respective mega environment. Among the study locations, Cumilla (E3) and Rajshahi (E6) showed the ideal and highly representative environment for testing long, medium and short duration genotypes respectively.

It is found that when we adopt the potential high yielding variety at the respective season and region with the best crop management practices (BRRI recommended) then total clean rice production increases 14.31% than as usual production. In case of the selecting highest yielding variety production increased 5.95% but for wrong selection of variety (low yielding variety) production decreased more than 48%.

In the reporting year it is foun that, the Aus rice area and production maintained decreasing growth rate throught the country where yield of Aus rice was found significant increasing growth rate. In case of Aman season, growth rate of area was decreasing but growth rate of production and yield significantly increased. All three aspects area, production and yield showed significant increasing trend for Boro season in Bangladesh.

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, BRRI dhan48 produced the highest yield (5.57 t ha-1) at 80 kg N/ha and lowest (1.59 t ha^{-1}) when applied at 40 kg N/ha. The highest and lowest yielder variety were found BRRI dhan82 (5.69 t ha^{-1}) and BR26 (1.82 t ha^{-1}) variety for irrigation experiment when applied AWD 15 cm condition. In time of planting experiment, the highest and lowest performance was found BRRI dhan48 when the transplanting time 30 April (5.71 t ha^{-1}) and 10 May (2.06 t ha^{-1}), respectively.

In Aman season BRRI dhan87 is suitable in central, south central and some northern parts of Bangladesh. North-western side, north central side and some areas of south-western parts of Bangladesh are suitable for BRRI dhan89 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.

Temporal signature of various types of rice and others features in Barind area were extracted and finally rice map has been prepared.

The highland agricultural area was found 1.81 mha and Medium Highland1 agricultural area were found 0.66 mha and the total Aus prospected area was found 2.47 mha.

In the reporting year four types of training was conducted under “experimental data analysis” programme. A total of 150 participants were trained through the training programmes. The participants of these training were scientists, AE and SA of BRRI.

This division has developed ‘Rice doctor’ web and mobile apps both English and Bengoli version with the help of different divisions of BRRI. Developed dynamic view connectivity, bangla search and inner banner system for BRKB web apps. Also, digitalized labour management system (DLMS) and casual leave (CL) application of BRRI. Besides, modified the RKB mobile apps and developed push notification for RKB. We organized five-day-long, two-day-long, day-long ‘Public Service Innovation’ training workshops in the reporting year. A total of 75 participants were trained through the innovation trainings.

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 2002-19 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 season, the numbers of varieties were 42. The design was RCB with three replications and the effective plot size (harvest area) was 2.6-x-2.6 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 T. Aman varieties, BRRI dhan49, BRRI dhan79 and BRRI dhan87 were found stable with stability index 2.05, 2.03 and 2.01 respectively while BR3, BR5, BRRI dhan25, BRRI dhan33, BRRI dhan37, BRRI dhan38, BRRI dhan39, BRRI dhan46, BRRI dhan56, BRRI dhan57, BRRI dhan70, BRRI dhan76 and BRRI dhan77 appeared to be below average stable. BR4, BR10, BR11, BR22, BR23, BR25, 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 dhan76, BRRI dhan78, BRRI dhan79, BRRI dhan80, BRRI dhan87, BRRI hybrid dhan4 and BRRI hybrid dhan6 were found having average stability among T. Aman varieties. BRRI dhan34 and BRRI dhan62 were found as unstable varieties in T. Aman season (Table 1).

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 2019. Forty-two BRRI released T. Aman rice varieties were evaluated in nine environmental conditions of Bangladesh, such as Barishal (E1), Bhanga (E2), Cumilla (E3), Gazipur (E4), Rajshahi (E5), Rangpur (E6), Satkhira (E7), Sonagazi (E8) and Kushtia (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 3 m × 2 m. Standard agronomic practices were followed and plant protection measures were taken according to Adhunik dhaner chash, BRRI (2018). AMMI model was used to quantify the effect of

Table 1. Stability parameters of grain yield for T. Aman.

Variety	Stability parameter 2001-2019			Stability index	Stability rank	Nature of stability
	Si	Di	Pi	Gi	Ri	
Non-aromatic rice						
BR 3	18.62	-9.54	81	0.55	34	BAS
BR 4	12.74	0.84	75	1.05	24	AS
BR 10	13.51	9.09	71	1.30	8	AS
BR 11	14.12	6.88	76	1.24	13	AS
BR 22	14.35	6.50	73	1.20	17	AS
BR 23	14.88	3.01	77	1.06	23	AS
BR 25	15.56	-0.21	74	0.93	29	BAS
BRRI dhan30	13.13	6.85	75	1.28	9	AS
BRRI dhan31	14.62	1.72	76	1.03	26	AS
BRRI dhan32	16.47	8.03	81	1.27	10	AS
BRRI dhan33	20.07	-11.02	69	0.39	36	BAS
BRRI dhan39	18.39	-2.45	70	0.75	31	BAS
BRRI dhan40	14.25	6.29	80	1.25	11	AS
BRRI dhan41	15.96	5.43	77	1.12	20	AS
BRRI dhan44	14.59	7.53	52	1.20	15	AS
BRRI dhan46	16.06	1.84	48	0.96	28	BAS
BRRI dhan49	10.27	12.06	43	2.01	3	Stable
BRRI dhan51	14.87	3.93	37	1.09	22	AS
BRRI dhan52	10.09	9.11	39	1.54	4	AS
BRRI dhan53	15.38	3.24	30	1.03	25	AS
BRRI dhan54	17.45	9.26	27	1.16	19	AS
BRRI dhan56	16.43	-4.83	31	0.71	33	BAS
BRRI dhan57	22.19	-21.79	35	0.04	38	BAS
BRRI dhan62	29.42	-24.06	26	-0.12	42	Unstable
BRRI dhan66	13.63	5.04	22	1.20	16	AS
BRRI dhan70	19.36	-9.58	19	0.52	35	BAS
BRRI dhan71	11.96	6.60	15	1.23	14	AS
BRRI dhan72	12.23	12.78	14	1.41	7	AS
BRRI dhan73	16.75	6.84	19	1.18	18	AS
BRRI dhan75	14.70	0.74	19	1.01	27	AS
BRRI dhan76	12.02	-4.36	19	0.93	30	BAS
BRRI dhan77	13.39	-6.72	17	0.73	32	BAS
BRRI dhan78	8.02	4.92	9	1.52	5	AS
BRRI dhan79	6.76	8.83	9	2.03	2	Stable
BRRI dhan80	10.72	3.09	9	1.24	12	AS
BRRI dhan87	10.32	22.11	9	2.05	1	Stable
BRRI Hybrid dhan4	15.92	3.12	28	1.12	21	AS
BRRI Hybrid dhan6	13.80	13.09	13	1.45	6	AS
Aromatic rice						
BR5	18.86	-22.94	76	0.04	40	BAS
BRRI dhan34	19.37	-27.10	78	-0.12	41	Unstable
BRRI dhan37	17.49	-23.15	77	0.04	39	BAS
BRRI dhan38	16.29	-21.03	72	0.12	37	BAS

Note: AS=Average Stable, BAS=Below Average Stable.

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 x 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 54.57, 48.27 and 40.27% of the total variation for medium, short and long duration respectively. Additionally, the relative contribution of genotype sum of squares was found 12.47, 12.26 and 1.82% for long, short and medium duration respectively. Genotype by environment (G × E) contributed the most 15.74% to the total variation for long duration followed by 12.19% and 10.60% for short and medium duration (Table 2). 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 75.89%, 72.28%, and 74.94% of the total variation of the environments for long, medium and short duration respectively. In long duration (Fig. 1a), there were three clusters of environments, one contains Barishal (E1) and Cumilla (E3); another contains Bhanga (E2) and Rangpur (E7); the other cluster contains Kushtia (E5), Rajshahi (E6) Satkhira (E8) and Sonagazi (E9). Among them Barishal (E1) and Cumilla (E3) were closely associated (Fig. 1a). Gazipur (E4) had the longest vector and hence was highly discriminating. The locations Rajshahi (E6), Satkhira (E8) were highly representative environments (Fig. 1a). Overall, the location Rajshahi (E6) can be considered ideal for evaluating long duration genotypes.

GGE biplot showed two distinct clusters in medium duration: one contains Barishal (E4), Satkhira (E8) and Sonagazi (E9) and other contains Kushtia (E5), Rajshahi (E6), and Rangpur (E7) (Fig. 1b). The closest association were observed between the environments Satkhira (E8) and Sonagazi (E9) and Kushtia (E5) and Rangpur (E7). The location Cumilla (E3) showed negative or no correlation with Gazipur (E4), Rajshahi (E6) and Barishal (E1). The ideal environment was found Rajshahi (E6) for medium duration (Fig. 1a). Barishal (E1), Bhanga (E2), Cumilla (E3) and Gazipur (E4) had the longest vector and hence was a highly discriminating location (Fig. 1b). The locations Kushtia (E5), Rangpur (E7), Satkhira (E8) and Sonagazi (E9) were highly representative of other locations. Considering the above two qualities together, Rajshahi (E6) was 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 (Fig. 1c). Barishal (E1) and Kushtia (E5) considered one cluster and the second cluster contains Cumilla (E3), Rajshahi (E6), Satkhira (E8) and Sonagazi (E9) and the rest cluster contain two locations Gazipur (E4) and Rangpur (E7). Bhanga (E2) and Rangpur (E6) showed the longest vector, making it more discriminating than the other environments. Considering the criteria of ideal environment, Cumilla (E3) and Rajshahi (E6) showed a smaller angle with the AEA and hence was highly representative environment (Fig. 1c) for testing short duration genotypes.

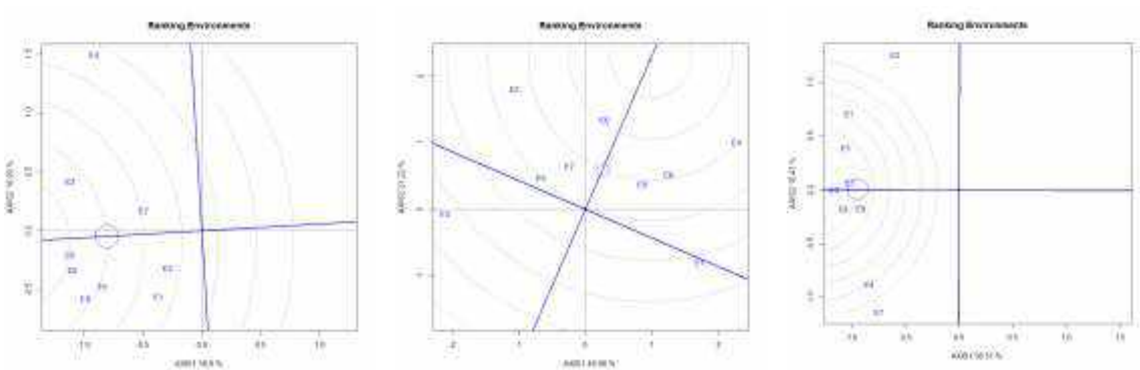
Performance and stability of rice genotypes across tested environments

Within a single mega-environment, genotypes should be evaluated on both mean performance and stability across environments. Figures 2a, 2b and 2c shows average-environment coordination (AEC) views of the GGE biplot for grain yield of long, medium, and short duration. Table 3 shows the yield performances and summary of ideal genotypes

Table 2. ANOVA of individual category (long, medium and short).

SV	Long duration			Medium duration			Short duration		
	DF	MS	SS (%)	DF	MS	SS (%)	DF	MS	SS (%)
ENV	8	54.80**	40.27	8	47.56**	54.57	8	56.67**	48.27
REP(ENV)	18	14.97**	24.75	18	10.70**	27.61	18	11.79**	22.60
GEN	16	8.49**	12.47	10	1.27**	1.82	13	8.86**	12.26
ENV:GEN	128	1.34**	15.74	80	0.92**	10.60	104	1.1**	12.19
Residuals	288	0.26	6.77	180	0.21	5.39	234	0.19	4.68
CV(%)		12.74			10.66			9.81	
$LSD_{0.05}$		0.84			0.74			0.69	

Note: ENV=environment, GEN= genotype, DF = degrees of freedom; MS = mean sum square; SS (%) = explain % sum of squares; ** = significant at 1% level.



a b c

Fig. 1. Association among the test environments based on the average environmental coordinate (AEC), considering stability and adaptability of rice genotypes evaluated across different environments of Bangladesh for grain yield categorized by (a) Long duration, (b) Medium duration, and (c) Long duration in T. Aman 2019 growing seasons.

and genotypes with stable and high mean yields in different categories (long, medium and short duration). BRRI dhan30 (G8) recorded the highest average grain yield in long duration (Fig. 2a). BR10 (G4), BR11 (G5), and BRRI dhan41 (G13) were the most stable genotypes with above-average yields. Thus, the BR10 (G4) and BR11 (G5) were the most ideal genotype with the highest mean yield and stability among the tested genotypes. The genotype BRRI dhan49 (G21) was the most stable genotype with above-average yield in medium duration (Fig. 2b). BRRI dhan79 (G27), BRRI dhan52 (G23), BRRI dhan78 (G26) recorded the above-average yields. Other stable genotypes with above-average yields were BRRI dhan52 (G23), BRRI dhan54 (G24) and BRRI dhan79 (G27). BRRI dhan87 (G40) recorded the highest average grain yield, most stable and ideal genotype in short duration (Fig. 2c). Also, BRRI hybrid dhan6 (G42), BRRI dhan72 (G37), and BRRI hybrid dhan4 (G41) were the most stable genotypes and above average yielder.

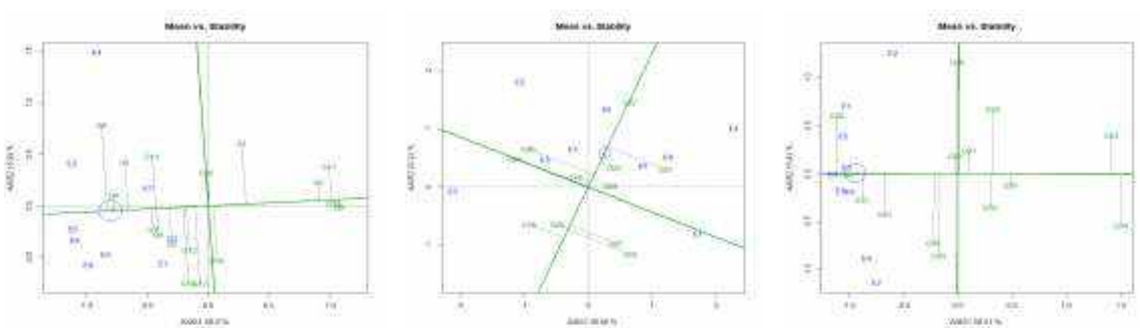
Identification of which-won-where and mega-environment

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.

The biplot showed three sectors containing all the test environments in long duration and accordingly three mega-environments were identified (Fig. 3a): One mega-environment had three locations, Bhanga (E2), Gazipur (E4) and Rangpur (E7); the second consisting of four locations-Kushtia (E5), Rajshahi (E6), Satkhira (EE8), and Sonagazi (E9). Hence, the winning genotype in those environments was BR10 (G4) and BRRI dhan30 (G8) for first; BR22 (G6) and BR23 (G7) for another mega environment (Fig. 3a). BRRI dhan34 (G9), BRRI dhan37 (G10), BRRI dhan38 (G11) and BR5 (G3) were the low yielder of long duration genotypes.

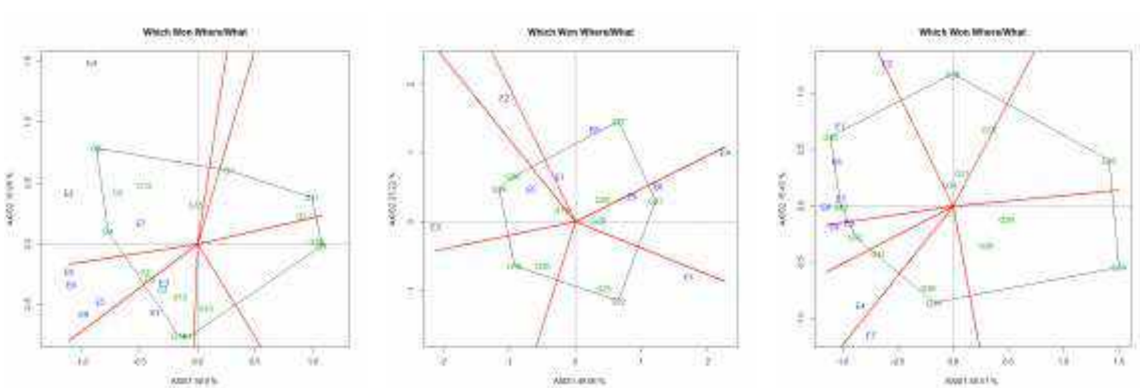
In medium duration, the biplot grouped the test locations into three mega-environments (Fig. 3b). The first mega-environment had three locations, Gazipur (E4), Satkhira (E8) and Sonagazi (E9). The second had two locations those were Rajshahi (E6) and Rangpur (E7). The third contained two locations Cumilla (E3) and Kushtia (E5). BRRI dhan49 (G21) was the winning genotype in the first mega-environment while BRRI dhan79 (G27) was the winner in the second and BRRI dhan54 (G24) was the winner in the last mega-environment. BR25 (G18), BRRI dhan51 (G22), BRRI dhan32 (G20) and BRRI dhan70 (G25) were the low yielder of medium duration genotypes.

The biplot was divided into three mega-environments in short duration (Fig. 3c). The first mega-environment had four locations-Barishal (E1), Cumilla (E3), Kushtia (E5) and Rajshahi (E6) with BRRI dhan87 (G40) being the winning genotypes. The second mega-environment had two locations-Satkhira (E8) and Sonagazi (E9) and BRRI dhan72 (G37) was the winner in this mega-environment. The third mega-environment consisted of one location-Rangpur (E7) and BRRI dhan66 (G35) was the winning genotypes.



a b c

Fig. 2. GGE biplot of mean and stability of rice genotypes for yield and specific genotype × environment interactions of different categories (a) Long duration, (b) Medium duration, and (c) Long duration in T. Aman 2019 growing seasons.



a b c

Fig. 3. GGE biplot identification of winning genotypes and their related mega-environments of different categories (a) Long duration, (b) Medium duration, and (c) Short duration in T. Aman 2019 growing seasons.

Table 3. Grain yield performance of BRRI released T. Aman rice varieties during 2019.

Variety	Gen code	Barishal (E1)	Bhanga (E2)	Cumilla (E3)	Gazipur (E4)	Kushtia (E5)	Rajshahi (E6)	Rangpur (E7)	Satkhira (E8)	Sonagazi (E9)	Average yield (t ha^{-1})
						Long duration					
BR3	G1	5.24	1.97	3.20	4.03	2.44	4.69	4.68	3.61	3.75	3.73
BR4	G2	5.34	2.63	4.17	2.89	4.08	4.90	4.97	4.51	4.83	4.26
BR5	G3	4.65	1.67	4.20	2.67	2.58	3.66	4.38	2.86	3.04	3.30
BR10	G4	4.71	3.14	4.45	4.16	3.67	5.63	4.43	5.29	5.39	4.54
BR11	G5	4.34	3.01	4.35	4.56	2.95	5.39	4.54	5.35	5.48	4.44
BR22	G6	4.77	3.81	4.61	2.64	3.66	5.37	4.42	4.34	4.87	4.28
BR23	G7	5.49	3.57	4.37	3.13	3.41	5.22	3.68	5.03	4.73	4.29
BRRI dhan30	G8	4.39	4.38	4.35	4.78	3.94	5.42	5.32	4.64	4.53	4.64
BRRI dhan34	G9	3.87	1.56	4.31	1.95	2.03	3.52	3.93	3.03	3.59	3.09
BRRI dhan37	G10	4.01	2.28	3.75	1.89	2.51	3.26	3.30	3.06	3.45	3.06
BRRI dhan38	G11	4.01	1.32	3.78	2.88	1.94	3.68	3.82	3.28	3.35	3.12
BRRI dhan40	G12	5.08	3.72	4.24	1.93	3.16	5.55	4.71	3.87	4.48	4.08
BRRI dhan41	G13	4.94	3.43	4.68	4.24	3.48	5.03	5.10	4.27	4.35	4.39
BRRI dhan44	G14	4.94	1.96	4.42	2.36	3.74	5.08	4.26	4.68	5.49	4.10
BRRI dhan46	G15	4.77	2.53	4.02	3.74	2.99	4.33	4.70	4.17	4.58	3.98
BRRI dhan76	G16	5.39	1.35	4.61	2.68	3.33	4.75	4.72	4.65	4.59	4.01
BRRI dhan77	G17	5.55	1.96	4.45	2.18	3.53	5.01	4.77	4.64	4.82	4.10
Mean average											3.97
						Medium duration					
BR25	G18	3.97	2.40	5.51	2.17	4.17	4.41	4.59	4.05	4.58	3.98
BRRI dhan31	G19	5.08	3.12	4.98	3.09	4.17	5.28	4.52	4.31	4.39	4.33
BRRI dhan32	G20	5.02	2.59	4.98	2.31	4.12	4.80	4.48	3.78	4.66	4.08
BRRI dhan49	G21	6.00	2.60	3.67	4.11	3.67	5.25	5.11	5.25	5.45	4.57
BRRI dhan51	G22	5.39	1.00	4.51	3.79	3.28	5.13	4.36	4.12	4.40	4.00
BRRI dhan52	G23	5.70	2.48	4.48	3.47	3.95	5.97	5.63	4.37	4.79	4.54
BRRI dhan54	G24	4.24	3.45	5.61	2.01	4.00	5.80	5.33	3.60	4.53	4.29
BRRI dhan70	G25	6.18	2.29	3.87	2.18	3.61	5.09	4.20	4.58	4.97	4.11
BRRI dhan78	G26	4.48	3.58	5.62	2.40	4.47	5.81	4.86	4.20	4.21	4.40
BRRI dhan79	G27	4.39	3.35	3.88	4.35	3.95	6.16	4.52	4.94	5.34	4.54
BRRI dhan80	G28	5.24	2.36	4.68	3.70	4.37	5.63	3.89	4.58	4.64	4.34
Mean average											4.29
						Short duration					
BRRI dhan33	G29	4.87	2.56	3.49	3.75	2.98	4.93	4.77	4.09	4.51	3.99
BRRI dhan39	G30	4.77	3.58	5.12	3.89	3.87	5.42	4.66	4.28	4.54	4.46
BRRI dhan53	G31	4.87	4.48	4.67	3.94	4.15	4.17	5.27	3.82	4.50	4.43
BRRI dhan56	G32	4.55	4.35	5.88	3.28	3.27	4.69	4.73	3.98	4.16	4.32
BRRI dhan57	G33	3.65	2.18	3.91	3.00	2.87	3.67	3.73	3.67	3.72	3.38
BRRI dhan62	G34	3.34	1.92	3.35	3.52	0.78	3.27	4.43	3.82	4.43	3.21
BRRI dhan66	G35	3.93	2.44	6.17	4.34	4.36	4.98	5.58	4.46	4.10	4.48
BRRI dhan71	G36	4.94	1.40	5.14	3.99	4.01	4.70	5.23	5.08	5.55	4.45
BRRI dhan72	G37	5.23	3.70	5.74	4.11	4.31	5.97	5.72	5.31	5.55	5.07
BRRI dhan73	G38	5.38	4.36	5.06	3.68	4.54	4.71	3.42	4.45	4.83	4.49
BRRI dhan75	G39	4.39	2.09	4.24	3.65	3.45	4.58	4.87	4.60	5.36	4.14
BRRI dhan87	G40	6.12	4.37	5.70	3.72	4.59	6.13	4.88	5.70	6.49	5.30
BRRI Hybrid dhan4	G41	4.95	3.03	5.71	3.88	3.78	6.36	5.71	4.58	6.45	4.94
BRRI Hybrid dhan6	G42	5.10	3.80	6.33	4.03	4.88	5.98	5.20	5.29	6.34	5.22
Mean average											4.42

REGION SPECIFIC BRRI VARIETY ADOPTION: A SIMPLE WAY OF INCREASING NATIONAL YIELD

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 structure of GEI is very important in plant breeding programmes because a significant GEI can seriously impair efforts in selection of superior genotypes in relation to new crop introductions and cultivar development programmes lead to successful evaluation of stable genotype, which could be used for general cultivation (Yan and Racjan, 2002; Vasgas *et al.* 2001; Reza *et al.* 2007). So, the main objectives of the study were to find out the region specific potential, the highest, average and the lowest yielded varieties and to project the national production of rice in Bangladesh according to that selection.

District wise total area and production of the three different seasons are collected from yearbook of Agricultural Statistics-2019 which is published in May 2020 and divided at different specific regions (Table 4) according to the availability of the trail data. Replicated trial in RCB design with BRRI released 42, 42 and 10 varieties set up in 10, 9 and 7 regions (BRRI HQ and other BRRI RSs at different regions) for Boro, T. Aman and Aus seasons respectively. BRRI recommended management practices were followed to conduct the trials. After collecting, data were compiled, tabulated and analyzed according to the objectives of the study. The analysis was performed by MS excel, and the third generation programming language R.

AUS season. In Aus season 10 different BRRI released Aus varieties were used in the trial at seven different locations. We found the potential high yielding variety BRRI dhan48 (4.96 t ha^{-1}) at BRRI HQ and the lowest BR21 1.82 t ha^{-1}) in BRRI RS, Rajshahi. In case of the lowest yielding variety BRRI dhan27 showed the minimum yield (0.74 t ha^{-1}) in BRRI RS, Rajshahi.

From the ANOVA results of combined analysis it is clear that the locations have significant yield difference though the same varieties and management practice were used. Also the varieties showed the significant difference according to yield performance. The DMRT result showed that the location BRRI RS, Cumilla has significant yield difference compared to the other locations with average yield of 4.94t/ha and some other location showed significant yield difference to each other.

Aman season. In Aman season 42 different BRRI released varieties were used in the trial at nine different locations of Bangladesh. We found the highest potential yielding variety BRRI dhan87 (7.8 t ha^{-1}) at BRRI RS, Rangpur and the lowest BRRI dhan72 (4.56 t ha^{-1}) in BRRI RS, Rajshahi. In case of the lowest yielding variety BRRI dhan34 showed the minimum yield (1.45 t ha^{-1}) in BRRI RS, Bhanga.

Table 4. Season and region-wise district distribution.

<table>
<tr><th>Season→
Region↓</th><th>Boro</th><th>Aman</th><th>Aus</th></tr>
<tr><td>Region 1
(Rangpur)</td><td>Kurigram, Lalmonirhat, Rangpur, Gaibanda, Ponchgor, Takurgaon, Nilfamari, Dinajpur</td><td>Kurigram, Lalmonirhat, Rangpur, Gaibanda, Ponchgor, Takurgaon, Nilfamari, Dinajpur</td><td>Kurigram, Lalmonirhat, Rangpur, Gaibanda, Ponchgor, Takurgaon, Nilfamari, Dinajpur</td></tr>
<tr><td>Region 2
(Rajshahi)</td><td>Rajshahi, chapainawabganj , Natore, Nogoan, Sirajganj, Pabna, Joypurhat, Bogura</td><td>Rajshahi, chapainawabganj, Natore, Nogoan, Sirajganj, Pabna, Joypurhat, Bogura</td><td>Rajshahi, chapainawabganj, Natore, Nogoan, Sirajganj, Pabna, Joypurhat, Bogura</td></tr>
<tr><td>Region 3
(Barishal)</td><td>Barishal, Bhola, Jhalokati, Potuakhali, Pirojpur, Borguna</td><td>Barishal, Bhola, Jhalokati, Potuakhali, Pirojpur, Borguna</td><td>Barishal, Bhola, Jhalokati, Potuakhali, Pirojpur, Borguna,</td></tr>
<tr><td>Region 4
(Bhanga)</td><td>Rajbari, Magura, Faridpur, Gopalganj, Narail, Madaripur, Shariotpur</td><td>Rajbari, Magura, Faridpur, Gopalganj, Narail, Madaripur, Shariotpur</td><td>Rajbari, Magura, Faridpur, Gopalganj, Narail, Madaripur, Shariotpur</td></tr>
<tr><td>Region 5
(Kushtia)</td><td>Kushtia, Meherpur, Chuadanga, Jhenaidah</td><td>Kushtia, Meherpur, Chuadanga, Jhenaidah</td><td>Kushtia, Meherpur, Chuadanga, Jhenaidah</td></tr>
<tr><td>Region 6
(Satkhira)</td><td>Satkhira, Jashore, Khulna, Bagerhat</td><td>Satkhira, Jashore, Khulna, Bagerhat</td><td>Satkhira, Jashore, Khulna, Bagerhat</td></tr>
<tr><td>Region 7
(Sonagazi)</td><td>Feni, Noakhali, Laxmipur, 5 district of Chattogram.</td><td>Feni, Noakhali, Laxmipur, 5 district of Chattogram.</td><td rowspan="3">Cumilla, Brahmanbaria, Chandpur, Feni, Noakhali, Laxmipur, 5 district of Chattogram., Habiganj, Sylhet, Sunamganj, Moulovibazar</td></tr>
<tr><td>Region 8
(Cumilla)</td><td>Cumilla, Brahmanbaria, Chandpur</td><td rowspan="2">Cumilla, Brahmanbaria, Chandpur, Habiganj, Sylhet, Sunamganj, Moulovibazar</td></tr>
<tr><td>Region 9
(Habiganj)</td><td>Habiganj, Sylhet, Sunamganj, Moulovibazar</td></tr>
<tr><td>Region 10
(Gazipur)</td><td>Gazipur, Dhaka, Manikganj, Munsiganj, Narayanganj, Narsingdi, Jamalpur, Sherpur, Kishoreganj, Mymensingh, Netrakona, Tangail</td><td>Gazipur, Dhaka, Manikganj, Munsiganj, Narayanganj, Narsingdi, Jamalpur, Sherpur, Kishoreganj, Mymensingh, Netrakona, Tangail</td><td>Gazipur, Dhaka, Manikganj, Munsiganj, Narayanganj, Narsingdi, Jamalpur, Sherpur, Kishoreganj, Mymensingh, Netrakona, Tangail</td></tr>
</table>

According to the divided region, BBS published area and production data of Aus, Aman and Boro seasons of different regions were taken (Table 5).

Table 5. Area and production of Aus, Aman and Boro of different region in Bangladesh.

<table>
<tr><th rowspan="2">Season→
Region↓</th><th colspan="2">Boro</th><th colspan="2">Aman</th><th colspan="2">Aus</th></tr>
<tr><th>Area (ha)</th><th>Production (T)</th><th>Area (ha)</th><th>Production (T)</th><th>Area (ha)</th><th>Production (T)</th></tr>
<tr><td>Region 1 (Rangpur)</td><td>764037.9</td><td>3147449</td><td>1094220</td><td>3173651</td><td>48010</td><td>137801</td></tr>
<tr><td>Region 2 (Rajshahi)</td><td>814725.4</td><td>3353049</td><td>793805</td><td>2057113</td><td>209585</td><td>572286</td></tr>
<tr><td>Region 3 (Barishal)</td><td>73731</td><td>392517</td><td>661082</td><td>1296824</td><td rowspan="2">256369</td><td rowspan="2">528848</td></tr>
<tr><td>Region 4 (Bhanga)</td><td>239567.3</td><td>1129959</td><td>296706</td><td>698302</td></tr>
<tr><td>Region 5 (Kushtia)</td><td>178074.9</td><td>773669.7</td><td>241683</td><td>682800</td><td>112981</td><td>312456</td></tr>
<tr><td>Region 6 (Satkhira)</td><td>295902.9</td><td>1331136</td><td>376385</td><td>946724</td><td>33178</td><td>81585</td></tr>
<tr><td>Region 7 (Sonagazi)</td><td>285163</td><td>1310954.5</td><td>570746</td><td>1431075</td><td rowspan="3">404037</td><td rowspan="3">1038918</td></tr>
<tr><td>Region 8 (Cumilla)</td><td>201330</td><td>1013284</td><td rowspan="2">659321</td><td rowspan="2">1632848</td></tr>
<tr><td>Region 9 (Habiganj)</td><td>470483</td><td>1580734</td></tr>
<tr><td>Region 10 (Gazipur)</td><td>981225.1</td><td>4161475</td><td>928002</td><td>2135537</td><td>41169</td><td>103586</td></tr>
</table>

From the ANOVA results of combined analysis it is clear that the locations have significant yield difference though the same variety and management practice were used. Also the varieties show the significant difference according to yield performance. The DMRT result shows that the location BRRI RS, Satkhira and Kushtia have significant yield difference compared to the other locations with average yield 5.35 t ha^{-1} and 5.26 t ha^{-1} and some other locations show significant yield difference to each other.

Boro season. In Boro season 42 different BRRI released varieties were used in the trial at ten different locations in Bangladesh. We found the highest potential high yielding variety BRRI hybrid dhan5 (8.50 t ha^{-1}) at BRRI RS, Barishal and the lowest BRRI dhan60 (5.22 t ha^{-1}) in BRRI RS, Rangpur. In case of the lowest yielded variety BRRI dhan60 shows the minimum yield (2.63 t ha^{-1}) in BRRI RS, Bhanga.

From the ANOVA results of combined analysis it is clear that the locations have significant yield difference though the same variety and management practice were used. Also the varieties showed significant difference according to the yield performance. The DMRT result showed that the location BRRI RS, Kushtia have significant yield difference compared to the other locations with average yield 6.91 t ha^{-1} and some other location shows significant yield difference to each other.

Total of Aus, Aman and Boro. According to the yield of the experimental data at different location of Bangladesh the total production at different seasons are estimated. From this paddy production we convert it into clean rice production using the average milling outturn 71% (Annual Report of GQN Division, BRRI). For visual convenience, Figure 4 shows the comparison of experimental production and BBS collected production.

Kabir *et al*. (2015) showed that the yield gap between farmers field and the experimental field is 20.7%. To consider this yield gap the total production of clean rice convert by that yield gap percentage (Table 6).

That means if we adopt the potential yielded variety at the respective season and region than the total clean rice production will be reached at 4,00,35,170 ton. In case of highest yielding variety it will reach at 33,71,09,562 ton. For average variety selection the estimated production will be 2,83,34,789 ton. But for wrong selection of variety (lowest yielding variety) production goes down to 1,79,63,980 ton (Less than half of present production).

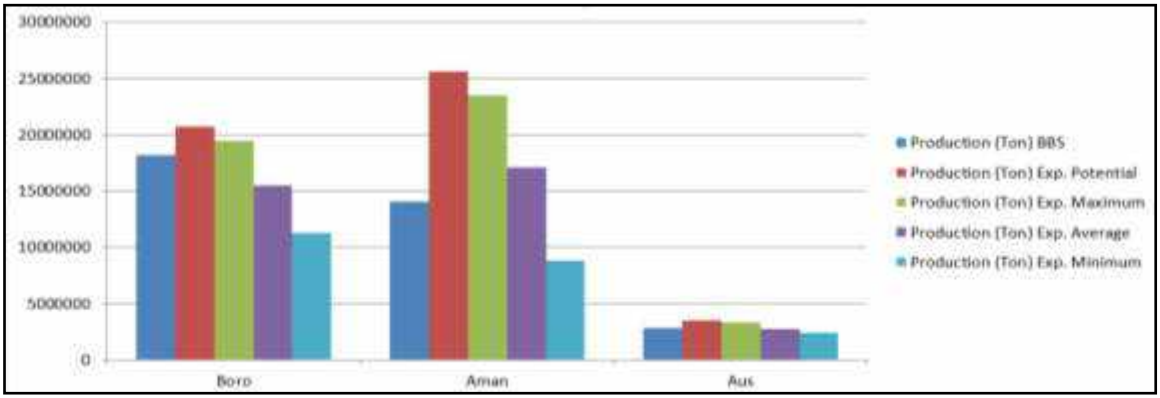


Fig. 4. Comparison of productions at different seasons in Bangladesh.

Table 6. Considering yield gap total clean rice production at different seasons in Bangladesh.

Season	Production (ton) BBS	Production (ton) exp. potential	Production (ton) exp. maximum	Production (ton) exp. average	Production (ton) exp. minimum
Aus	2775480	2804481	2648313	2218664	1887519
Aman	14054874	20575639	18862768	13680883	7048141
Boro	18194227	16655050	15598482	12435242	9028320
Total	35024581	40035170	37109562	28334789	17963980

To increase national production of rice we adopt the potential yielded variety at the respected season and region with best crop management practice (BRRI recommended) than total clean rice production will increase 14.31% than present production. In case of the highest yielding variety it will increase 5.95% but for wrong selection of variety (lowest yielding variety) production will decrease more than 48%.

MAINTENANCE OF RICE DATABASE

Secondary data of rice and other important crops are collected periodically from Bangladesh Bureau of Statistics (BBS), Agricultural Marketing Directorate, 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.

REGIONAL GROWTH AND TREND ANALYSIS OF RICE AREA, PRODUCTION AND YIELD IN BANGLADESH

The study was conducted to determine regional growth rate and trend of area, production and yield of rice in Bangladesh, also measure regional disparities. We used secondary district wise time series data on important variables like area, production and yield of rice in Bangladesh from 1982-83 to 2017-18 for different cropping seasons like Aus, Aman and Boro. Data were taken from various issues of Year Book of Agricultural Statistics and Statistical Year Book of Bangladesh published by Bangladesh Bureau of Statistics. Growth rates of area, production and yield for each cropping season (Aus, Aman and Boro) of rice were estimated by the regression model and performed by different statistical tools such as the linear growth model ($Y= a+bt$), exponential function ($Y = ab^t$) and quadratic function ($Y = a+bt+ct^2$). On the basis of accuracy measures the best model will be selected. We used mean absolute deviation (MAD), mean absolute percentage error (MAPE) and mean squared deviation (MSD) for selecting best model. Minimum errors of accuracy measures are selected as superior fitted model by Karim *et al.* (2010). All the analysis were performed using programing R. Tables 7, 8 and 9 present the region-wise variation of growth rate in area, production and yield of rice (Aus, Aman and Boro) in different regions of Bangladesh.

Area

Region wise estimation on rice production shows large variation in the growth rates of area under Aus, Aman and Boro rice (Tables 7, 8 and 9). During the period of 1994-95 to 2005-06, growth rate of Aus rice area increased from -4.36 percent in 1994-95 to 2005-06 to 0.64 percent in 2006-07 to 2017-18 in overall Bangladesh. But, for whole period (1982-83 to 2017-18), there had been significant decreasing growth rate in overall Bangladesh with the rate of change -3.63 percent. However, at region wise level there are mixed results as in some region there has been a decrease in growth of Aus rice area while in some other regions there is increase in growth of Aus rice area. During whole period (1982-83 to 2017-18), all the regions of Bangladesh had significant decreasing growth rate in area under Aus rice cultivation except Rangamati. Cumilla, Rajshahi, Rangamati, Rangpur and Sylhet recorded significant increasing growth rate in area under Aus rice cultivation during recent era 2006-07 to 2017-18 where the highest growth rate was 29.62% for Rangpur region.

The area of Aman rice was found with significant decreasing growth rate (-0.16%) in overall Bangladesh during the whole period (1982-83 to 2017-18). During recent period (2006-07 to 2017-18), overall Bangladesh growth rate of Aman rice area increased from -0.2 percent in 1994-95 to 2005-06 to 0.48 percent in 2006-07 to 2017-18. However, in case of Cumilla, Dhaka, Faridpur, Khulna, Rajshahi, Rangpur and Sylhet regions were found with decreasing growth rate in Aman rice area during the whole period and rest of the region showed increasing growth rate. In recent period (2006-07 to 2017-18) all the regions of Bangladesh had positive growth rate except Cumilla and Khulna. Significant increasing growth rate was found in Chattogram (0.91%), Dinajpur (1.39%), and Rangpur (0.94%) in recent period. During whole period (1982-83 to 2017-18), growth rate of Boro rice area showed an increasing growth rate with a rate of change 3.57 percent per year for overall Bangladesh. In recent period, the growth rate was decline from 4.28 percent per year in 1994-95 to 2005-06s to 0.53 percent per year in 2006-07 to 2017-18. All the regions of Bangladesh showed significant ($p.value \leq 0.05$) increasing growth rate with a rate of change ranges from 0.52 to 8.58 percent per year during the whole period. The highest and lowest growth rates were found for Dinajpur and Chattogram respectively.

Production

There has also been large variation in the growth rates of production of Aus rice across different regions of Bangladesh (Table 7). During the whole period (1982-83 to 2017-18) all the region of Bangladesh were found in decreasing growth rate except Barishal, Chattogram, Cumilla and Rajshahi. The Aman rice production showed highly significant increasing growth rate ($p.value \leq 0.01$) for all regions of Bangladesh except Cumilla during whole period. The highest and lowest significant growth rate was found 2.61 percent per year for Rangamati and 0.95 per cent per year for Khulna respectively. In case of overall Bangladesh, the highest significant growth rate (2.69%) was found during period II followed by period III (2.59%) and period I (2.14%) (Table 8). Boro rice production showed highly significant increasing growth rate in all regions of Bangladesh. The highest and lowest significant increasing growth rate was found 10.25% per year for Dinajpur and 2.18% per year for Chattogram respectively. In case of overall Bangladesh, the highest significant growth rate (7.55%) was found during period I followed by period II (7.11%) and period III (1.36%) (Table 9).

Yield

The growth rate in yield of Aus rice during 1982-83 to 2017-18 across various regions shows large variation (Table 7). During the whole period, the growth rate in yield of Aus rice was positive ($p.value \leq 0.01$) for most of the regions and highest and lowest were found in Rajshahi (3.86% per year) and Rangamati (0.89% per year). The growth rate in yield of Aus rice during the last period was found to be positive with highly significant in all the regions except Rangamati. In the case of Aman rice yield, all the regions showed highly significant increasing trend ranging from 1.21% per year in

Rangamati to 2.95% per year in Faridpur. For overall Bangladesh, the Aman rice yield was found with increasing growth rate (1.89% per year) during 1982-83 to 2017-18. All the period showed increasing growth rate which was highly significant (Table 8). The yield of Boro rice was found positive with significant growth rate (1.30 to 2.78% per year) for all the regions. The growth rate in yield of Boro rice was found positive and significant with a rate of change 1.84% per year for overall Bangladesh during the whole period (Table 9). The highest growth rate (2.89% per year) was found in 1994-94 to 2005-06.

For the period 1982-83 to 2017-18, the Aus rice area and production had significant decreasing growth rate in overall Bangladesh where yield of Aus rice was found with significant increasing growth rate. In the case of Aman season, area growth rate was decreasing but production and yield growth rate were found with significant increasing trend. All the three aspects area, production and yield showed significant increasing trend for Boro season in overall Bangladesh.

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, efficient water management, labour and energy utilization, reduce losses and risks, reduce pollution with judicious use of agricultural chemicals through proper management in time and also provide guidelines for selection of the best-suited rice varieties according to the anticipated climatic conditions. This is how the system 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

Table 7. Region-wise annual growth rate in area, production and yield of Aus rice in Bangladesh from 1982-83 to 2017-18.

Region	Area				Production				Yield			
	PI	PII	PIII	Whole period	PI	PII	PIII	Whole period	PI	PII	PIII	Whole Period
Barishal	-.96	1.63**	-1.15	-0.43-	-0.58	6.58**	1.89	2.39**	0.38	4.96**	3.05**	2.83**
Bogura	-18.29**	-2.03*	0.55	-4.17**	-17.91**	2.74	6.44**	-0.93	0.37	4.77**	5.90**	3.25**
Chattogram	-3.90*	-0.11	-0.44	-1.41**	-.389	3.87**	1.56	.059	0.00	3.98**	2.00**	2.00**
Cumilla	-6.27**	-1.96	3.58**	-2.58**	-3.15	2.88	7.26**	0.14	3.11	4.84**	3.68**	2.72**
Dhaka	-7.95**	-13.12**	-8.52**	--13.84**	-9.43*	-8.61*	-1.68	-10.91**	-1.48	4.51**	6.83**	2.93**
Dinajpur	-10.86**	-16.89**	8.20	-10.18**	-10.8**	-7.88**	11.31*	-6.70**	0.07	9.00**	3.11**	3.48**
Faridpur	-2.16	-6.20**	-8.62**	-8.23**	0.13	-4.83*	-2.28	-5.89**	2.29	1.37	6.34**	2.34**
Jashore	-4.21**	-5.21**	2.01	-3.64**	0.04	-1.58	5.57**	-0.10	4.26	3.63**	3.56**	3.54**
Khulna	-1.01	-9.30**	-0.07	-2.23**	3.51	-7.81**	3.78	-0.06	4.52	1.49**	3.85**	2.17**
Mymensingh	-6.74**	-8.49**	-6.70**	-6.71**	-6.00**	-3.93**	-2.81*	-4.05**	0.74	4.56**	3.90**	2.65**
Rajshahi	-4.35**	-1.20	2.97*	-0.37	0.02	2.24	6.59**	3.49**	4.38	3.44**	3.62**	3.86**
Rangamati	-3.11**	-1.03	2.13*	-0.56**	-0.64	0.70	2.96**	0.33	2.74*	1.73**	0.83	0.89**
Rangpur	-11.28**	-32.49**	29.62*	-18.43**	-8.53**	-28.92**	37.56**	-15.33**	2.75	3.58**	7.94**	3.10**
Sylhet	-2.45	-5.72**	4.48**	-1.87**	1.46	-3.64*	8.06**	1.07*	3.91*	2.07*	3.58**	2.95**
Bangladesh	-5.91**	-4.36**	0.64	-3.63**	-3.98	-0.37	4.40**	-0.60	1.93	3.99**	3.76**	3.03**

Note: PI=1982-83 to 1993-94, PII = 1994-95 to 2005-06, PIII = 2006-07 to 2017-18, Whole Period = 1982-83 to 2017-18

**Significant at the 1% level,

*Significant at the 5% level

Table 8. Region-wise annual growth rate in area, production and yield of Aman rice in Bangladesh from 1982-83 to 2017-18.

Region	Area				Production				Yield			
	PI	PII	PIII	Whole period	PI	PII	PIII	Whole period	PI	PII	PIII	Whole Period
Barishal	0.41	0.12	0.60	0.10	1.08	3.81*	3.78**	1.54**	0.67	3.66**	3.22**	1.43**
Bogura	-2.24	0.68	0.71	0.14	1.63	3.13**	3.33**	1.89**	3.86**	2.44**	2.61**	1.75**
Chattogram	0.28	1.99	0.91*	0.04	2.05**	3.04	2.40**	1.53**	1.77**	1.05	1.49**	1.50**
Cumilla	-0.57	-4.93**	-0.29	-1.54**	1.80	-2.17	1.39	-0.06	2.35**	2.79**	1.68**	1.49**
Dhaka	-3.91	2.29	0.29	-0.80*	-2.44	6.03	1.32	1.10*	1.45	3.75*	1.06**	1.90**
Dinajpur	1.91**	0.45	1.39**	0.75**	4.66**	3.04*	3.41**	2.76**	2.76**	2.59*	2.02*	2.01**
Faridpur	-2.22*	-0.82	0.84	-1.48**	-0.18	3.16	4.79**	1.46**	2.08	3.94**	3.97**	2.95**
Jashore	2.96**	-2.24	0.39	0.60**	7.48**	2.53*	2.15**	2.78**	4.53**	4.77**	1.76**	2.19**
Khulna	0.09	-1.23**	-2.08**	-1.03**	2.15*	2.22*	0.28	0.95**	2.07*	3.44**	2.36**	1.97**
Mymensingh	-2.21*	0.52	0.40	0.11	0.18	3.64*	2.95**	1.92**	2.41**	3.11**	2.53**	1.81**
Rajshahi	-0.71	-0.12	0.43	-0.09	3.85*	3.24**	1.85**	2.34**	4.57**	3.35**	1.43**	2.44**
Rangamati	-1.66	5.08**	0.70	2.40**	0.65	7.03**	1.96*	3.61**	2.31**	1.94**	1.27*	1.21**
Rangpur	1.19**	0.11	0.94**	-0.10	2.98**	1.40	3.77**	1.50**	1.80**	1.28	2.83**	1.61**
Sylhet	-1.41	-1.40**	0.78	-0.43**	1.46	1.61*	1.42	1.84**	2.86**	3.01**	064	2.27**
Bangladesh	-0.43	-0.20	0.48	-016*	2.14**	2.69*	2.59**	1.73**	2.57**	2.90**	2.11**	1.89**

Note: PI=1982-83 to 1993-94, PII = 1994-95 to 2005-06, PIII = 2006-07 to 2017-18, Whole Period = 1982-83 to 2017-18
**Significant at the 1% level, *Significant at the 5% level

Table 9. Region-wise annual growth rate in area, production and yield of Boro rice in Bangladesh from 1982-83 to 2017-18.

Region	Area				Production				Yield			
	PI	PII	PIII	Whole period	PI	PII	PIII	Whole period	PI	PII	PIII	Whole Period
Barishal	3.05	8.16**	-0.10	4.77**	4.73	11.06**	0.78	6.66**	1.68*	2.90**	0.89*	1.89**
Bogura	10.56**	4.80**	0.01	3.76**	10.68**	6.73**	0.07	5.06**	0.12	1.93**	0.06	1.30**
Chattogram	3.27**	0.35	0.38	0.52**	2.15*	2.82*	1.85*	2.18**	-1.12	2.46**	1.47**	1.66**
Cumilla	7.82**	4.21**	0.31	3.15**	8.38**	7.03**	0.63	4.48**	0.56	2.83**	0.32	1.34**
Dhaka	5.04**	3.46**	0.13	2.61**	4.78**	6.80**	1.14*	4.17**	-0.26	3.35**	1.01**	1.56**
Dinajpur	19.64**	7.45**	0.40	8.58**	20.51**	10.27**	0.87	10.25**	0.88	2.82**	0.46	1.66**
Faridpur	9.36**	9.29**	-1.4**	4.12**	9.31**	13.35**	-032	5.93**	-0.06	4.06**	1.12**	1.81**
Jashore	16.43**	7.33**	0.31	6.68**	16.99**	10.08**	1.09*	8.03**	0.56	2.75**	0.78**	1.35**
Khulna	8.94**	8.62**	2.67**	6.94**	9.79**	11.15**	3.80**	9.11**	0.85	2.53**	1.13**	2.17**
Mymensingh	5.26**	2.24**	0.95*	2.97**	6.46**	5.21**	2.32**	5.00**	1.20**	2.97**	1.37**	2.03**
Rajshahi	12.71**	5.78**	-0.07	5.01**	14.12**	7.78**	0.20	6.71**	1.41	2.00**	0.27	1.70**
Rangamati	-1.82	3.83**	1.23*	2.84**	-3.02*	6.44**	2.30**	4.30**	-1.20*	2.61**	1.07**	1.47**
Rangpur	13.45**	4.94**	1.58**	5.71**	12.35**	6.59**	2.13**	7.53**	-1.10	1.65**	0.56*	1.82**
Sylhet	1.99**	1.26**	0.00	1.46**	2.07	5.70**	2.19	4.24**	0.07	4.45**	2.19**	2.78**
Bangladesh	6.87**	4.28**	0.50	3.57**	7.55**	7.17**	1.36*	5.41**	0.69*	2.89**	0.86**	1.84**

Note: PI=1982-83 to 1993-94, PII = 1994-95 to 2005-06, PIII = 2006-07 to 2017-18, Whole Period = 1982-83 to 2017-18
**Significant at the 1% level, *Significant at the 5% level

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 2019 to May 2020) 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 10 and 11 show as a sample how the weather forecast and advisory looks like.

Table 10. Weather forecast for BRRI HQ, Gazipur.

Agriculture weather element	2020-02-23	2010-02-24	2010-02-25	2010-02-26	2010-02-27	2010-02-28	2010-02-29
Total rainfall (mm)	0	0	0.22	0	0	0	0
Min. Tem. (°C)	18.26	15.38	15.53	14.22	12.08	14.05	13.3
Max. Tem.(°C)	30.42	30.58	27.38	27.16	27.68	28.91	29.89
Min. RH (%)	30.11	29.5	37.23	38.87	36.75	33.23	28.19
Max. RH (%)	57.07	70.18	85.2	85.54	94.01	77.04	77.59
Min. wind speed (m/s)	0.34	0.56	1.82	1.11	1.31	0.57	0.98
Max. wind speed (m/s)	3.76	3.25	5.6	2.87	3.23	3.07	3.34

Table 11. Weather forecast based rice advisories at BRRI HQ and different R/Ss.

Probable problems and measures of Boro crop season based on weekly weather forecast at BRRI HQ.
Growth stage: Mid tillering
Production management / Probable problems and tasks
Fertilizer management
The first installment urea should be applied 15-20 days after planting and the second installment urea should be applied 30-35 days later. In many cases. 30-35 days after planting, when the seedlings are in the mid tillering stage, the second installment of urea fertilizer should be given.
Weed management
40-45 days after planting the fields should be weeded for the last time by hand weeding.
Irrigation
The land should be irrigated using AYVD method. Irrigation in this method increases the effectiveness of urea and also increases the number of tillering in the plant.
Insect management
At this time, the mainland can be attacked by leaf folder, rice hispa. stem borer. In such cases, setting up of light traps (without rice hispa) on the side of the affected land, catching insects with hand nets, letting the stalk on the ground, destroying *eggmases* and larvae of stem-borer. In the harmful phase of stem-borer attack, approved pesticides such as *Diazinon* or *Carbofuran* or *Virtako* and leaf folder pest attacks *Darsban* should be used in doses at a moderate level.
Disease management
At this stage of the rice plant and in this weather condition, early signs of bakanae disease may appear. Infected tillers should be broken after the obvious symptoms of sheath blight disease. Moreover, due to the rise in temperature, symptoms of scabies may also appear. However, there is no need to take any action for the time being.

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.

SIMULATING OF 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 time of planting (30 April, 10 May, 20 May and 01 June) experiments were conducted separately in each study area for T. Aus 2019 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 time of planting for maximum growth and yield for T. Aus season. Another objective of this study 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 performs the highest yield (5.43 t ha^{-1}) at Sonagazi and lowest yield (1.88 t ha^{-1}) at Sirajganj when N applied at 40 kg/ha and 100 kg/ha (Fig. 5). The highest performance of BRRI dhan48 was 5.57 t ha^{-1} when N applied at 80 kg/ha at Gazipur and the lowest was 1.57 t ha^{-1} when N applied at 40 kg/ha at Habiganj (Fig. 6). BRRI dhan 82 recorded highest yield (5.36 t/ha) at Kushtia and the lowest yield (1.72 t ha^{-1}) at Habiganj when N applied at 40 kg/ha (Fig. 7). In irrigation experiment, BR26 perform the highest yield (5.41 t ha^{-1}) at Rajshahi when irrigation practice applied AWD 30 cm condition, and lowest yield (1.82 t ha^{-1}) at Habiganj when irrigation practices applied AWD 15 cm condition (Fig. 5). The highest performance of BRRI dhan48 was 5.58 t ha^{-1} at Rajshahi and the lowest was 1.93 t ha^{-1} at Sirajganj when irrigation practice applied AWD 30cm condition (Fig. 6). BRRI dhan 82 recorded highest yield (5.69 t ha^{-1}) at Satkhira and lowest yield (1.99 t ha^{-1}) at Sirajganj when irrigation practices applied AWD 15 cm and AWD 30 cm condition, respectively (Fig. 7). BR26 performed the highest yield (5.44 t ha^{-1}) at Rajshahi when it was transplanted on 10 May, and the lowest yield (2.11 t ha^{-1}) at Sirajganj when transplanting time was 30 April (Fig. 5). The highest performance of BRRI dhan48 was 5.71 t/ha at Rajshahi and the lowest was 2.06 t ha^{-1} at Sirajganj when the transplanting time 30 April and 10 May respectively (Fig. 6). BRRI dhan 82 recorded the highest yield (5.15 t ha^{-1}) at Rajshahi and the lowest yield (2.22 t ha^{-1}) at Sirajganj when it was transplanted 20 May and 30 April, respectively (Fig. 7).

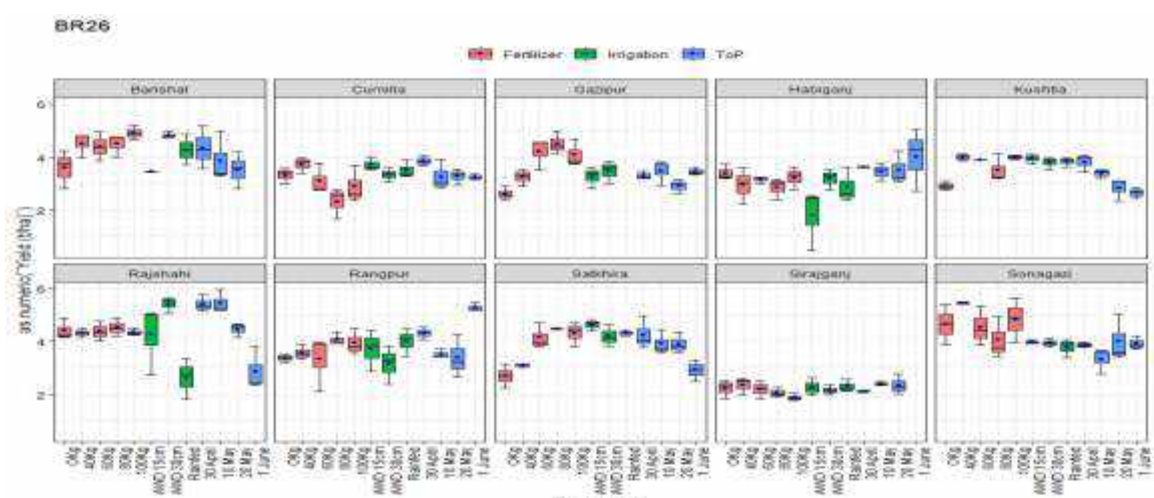


Fig. 5. Yield performances BR26 in fertilizer, irrigations and time of planting experiment in different locations in Bangladesh during Aus 2019 season (dot indicates the average).

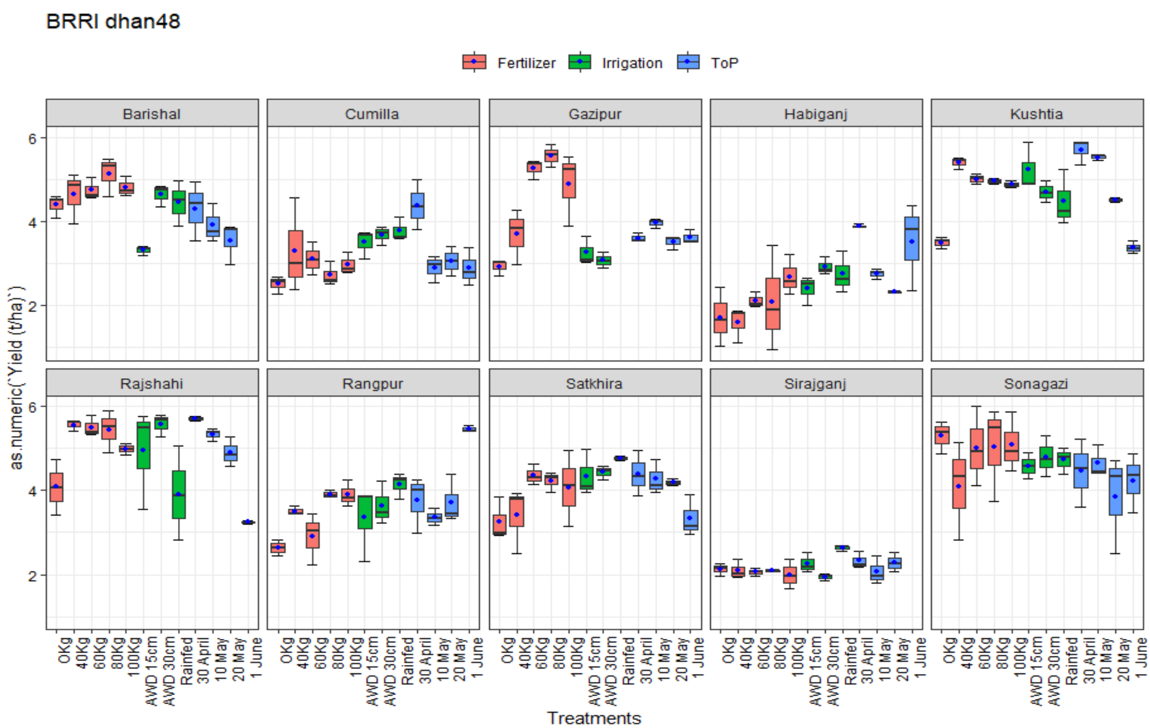


Fig. 6. Yield performances BRRI dhan48 in fertilizer, irrigation and time of planting experiment in different locations of Bangladesh during Aus 2019 season (dot indicates the average).

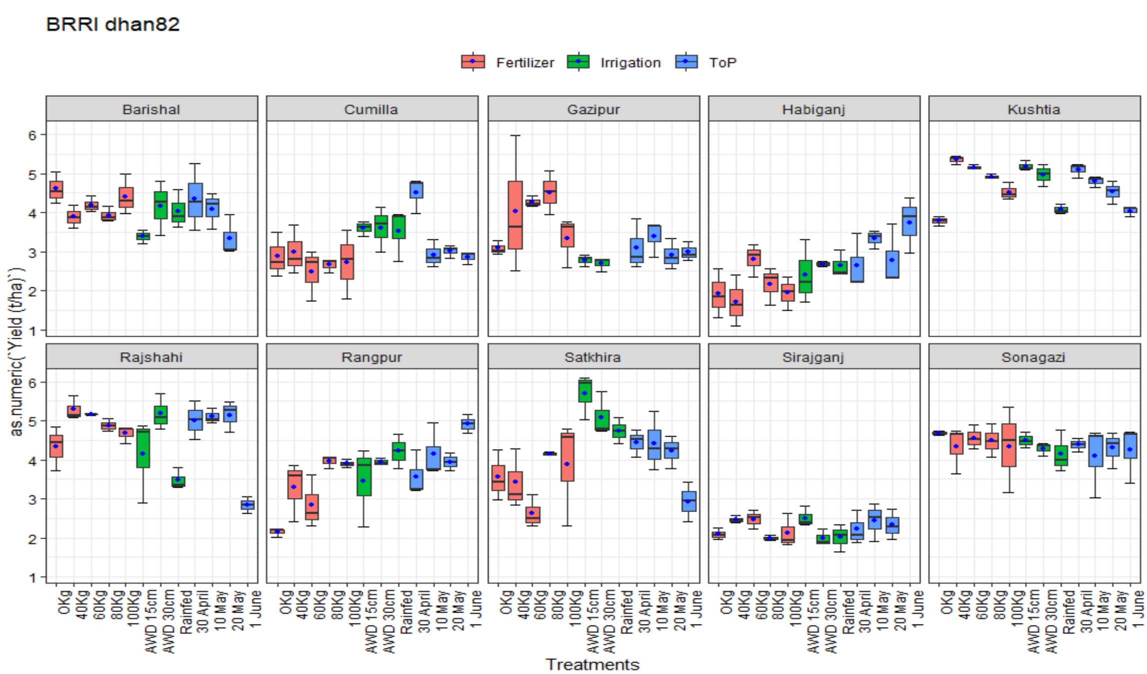


Fig. 7. Yield performances of BRRI dhan82 in fertilizer, irrigation and time of planting experiment in different locations in Bangladesh during Aus 2019 season (dot indicates the average).

SUITABILITY MAPPING OF BRRI DHAN87 TO BRRI DHAN89

Our land is not homogenous all over the Bangladesh. Various physical and chemical properties of soil varies spatially. On the other hand various rice varieties are suitable for some specific physical and chemical properties. 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 dhan87 to BRRI dhan89 are very prospective varieties. So, these varieties suitability maps 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.

Suitable areas for respective rice varieties =cultivation in Bangladesh were determined by two steps. Step 1: input vector themes of land type and other soil physical properties were converted into grid themes for analysis in the Model Builder environment using Arc GIS10.3 Spatial Analyst Module. Step 2: each input grid was weighted by the relative influence for suitability assessment. The relative influences were the relative weights in percent assigned to grid themes of soil parameters. These weights were the values of "Percent Influence Field" in the weighted overlay table of the Model Builder.

Proactivity will increase if we cultivate rice varieties according to their suitable area.

BRRI dhan87 is a variety of Aman season. It is suitable in central, south central and some northern parts of Bangladesh. Figure 8 shows the suitability map of BRRI dhan87. BRRI dhan89 is a variety of Boro season. North-western side, north central side and some areas of south-western side of Bangladesh are suitable for BRRI dhan89. Figure 9 shows the suitability map of BRRI dhan89.

CLIMATE MAPPING OF TEMPERATURE (MAXIMUM & MINIMUM) AND RAINFALL

Bangladesh is an agro-based country. Climatic factors such as temperature, rainfall, atmospheric carbon dioxide and solar radiation etc are closely linked with agriculture production. Thus, climatic factors mapping would be great tool for climatic factors analysis and assist to increase crop production. Hence objectives of the study to determine expected maximum and minimum temperature and rainfall in different region in Bangladesh to determine areas of critical maximum and minimum temperature and rainfall map of Bangladesh and year-wise comparison of various climatic factors maps and determine their change directions.

Data on daily maximum and minimum temperature and rainfall of 35 weather stations of BMD for the years 2018 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.

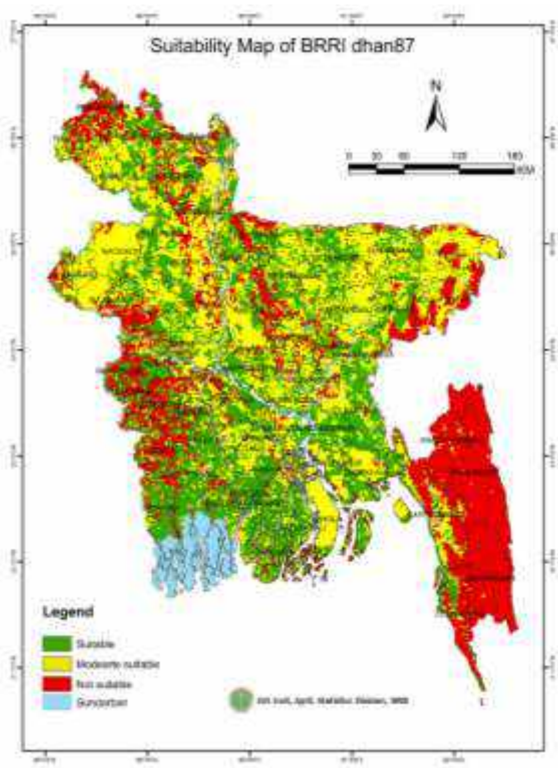


Fig. 8. Suitability map of BRRI dhan87

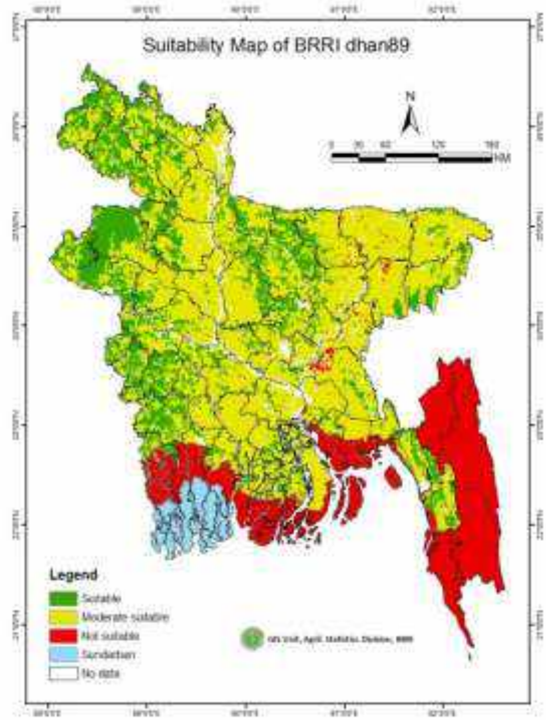


Fig. 9. Suitability map of BRRI dhan89

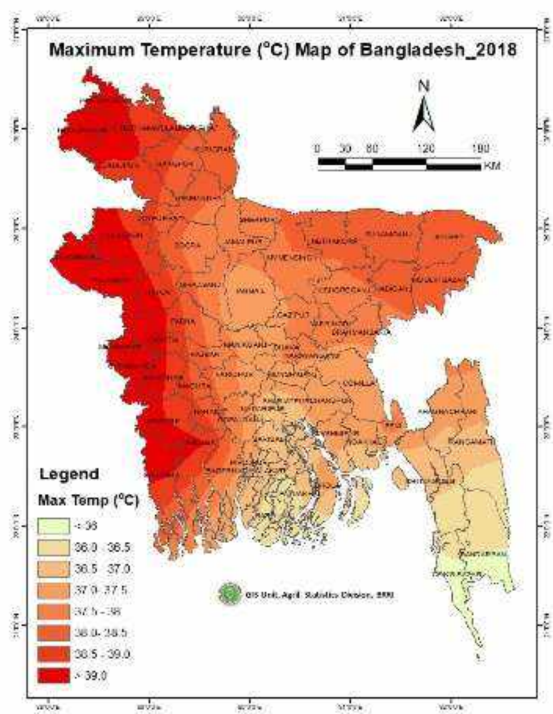


Fig. 10. Maximum temperature map of Bangladesh for 2018

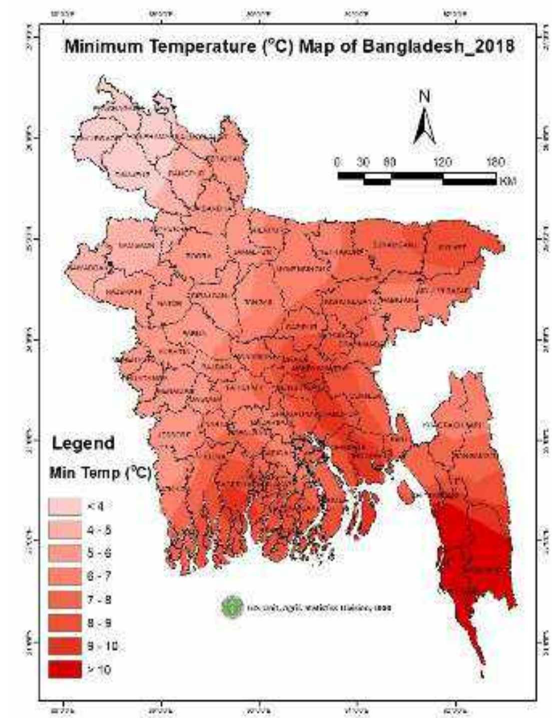


Fig. 11. Minimum temperature map of Bangladesh for 2018

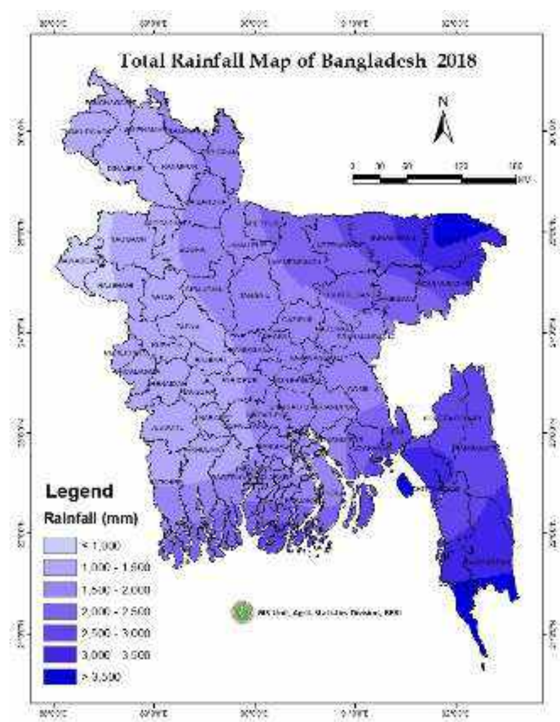


Fig. 12. Total rainfall map of Bangladesh for 2018

Then by using geo-statistical tools of Arc GIS10.3 software maps were prepared. In the maps scenario of climatic factors were described.

Maximum temperature was high in western side of Bangladesh. Figure 10 shows the maximum temperature map of Bangladesh for 2018. In 2018 minimum temperature was low in northern side of Bangladesh and minimum temperature was high in south eastern side of Bangladesh. Figure 11 shows the minimum temperature map of Bangladesh for 2018. Total rainfall was the highest in eastern side of Bangladesh. Figure 12 shows the total rainfall map of Bangladesh for 2018.

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.

RICE CROP MAPPING USING SATELLITE REMOTE SENSING TECHNOLOGY IN SOME SELECTED AREAS OF BANGLADESH

Bangladesh is an agro-based country and rice is the main agricultural product. Timely and accurate information on rice is very important to the rice-growing and consuming nations. The traditional ground survey methods are difficult to acquire annual crop information due to the less economic efficiency and some features of agricultural production, for e.g., the large coverage, the strong seasonal, strong spatial heterogeneity. Using remote sensing technology is feasible and effective way to solve this problem. The achievements are remarkable, since remote sensing was used to crop identification and area extraction, the technology and theory have been in continuous improvement. Identification of crop types is the first step of crop mapping, area estimation, monitoring system and crop yield forecasting.

Aman rice is a Kharif season crop. This time is the monsoon time of Bangladesh and covered by cloud. Microwave remote sensing has the advantages to penetrate clouds and to some extent rain. Multi-temporal SAR data can be used to retrieve the rice growing cycle based on the temporal variations in the synthetic aperture radar (SAR) backscatter (σ°(dB)) signal. Prime focus of the study was extracting the temporal signature of rice types and classification of various rice types based on unique temporal signature in Barind area of Bangladesh.

Six days and 12 days interval Sentinel-1A data were downloaded from the European Space Agency (ESA) for Kharif seasons from 27 July 2019 to 31 October 2019. The preprocessing of Sentinel-1A data includes five main steps: Orbit file correction, speckle noise filtering, radiometric calibration, terrain correction and data conversion from sigma nought (σ°) values to dB values. These scenes were then stacked into a multi-temporal composite scene. Then temporal signature of various types of rice and others were extracted. Finally, with the temporal signatures, classified map for rice were prepared. Figure 13 show the rice map of study area.

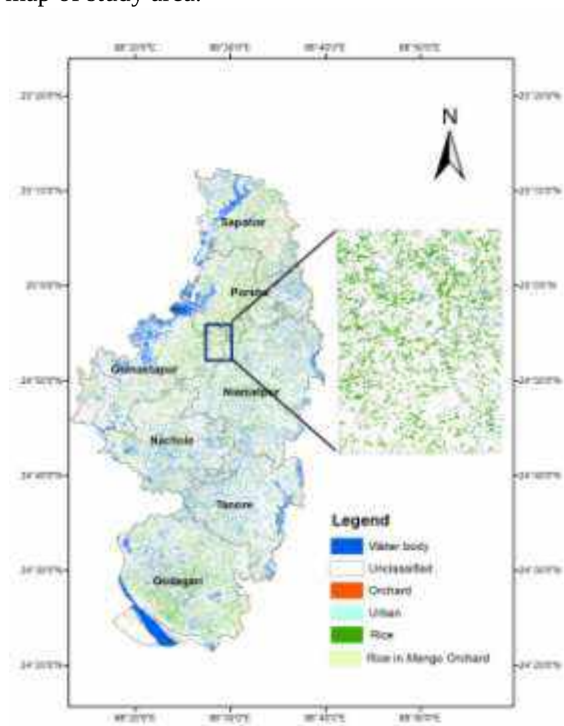


Fig. 13. Rice map of study area

PROSPECT OF AUS RICE AREA IN BANGLADESH

Rice is the main agricultural product in Bangladesh. There are three rice seasons in Bangladesh i.e. Aus, Aman and Boro. Aus season rice contributes about

7.8 % of total rice production. In the year 2018-19 Aus area was 1145.13 ‘000’ ha. But In Bangladesh there are more areas where aus rice production is possible, especially Highland i.e. land which is above normal flood level and medium highland1 i.e. land which is normally flooded up to 30 cm deep during flood time. In these two types of land, aus production is possible as land that stay above normal inundation level and hold good residual soil moisture in the winter, are extensively used for wide range of both seasonal and perennial crops. In Bangladesh there are about 4.04 mha and 1.07 mha land of Highland and Medium Highland1 respectively. Thus we have a large prospect to extend Aus area in Bangladesh. Thus the aim of this study is determination of mouza wise highland and medium mighland1 agricultural area for Aus rice in Bangladesh.

Spatial data of land type, agricultural land, Agro ecological zone (AEZ) of Bangladesh, mouza shape file of Bangladesh were considered and Arc GIS version10.3 was used. Highland and medium highland1 land types were separated from land type map. Then overlap area of highland and agricultural area according to mouza wise were determined, from this area High Barind Tract ecological zone area i.e. AEZ 26 and hill tracts except valley area (Rangamati, khagrachari and Bandarban districts) were excluded as because AEZ 26 has no irrigation scope early Aman rice may be hampered by Aus rice and hill tracts are under *Jhum* cultivation. Finally, highland agricultural areas were determined (Fig. 14) and a database were prepared for mouza wise and similarly for medium highland1 agricultural area were determined (Fig. 15). Then combining above two maps total Aus possible area map were prepared (Fig. 16).

The highland agricultural area was found 1.81 mha and medium highland1 agricultural area were found 0.66 mha and the total Aus prospected area was found 2.47 mha (Table 12).

TRAINING PROGRAMME ON EXPERIMENTAL DATA ANALYSIS

To set up the experiments, collecting, compiling, reporting, analyzing and presenting of the experimental data and increase the accuracy of the findings and developing skills on research four types of training programmes were conducted in 2019-20. 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 ‘Programming R for experimental design and data analysis’. Online data management system, estimation of genetic gain and data collection procedures for stability analysis was the topics of ‘Breeding4Rice Online Data Management System’ and ‘Estimation of Genetic Gain of Breeding Lines Using R’ and ‘Data collection procedures of Stability Analysis of BRRI varieties’ training programmes respectively.

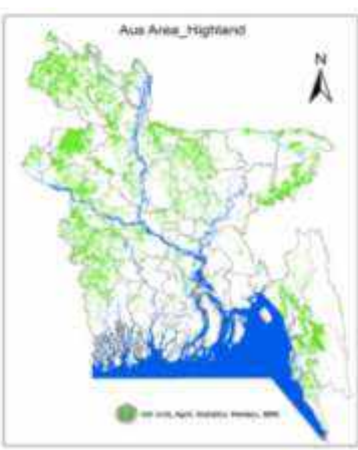


Fig. 14. Aus area in highlend

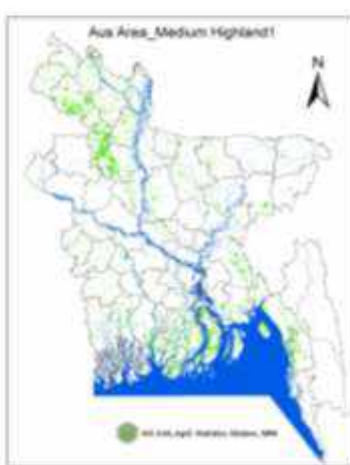


Fig. 15. Aus area in medium high land1

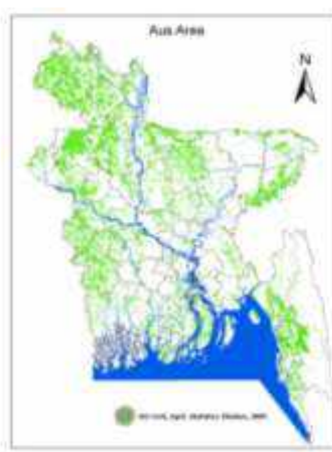


Fig. 16. Aus area

Table 12. District-wise Aus rice cultivable area of Bangladesh.

District	High land (ha)	Medium highland1 (ha)	Total area (ha)	District	High land (ha)	Medium highland1 (ha)	Total area (ha)
Bagerhat	6142.59	14635.27	20777.86	Magura	15667.98	4674.10	20342.08
Bandarban	52520.31	52.67	52572.99	Manikganj	10090.66	2735.67	12826.33
Barguna	62.49	20022.88	20085.37	Maulvibazar	88113.87	3163.16	91277.03
Barishal	9431.12	15057.57	24488.68	Meherpur	22869.18	2024.73	24893.91
Bhola	153.27	40051.06	40204.33	Munshiganj	3013.96	1070.89	4084.85
Bogura	25698.06	47202.12	72900.17	Mymensingh	106330.75	20408.90	126739.65
Brahamanbaria	2785.70	3528.91	6314.61	Naogaon	135614.46	3230.49	138844.95
Chandpur	1864.33	1732.74	3597.07	Narail	3382.02	2264.60	5646.63
Chattogram	114838.22	45507.33	160345.56	Narayanganj	4182.73	841.18	5023.91
Chuadanga	37508.81	4390.01	41898.82	Narsingdi	9158.15	1983.73	11141.88
Cox’s Bazar	38536.01	4621.96	43157.96	Natore	40424.67	1727.43	42152.10
Cumilla	4644.54	23565.15	28209.69	Nawbganj	26413.80	1362.54	27776.34
Dhaka	9693.00	2357.21	12050.22	Netrakona	29148.12	10198.57	39346.69
Dinajpur	90614.07	62495.43	153109.50	Nilphamari	44426.70	11851.98	56278.68
Faridpur	12448.56	2987.45	15436.00	Noakhali	657.49	12430.18	13087.67
Feni	5252.32	4628.26	9880.98	Pabna	22378.59	3242.92	25621.51
Gaibandha	30903.27	22098.11	53001.38	Panchagarh	43537.17	4026.72	47563.88
Gazipur	25323.94	1243.27	26567.21	Patuakhali	1288.83	35670.88	36959.71
Gopalganj	2818.14	1294.14	4112.27	Pirojpur	1531.93	13654.88	15186.81
Habiganj	32512.44	7101.19	39613.63	Rajbari	22422.55	2303.60	24726.15
Jamalpur	30636.76	7440.59	35377.36	Rajshahi	54720.02	1052.18	55772.20
Jashore	69773.08	7519.23	77292.32	Rangamati	9914.17	70.45	9984.62
Jhalokati	950.26	8250.28	9200.54	Rangpur	52500.83	21357.75	73858.57
Jhenaidah	65557.97	5344.85	70902.83	Satkhira	27535.09	12016.06	39551.15
Joypurhat	7428.99	32790.41	40219.39	Shariatpur	5308.63	1488.38	6797.02
Khagrachari	15361.46	0.00	15361.46	Sherpur	45170.18	6529.79	51699.97
Khulna	4147.05	13972.64	18119.69	Sirajganj	25326.42	8360.66	33687.08
Kishoreganj	8560.81	7078.81	15639.62	Sunamganj	14497.93	4495.99	18993.92
Kurigram	16072.74	11438.12	27510.86	Sylhet	464459.18	5601.58	52060.76
Kushtia	32447.60	3998.94	36448.53	Tangail	30912.68	13290.83	44203.51
Lakshmipur	2875.31	7561.32	10436.63	Thakurgaon	79784.56	10484.15	90268.72
Lalmonirhat	24209.88	7998.80	32208.67				
Madaripur	6386.74	2541.38	8928.12	**Bangladesh**	**1810943.13**	**661423.07**	**2472366.20**

A total of 150 participants were trained through the training programmes. Through the training on ‘Programming R for experimental design and data analysis’ 71 participants were trained in four batches that included 58 SO, nine SSO, two AE and two other officers of BRRI. The duration of this training were five days. Another, two training programmes was ‘Breeding4Rice Online Data Management System’ and ‘Estimation of Genetic Gain of Breeding Lines Using R’. A total of 64 participants were trained through this two training programme. The participants were CSO, PSO, SSO and SO of BRRI. The forth training programme was ‘Data collection procedures of Stability Analysis of BRRI varieties’. A total of 19 participants including SSO, SO and SA were trained through this training.

ICT ACTIVITIES

‘Rice Doctor’ mobile and web app for BRRI

Rice doctor is BRRI developed mobile and web application which is rice varieties, modern rice cultivation practices, insect-pest and disease related dynamic diagonosis tools (Fig. 17). It is an interactive crop diagnostic tool developed to cater to the needs of the extension and advisory service providers and farmers, extension workers and other users who want to learn and control insect and disease and other problems and to identify insect pests, diseases, nutrient deficiencies, toxicities, and agronomy related problems of rice. It provides information on these problems as well as recommendations to address them. It can also be useful for scientists/researchers, teachers, students and private input dealers. The English version is currently available online at google play store of android smart phone as a mobile app that can be downloaded free of cost. Bangla version will be available very soon.

Mobile apps of ‘RKB’ (Rice Knowledge Bank)

Mobile application of RKB (Rice Knowledge Bank) is a type of application software designed to run on a mobile device, such as a smart phone or tab. RKB application has been developed with the information of BRRI released rice varieties, modern rice cultivation and agricultural machinery technologies, pest and disease management, soil and fertilizer management, irrigation and water management, quality rice seed production, training and publications. It is available for android-based smart phone. So anybody can free download it from Google Play Store. Besides, this mobile app can be shared from other smart phone by ‘SHAREit’ software. RKB is being regularly updated with latest rice releted information. A total of 12,000 users have downloaded it from play store.

BRKB website management

Bangladesh Rice Knowledge Bank (BRKB) is a hub of rice knowledge. This is a dynamic source of knowledge and also updated regularly to keep consistency with the latest innovations and users' feedback. BRKB website is managed, maintained and modified by ICT Cell, Agricultural Statistics Division in collaboration with Training, Breeding and others research divisions. BRKB is updated regularly with the latest information.

Dynamic view connectivity system and Bangla searching system for BRKB website

We developed dynamic view connectivity and Bangla searching system for BRKB website (Fig. 18). Dynamic view connectivity works dynamically between BRKB website and Facebook page. 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. 17. Rice Doctor mobile apps

Fig. 18. Dynamic view connectivity system

Web mail and group mail

BRRI web mail server sends, receives and stores e-mail for all users. Almost every internet service provider (ISP) includes at least one mailbox on their mail server as part of their basic service. When a client connects to a server, both the computers must be communicated by same protocol. The most widely protocol is POP3 (Post Office Protocol version 3). It is almost always used in conjunction with SMTP (Simple Mail Transfer Protocol). POP3 is used to retrieve mail from the server (incoming) while SMTP is used to send mail through the server (outgoing). We have created individual e-mail account into BRRI domain for all scientists and all class one officers as per requirement of MoA. BRRI Web mail and Group mail have been hosted into BCC (Bangladesh Computer Council) server.

Developing secure system for BRRI Web Mail and Group Mail

Secure Sockets Layer (SSL) Certificates provide secure, encrypted communications between a web mail user and an internet browser. SSL stands for Secure Sockets Layer, the protocol which provides the encryption. SSL Certificates are typically installed on pages that require end-users to submit sensitive information over the internet. We incorporated secure sockets layer system 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, whole system (BRRI web mail) is safe from the block of Gmail, yahoo, webmail or other e-mail servers. We have developed automatic active and close system (AACS) and also incorporated in BRRI web mail. Now web mail is more secure.

Online application system of BRRI

The online application system for recruitment is an ideal portal for the Government. BRRI wants to manage its recruitment related activities through online. So BRRI introduced this online system to decrease hassles of applicants/students for job application. It also reduces time of job application processing for the employer. BRRI already started online application system for the first time since 23 May to 12 June 2019. Applicants completed their application through this system and got admit card, written test date notification, result and all kinds of information through this online system and SMS based application. This system developed by Teletalk Bangladesh Limited. An agreement conducted between BRRI and Teletalk Bangladesh Limited on 8 March 2017 for Web and SMS based application.

e-Nothi management system of BRRI

The implementation of e-Nothi system to ensure faster movement of files through the different layers in government offices, increased transparency throughout the organization, and increased accountability in governance. BRRI has taken initiative to ensure a paperless office management system through e-Nothi system on 24 September 2017. At present, BRRI obtained 4th position among all govt. organizations and departments for using e-Nothi system. Now e-Nothi system is being used 100% in all divisions and sections of BRRI as well as regional stations.

e-Tender System of BRRI

The e-Tender system software known as e-GP system is developed under Central Procurement Technical Unit (CPTU), IMED. BRRI introduced e-GP on 1 July 2016. BRRI has been incorporated as a first organization among the NARS institute and also a first organization under Ministry of Agriculture (MoA). BRRI has already submitted about 300 tenders into e-GP system and the submission process is being continued.

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 digitalized labour management system (LMS) for BRRI. The system is a web application using XAMPP, HTML, PHP and Javascript (JS). Now the system is in live in the BRRI LAN (172.16.101.17/lms). The system included labour informations, attendance report, wages report and other reports with printable format.

Digitalized Casual Leave (CL) Application of BRRI

Agricultural Statistics Division developed a web application of casual leave (CL) using XAMPP, HTML, PHP and Javascript (JS). This is very easy to access, accurate, consistent and most flexible casual leave (CL) application procedure with the usual system. Now, this system is ready only for a division. It was obtained in the form of documents whenever the user needs.

Management of local area network and internet connectivity of BRRI HQ and regional stations

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 60 Mbps to 120 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 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 portal are in Bangla and English languages. It is connected to the largest web portal (www.portal.gov.bd) in the country of the world and BRRI is incorporated with it as a first organization among the NARS institute.

BRRI networks update, maintenance and extension

BRRI Networks is a Facebook group, where only official interactions, various problems and their solutions can be posted. It’s a big forum for all the scientists, officers and staff’s of BRRI. ICT Cell created this Facebook group to post research related work for noble work of rice and rice related activities of this forum. The Facebook group of BRRI Network link is (https://www.facebook.com/groups/1409267722690061/). It is also tagged with the largest web portal of the World, which is named National Web Portal of Bangladesh (http://www.bangladesh.gov.bd/). Thus the BRRI Network is continuing with regular updating posted by everybody of this group. At present, 418 individuals have joined this group. It is increasing gradually. It has stored at least 4000 and more photos of all national programmes and research activities of head quarter and all regional stations. It has also uploaded around 200 necessary pdf and word file document for all members.

Video conference system

Video conferencing system is a two-way communication with live video and audio system. So it needs brands of videophones, webcams, headphones (it can be done with bluetooth headphone also) and video conferencing hardware systems. We have established video conferencing system (VCS) at BRRI to communicate with MoA and other government organizations. Also, we have established Distance Communication Center (DCC) at BRRI with the help of Bangladesh Research and Education Network (BDREN) funded by University Grants Commission (UGC), which is similar to VCS. Besides, we have created Skype account for all divisional head and regional stations heads. The communications between BRRI headquarter and other regional stations have been conducted by video conference system in every monthly co-ordination meeting.

Management Information System (MIS) of BRRI

A management information system (MIS) is a computerized database of information organized and programmed in such a way that it produces regular reports on operations for every level of management in an organization. It is usually also possible to obtain special reports from the system easily. The MIS software of BRRI has nine modules (HRMIS, FMIS, PMIS, RMIS, LMIS, VMIS, TMIS, IMIS, Data Bank). The MIS Software will be developed under NATP-2 using PHP, JAVA, HTML, CSS, JAVASCRIPT and ORACLE will manage the data.

Integrating Digital Signature with e-Nothi System of BRRI and its management

The Digital Signatures require a key pair (a symmetric key pairs, mathematics related large numbers) called the Public and Private Keys. 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 email, 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 workers, scientists, researches, teachers, students and other users who want to learn and control insect and disease and other problems that can occur in rice.

Personal data sheet database

We have created 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.

Heritage of BRRI

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). Here, it has created individual pages like former DG and Directors, former CSO, PSO, SSO, Officers and Staff’s etc. It has included almost ex. Scientists personal photo, short description as well as a link where anybody can find out their detailed information. Thus it has made the *Heritage*. ICT cell of Agricultural Statistics Division provides ICT related support services to other divisions such as updating data and uploading information to BRRI.

Fig. 19. Pictorial views of different innovation and e-learning workshops.

Innovation team activities

BRRI formed an innovation team and reformed this team on 11 October 2017 following the Innovation Team Gazette 2013. BRRI has implemented all innovations under Innovation Action Plan Guideline 2015 and several annual innovation work plan of BRRI. This division organized Five day-long, Two day-long, day-long 'Public Service in Innovation' workshop and Two day-long 'e-Learning workshop' regularly by Access to Information (A2i), Ministry of ICT (MoICT) and Cabinet Division. BRRI has participated showcasing programmes several times at BARC arranged by A2i and Ministry of Agriculture (MoA). We organized monthly innovation team meeting regularly and review performance properly. Figure 19 shows innovation and e-learning Innovation Workshop.

ICT and related fair

ICT cell of Agricultural Statistics Division participated several ICT and related fairs such as Digital World Fair, Development Fair, Tattha Mela and World Food Fair etc.

Other 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. Fifty 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 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

SUMMARY

This experiment was conducted at the West Byde of BRRI farm, Gazipur during T. Aman 2019 and Boro 2019-20 seasons to find out the suitable transplanting date and spacing of short duration rice varieties. During T. Aman season, transplanting date 15 July to 16 August produced statistically identical and highest yield (5.60 to 5.94 tha^{-1}). The (15 cm × 15 cm) spacing gave the highest (5.84 t ha^{-1}) grain yield in T. Aman season for short duration (growth duration 113 to 115 days) rice varieties which is statistically identical with the spacing 20 cm × 15 cm (5.49 t ha^{-1}) and in Boro season, 16 January produced the highest grain yield (7.55 t ha^{-1}) followed by 31 December, 15 December and the lowest in 1 February (6.35 t ha^{-1}). Among the spacing the (20 cm × 15 cm) produced the highest grain yield (7.67 t ha^{-1}) and the lowest in 20 cm × 20 cm spacing (6.89 t ha^{-1}).

This experiment was initiated on a permanent layout at the BRRI farm, Gazipur during T. Aman 2019 and Boro 2019-20 to find out the suitable management practice for yield maximization of rice and soil health. Seven treatments in Randomized Complete Block Design with three replications were imposed and each treatment was assigned in 4 m × 5 m 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^{-1} Poultry manure, T_6 = STB dose + 1 t ha^{-1} Vermicompost and T_7 = STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC. Thirty-day-old seedling of BRRI dhan87 in T. Aman and forty-two-day-old seedling of BRRI dhan89 in Boro season were transplanted at 20 cm × 20 cm spacing in both the seasons. Grain yield, tiller number, panicle number, plant height and Grain number were significantly affected by the different effect of integrated nutrient management in both T. Aman and Boro season. Poultry litter related treatments and BRRI recommended dose performed better than in all the parameter except 1000-grain weight. On the other hand control plot (No nutrient supply) showed the lowest result.

Survey and monitoring of labourers' 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 488-543. The wage rates day^{-1} during the peak periods of the year Tk 500 to 550 in May, Tk 500 to 560 in July-August and Tk 500 to 560 in December -January were existed. The wage rate varied between Tk 410-430, 360-460, 450-510, 400-460, 450-505, 360-455 and 455-510 at Habiganj, Rangpur, Rajshahi, Barishal, Sonagazi, Cumilla, Satkhira and Khulna, respectively

This division produced about 25855 kg rice of which 22,118 kg seed (TLS) and 3,737 kg mixed rice.

BRRI has 732 labourers of which 521 regular and 211 irregular (Table 5). In BRRI HQ, total labourer number is 458 of which 303 regular and 155 irregular labourers. BRRI has 286.33 ha of land of which 172.64 ha is cultivable. Total labour utilization in different divisions was 1,93,630 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 9,35,98,475 /- of which Tk 4,78,47,540 /- and Tk 4,22,59,712 /- and Tk 34,91,223 /- were paid to the labours for research work, support service works, leaves and holidays, respectively. A total of 86.01 ha of land were utilized by different divisions in different seasons of which 10.62 ha in Aus, 38.72 ha in Aman and 36.67 ha in Boro season. This division manages the BRRI flower garden to maintain the aesthetic view of the campus 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

This experiment was conducted at the West Byde of BRRI farm, Gazipur during T. Aman 2019 and

Boro 2019-20 seasons to find out the suitable transplanting date and spacing of short 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= 15 cm × 15 cm, S_2=20 cm × 15 cm and S_3= 25 cm × 15 cm). In Boro, the treatments were four transplanting dates (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 and BRRI dhan81 were transplanted in T. Aman and Boro season, respectively. Twenty-five and 35-day-old seedling as per treatment were transplanted in T. Aman and Boro seasons respectively. All other intercultural operations were done as and when necessary. Yield and yield components data were taken at maturity. The collected data were analyzed using Crop Stat 7.2 Software programme.

PI: Dr K P Halder **CI:** M M Rashid, Dr M F Islam, M R Manir, M S Islam and Setara Begum

Experiment of T. Aman 2019

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 15 July followed by 31 July, 16 August and the lowest in 1 September but different transplanting dates had no significant effect on percentage of unfilled grain. Transplanting date 31 July produced the highest grain yield (5.94 tha^{-1}) followed by 15 July and 16 August but no significant difference between them. The lowest grain yield (4.95 tha^{-1}) was recorded in 1 September (Table 1).

Effect of spacing. The closest spacing (15 cm × 15 cm) produced the highest number of tiller and panicle $m\text{-}^{2}$; and number of unfilled grain $panicle^{-1}$ which was gradually decreased with increasing spacing. The (20 cm × 15 cm) produced the highest number filled grain per panicle which was statistically identical with 25 cm × 15 cm spacing and found the lowest in (15 cm × 15 cm) spacing. The 1000 grain weight (TGW) was not significantly affected by spacing. The highest grain yield (5.84 t ha^{-1}) was observed in closer (15 cm × 15 cm) spacing which was statistically identical with the yield (5.49 t ha^{-1}) of 20 cm × 15 cm spacing. The grain yield gradually decreased with increasing spacing. It was the lowest (5.10 t ha^{-1}) in widest (25 cm × 15 cm) spacing (Table 1).

It may be concluded that in T. Aman season, for short duration (113 to 115 days) rice varieties transplanting date 15 July to 16 August produced statistically identical and highest yield (5.60 to 5.94 t ha^{-1}). The 15 cm × 15 cm spacing produced the highest grain yield (5.84 t ha^{-1}) which was statistically identical with the spacing 20 cm × 15 cm.

Table 1. Yield and yield components of rice as affected by Transplanting date and Spacing T. Aman 2019.

	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 (t ha^{-1})
			Effect of transplanting date				
D_1 (15-Jul)	309	286	22.13	99	20	22.27	5.90
D_2 (31-Jul)	290	275	22.62	96	21	22.15	5.94
D_3 (16-Aug)	272	258	22.53	91	22	22.23	5.60
D_4 (1-Sep)	268	245	22.20	86	23	22.31	4.95
Lsd at 5%	20.20	11.38	ns	7.33	ns	ns	0.54
			Effect of spacing				
15cm × 15cm	320	295	22.23	93	21	22.16	5.84
20cm × 15cm	272	258	22.45	99	20	22.18	5.49
25cm × 15cm	261	235	22.43	98	18	22.09	5.10
	16.04	14.30	0.23	5.50	3.4	0.25	0.38

Experiment of Boro 2019-20

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 yield, none of the parameters was significantly affected by transplanting date (Table 2). Transplanting date 16 January produced the highest grain yield (7.55 tha^{-1}) followed by 31 December (7.51 tha^{-1}) and 15 December (7.47 tha^{-1}). The lowest grain yield (6.35 tha^{-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 (25 cm × 15 cm) spacing but no significant difference with (20 cm × 20 cm) and (20 cm × 15 cm) spacing. The lowest number of filled grain panicle^{-1} was observed in closest spacing (20 cm × 15 cm). The highest TGW was observed in (25 cm × 15 cm) spacing which was insignificant to (20 cm × 15 cm) and (20 cm × 20 cm) spacing. In Boro season season, the plants grown in 20 cm × 15 cm spacing produced the highest grain yield (7.67 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, 16 January produced the highest grain yield (7.55 t ha^{-1}) followed by 31 December, 15 December and lowest in 1 February (6.35 t ha^{-1}). Among the spacing the (20 cm × 15 cm) gave the highest grain yield (7.67 t ha^{-1}) which was statistacally similar with 25 cm × 15 cm spacing (7.28 t ha^{-1}) and the lowest in 20 cm × 20 cm spacing.

Integrated nutrient management for yield maximization of rice

PI: Md Mamunur Rashid **CI:** S Begum, A Jahan, Dr M F Islam, M S Islam and Dr K P Halder

This experiment was initiated on a permanent layout at the BRRI farm, Gazipur during T. Aman 2019 and Boro 2019-20 to find out the suitable management practice for yield maximization of rice and soil health. Seven treatments in randomized complete block design with three replications were imposed and each treatment was assigned in 4 m × 5 m 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^{-1} Cowdung, T_5 = STB dose + 1 t ha^{-1} Poultry manure, T_6 = STB dose + 1 t ha^{-1} Vermicompost and T_7 = STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC. Thirt-day-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 the 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 42-day-old seedling of BRRI dhan89 in Boro season were transplanted at 20 cm × 20 cm 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 components 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 parameters except TGW. 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 season (BRRI dhan87), different nutrient management practices have significant effects in rice plant height. The tallest rice plant (126.27 cm) was found in the STB

Table 2. Yield and yield components of rice as affected by Transplanting date and spacing Boro 2019-20.

	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 (t ha-1)
				Effect of Transplanting date			
D_1 (15-Dec)	316	287	21.91	120	15	22.17	7.47
D_2 (31-Dec)	321	295	21.73	119	17	21.92	7.51
D_3 (16-Jan)	307	294	21.70	115	16	21.98	7.55
D_4 (1-Feb)	304	280	21.65	111	17	21.82	6.35
Lsd at 5%	ns	ns	ns	ns	ns	ns	0.47
				Effect of spacing			
20cm × 15cm	336	317	22.45	117	16	21.80	7.67
25cm × 15cm	306	282	22.05	118	15	21.82	7.28
20cm × 20cm	275	254	21.80	118	17	21.75	6.89
	15.42	13.47	0.40	ns	ns	ns	0.41

dose + 1 t ha^{-1} Poultry manure management which is statistically similar with STB dose + 1 t ha^{-1} Cowdung, BRRI dose and STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC (vermicompost) used plot, followed by 123.90 cm in STB dose + 1 t ha^{-1} used plot and 122.60 cm in STB dose plot. The smallest rice plant (114.40 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 + 1 t ha^{-1} poultry litter plot produced statistically the highest tiller number followed by others treatment. STB dose + 1 t ha^{-1} poultry litter gave the highest number of tiller (314 tiller m^{-2}) whereas control plot produced the lowest number of tiller (230 tiller m^{-2}) among all the treatments. But BRRI recommended dose and STB dose + 1 t ha^{-1} cowdung plot produced statistically similar tiller number per square meter which significantly differ from STB dose + 1 t ha^{-1} poultry litter (Table 3).

Panicle number. Panicle production was significantly affected by all the nutrient management during T. Aman season. Here BRRI fertilizer dose and STB dose + poultry litter used plot produced statistically similar panicle number. The highest number of panicle (303 panicle m^{-2}) found in STB dose + 1 t ha^{-1} poultry manure followed by 283 panicle m^{-2} in STB + 1 t ha^{-1} cowdung and 268 panicle m^{-2} in STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC used plot. The lowest number of panicle (223 panicle m^{-2}) among all the treatments was observed in control plot (Table 3).

Grain number and grain weight. During T. Aman season STB dose + 1 t ha^{-1} Poultry litter, STB dose + 1 t ha^{-1} vermicompost and BRRI recommended dose used plot gave almost similar number of grain per panicle which was statistically significant from control plot. STB dose + 1 t ha^{-1} Poultry litter provides the highest number of grain per panicle (117 grain panicle^{-}1) whereas control plot produced the lowest number of grain (98 grain $panicle^{-1}$). And there was no significant difference among the treatments in case grain weight (Table 3).

Grain yield. During T. Aman, 2019, Grain yield was significantly affected by different nutrient management practices. STB dose + 1 t/ha poultry manure (5.52 t ha^{-1}) and BRRI dose (5.12 t ha^{-1}) gave the highest and statistically similar grain yield followed by STB dose + 1 t/ha cowdung (4.98 t ha^{-1}), STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC (4.67 t ha^{-1}), STB dose + 1 t/ha vermicompost (4.56 t ha^{-1}) and STB dose (4.34 t ha^{-1}) where STB dose + 1 t/ha cowdung, STB dose + 0.33 t/ha CD + 0.33 t/ha PM + 0.33 t/ha VC, STB dose + 1 t/ha vermicompost produced statistically similar grain yield. The lowest yield was observed in control plot (3.90 t ha^{-1}) (Table 3).

Table 3. Yield and Yield Components in T. Aman 2019.

Treatment	Plant height (cm)	Tiller m^{-2} (no.)	Panicle m^{-2} (no.)	Grain panicle^{-1} (no.)	1000 grain wt. (g)	Grain yield (t ha^{-1})
T_1 = Absolute control	114.40	230	223f	98	24.10	3.90
T_2= BRRI dose N-P-K-S@83-17-53-12 kg/ha	125.33	302	292	110	23.67	5.12
T_3 = Soil test based (STB) fertilizer dose N-P-K-S@67-10-40-10 kg/ha	122.60	252	241	99	24.17	4.34
T_4 = STB dose + 1 t/ha cowdung	125.53	294	283	101	24.43	4.98
T_5 = STB dose + 1 t/ha poultry manure	126.27	314	303	117	24.27	5.52
T_6 = STB dose + 1 t/ha vermicompost	123.90	264	255	112	24.40	4.56
T_7 = STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC	124.43	279	268	99	23.98	4.67
LSD at the 5% level	2.22	10.45	11.02	10.12	0.84	0.42
CV %	2.98	9.55	8.46	8.90	3.48	9.55

Yield and Yield Components in Boro

Plant height. During Boro season STB dose, BRRI dose, STB dose + 1 t ha^{-1} Poultry litter, STB dose + 1 t ha^{-1} cowdung, STB dose + 1 t ha^{-1} vermicompost and STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC used plot gave almost similar plant height which was statistically significant from control plot. STB dose provides the tallest plant (101.99 cm) whereas control plot gave the smallest plant (96.40 cm) (Table 4).

Tiller number. Tiller production varies significantly among the different nutrient management practices in Boro season. STB dose + 1 t ha^{-1} poultry litter plot produced statistically highest tiller number followed by other treatments. STB dose + 1 t ha^{-1} poultry litter produced the highest number of tiller (257 tiller m^{-2}) whereas control plot obtained the lowest number of tiller (202 tiller m^{-2}) among all the treatments. But BRRI recommended dose and STB dose plot produced statistically similar tiller number per square meter which were significantly similar with STB dose + 1 t ha^{-1} poultry litter (Table 4).

Panicle number. Panicle production was significantly affected by all the nutrient management during Boro season. Here STB dose + poultry litter used plot obtained statistically the highest panicle number. The highest number of panicle (254 panicle m^{-2}) was found in STB dose + 1 t ha^{-1} poultry manure followed by 244 panicle m^{-2} in BRRI dose, 242 panicle m^{-2} in STB dose and 240 panicle m^{-2} in STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC used plot. The lowest number of panicle (198 panicle m^{-2}) among all the treatments was observed in control plot. (Table 4).

Grain number and grain weight. During Boro season STB dose + 1 t ha^{-1} Poultry litter, STB dose + 1 t ha^{-1} cowdung and BRRI dose used plot produced almost similar number of grain per panicle which was statistically significant from control plot. STB dose + 1 t ha^{-1} Poultry litter provides the highest number of grain per panicle (158 grain panicle^{-1}) whereas control plot produced the lowest number of grain (110 grain panicle^{-1}). And there was no significant difference among the treatments in case of grain weight (Table 4).

Grain yield. In Boro 2019-20, grain yield was significantly affected by different nutrient management practices. STB dose + 1 t ha^{-1} poultry litter (8.26 t ha^{-1}) and BRRI dose (7.90 t ha^{-1}) obtained the highest and statistically similar grain yield followed by STB dose + 1 t ha^{-1} cowdung (7.36 t ha^{-1}), STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC (7.00 t ha^{-1}), STB dose + 1 t ha^{-1} vermicompost (6.54 t ha^{-1}) and STB dose (6.32 t ha^{-1}) where STB dose + 1 t ha^{-1} cowdung and STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC produced statistically similar grain yield. The lowest yield (3.16 t ha^{-1}) was observed in control plot (Table 4).

Grain yield, tiller number, panicle number, plant height and grain number were significantly affected by the different integrated nutrient management practices during both T. Aman and Boro seasons. Every parameter, Poultry litter related treatments and BRRI recommended dose performed the best. This study indicates STB dose with 1 t ha^{-1} poultry litter is better for rice yield. Further research may be needed to find out the suitable integrated fertilizer management.

Table 4. Yield and yield components in Boro 2019-20.

Treatments	Plant height (cm)	Tiller m^{-2} (no.)	Panicle m^{-2} (no.)	Grain $panicle^{-1}$ (no.)	1000 grain wt. (g)	Grain yield (t ha^{-1})
T_1 = Absolute control	96.40	202	198	110	24.59	3.16
T_2 = BRRI dose N-P-K-S@138-21-75-21 kg/ha	100.54	253	244	154	24.99	7.90
T_3 = Soil test based (STB) fertilizer dose (N-P-K-S@134-16-75-10 kg/ha)	101.99	255	242	139	24.73	6.32
T_4 = STB dose + 1 t ha^{-1} cowdung	99.22	249	242	153	24.63	7.36
T_5 = STB dose + 1 t ha^{-1} poultry manure	101.10	257	254	158	24.87	8.26
T_6 = STB dose + 1 t ha^{-1} vermicompost	98.98	247	238	141	24.67	6.54
T_7 = STB dose + 0.33 t ha^{-1} CD + 0.33 t ha^{-1} PM + 0.33 t ha^{-1} VC	99.55	248	240	149	24.97	7.00
LSD at 5% level	2.25	7.45	8.92	9.12	0.75	0.48
CV %	3.28	7.98	7.66	7.09	3.32	7.67

Monitoring labour wage rate at different locations of Bangladesh
PI: Dr K P Halder **CI:** M M Rashid, M S Islam, M R Manir, Dr M F Islam and S Begum

Survey and monitoring of labourers' 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 488-543. The wage rate day^{-1} during the peak periods of the year Tk 500 to 550 in May, Tk 500 to 560 in July-August and Tk 500 to 560 in December-January were existed. The wage rate varied between Tk 410-430, 360-460, 450-510, 400-460, 450-505, 360-455 and 455-510 at Habiganj, Rangpur, Rajshahi, Barishal, Sonagazi, Cumilla, Satkhira and Khulna respectively.

Rice seed production
PI: M M Rashid **CI:** M S Islam, M R Manir, Dr M F Islam, S Begum and Dr K P Halder

In different seasons, Farm Management Division produced about 25,855 kg rice of which 22,118 kg TLS seed and 3,737 kg mixed rice included.

Support services
PI: Dr K P Halder **CI:** M M Rashid, M S Islam, M R Manir Dr M F Islam and S Begum

Management of land and labour: Including Regional Stations, BRRI has 732 labourers of which 521 are regular and 211 are irregular (Table 5). In BRRI HQ, total number labourers is 458 of which 303 are regular and 155 are irregular. BRRI has 286.33 ha of land of which 172.64 ha is cultivable. Total labour utilization in different divisions was 1,93,630 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 9,35,98,475 of which Tk 4,78,47,540 and Tk 4,22,59,712 and Tk 34,91,223 were paid to the labourers for research work, support service works, leaves and holidays respectively. A total of 86.01 ha of land were utilized by different divisions in different season of which 10.62 ha in Aus, 38.72 ha in Aman and 36.67 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 5. Land and labor strength of BRRI, 2019-2020.

Name of Station	Total land (ha)	Cultivable land		Labor (no.)		
		Area (ha)	% of total land	Muster roll		Total
				Regular	Irregular	
HQ at Gazipur	76.83	44.45	57.86	303	155	458
Comilla	24.68	16.03	64.95	25	13	38
Hobiganj	35.03	25.90	73.94	28	11	39
Sonagazi	45.77	35.90	78.44	37	04	41
Barisal	41.10	10.74	26.13	26	03	29
Rajshahi	13.24	8.92	67.37	26	06	32
Bhanga	11.46	9.55	83.33	16	05	21
Rangpur	6.07	4.05	66.72	30	05	35
Satkhira	20.00	8.10	40.50	19	02	21
Kushtia	4.05	3.0	74.07	11	01	12
Sirajganj	4.05	3.0	74.07	-	-	-
Gopalganj	4.05	3.0	74.07	-	6	6
Total	286.33	172.64	60.29	521	211	732

Farm Machinery and Postharvest Technology Division

+ Workshop Machinery and Maintenance Division

SUMMARY

A study was aimed to fabricate a whole feed combine harvester at the FMPHT divisional workshop, Gazipur which will be have easy fabrication process, low cost, high capacity and less repairable. First version of the whole feed combine was developed and some problems were identified in the field test. Material selection was not good enough and frequent trouble was observed during field operation. Therefore, an initiative was taken to fabricatethe second version of the whole feed combine harvester and complete in the FMPHT divisional workshop considering the problems which were identified in previous version of the combine harvester. Performance test will be done after finishing of fine tuning of the machine.

Mixed fertilizer deep placement mechanism was incorporated in the walking (ARP-4UM) and riding type (S3-680) rice transplanter under NATP phase-II sub-project funding. Both the technology has improved based on problems identified during field trials in Boro 2018-19 and Aman 2019 seasons. In both type of rice transplanters, spiral type mechanism was incorporated as metering device to receive and dispense desired amount of mixed fertilizer. Engine power available at high rpm (more than 1800 rpm) was conveyed to the applicator with the arrangement of a belt-pulley, worm gearing, shaft-bearing, universal joint and bevel gear with engage-disengage facility resulting 23 rpm of the applicator main shaft. Fertilizer dispensing rate increased with the increase of number of the lever position. Developed rice transplanter cum fertilizer applicator (RTFA) was evaluated in the laboratory, soil bin, research field and farmer's field. In the lab test, it was found that fertilizer control lever can control fertilizer dispensing rate according to pre-calibration. In the soil bin test, it was observed that mixture fertilizer dispensed uniformly in the furrow and covered effectively. Agitator, which was used in the fertilizer hopper, rotated smoothly to prevent the bonding of fertilizer mixture.

A research was conducted to evaluate the field performance of the BRRI rice transplanter cum mixed fertilizer applicator in different locations during Boro and Aman season. RCB design was followed in both the seasons with three replications. In Boro 2018-19 season, average dispensing rate of fertilizer in lever position 4 was calibrated 67.94 g/rotation of the rice transplanter driving wheels based on recommended dose of fertilizer; while average deviation of fertilizer dispensing rate was about +3.72% due to clog of the dispensing channel of the transplanter during operation. The theoretical and actual field capacity and field efficiency of the RTFA were found 0.20 ha/h, 0.0.12 ha/h and 58.95% while it was 0.20 ha/h, 0.13 ha/h and 64.10% of the rice transplanter without fertilizer deep placement mechanism respectively. During field trials in Aman 2019 season, average dispensing rate of fertilizer in lever position 3 was calibrated 37.8 g/rotation of the rice transplanter driving wheels based on recommended dose of fertilizer while average deviation of fertilizer dispensing rate was about -4.86% due to slippage of the wheels during operation. In an average of seven trials, theoretical and actual field capacity and field efficiency of the RTFA were found 0.19 ha/h, 0.23 ha/h and 82.2% while it was 0.21 ha/h, 0.26 ha/h and 80.3% of the rice transplanter without fertilizer deep placement mechanism respectively. It was observed that grain yield varied with the mode and rate of fertilizer applicationin Aman 2019 season. Mechanical transplanting along with mixed fertilizer deep placement (80% of the recommended dose of urea) gave significantly higher yield and BCR compared to the mechanical and manual transplanting along with hand broadcasting of fertilizers.

A study was conducted to develop a walk behind type power operated rice transplanter in the FMPHT divisional research workshop. Power transmission system was analyzed to design different gears (worm, bevel, spiral bevel, spur), pulley, chain-sprocket, rotary picker, seedling releaser etc. Jigs and fix also fabricated for the different components of the transplanter for ease of replications. Fabrication drawing of the different components is under process. Detail report of design and field trials will be presented in the annual research review workshop.

A study was undertaken to design and development of a head feed thresher using locally available materials in Nayem Engineering workshop, Modan, Netrokona under private public partnership (PPP). BRRI provided design, drawing, technical and financial support to develop and fabricate this machine. The study was aimed at

design, fabrication and testing the performance of the prototype. The machine has already manufactured by the local workshop. Preliminary test of the machine was done in Boro 2020 season to find out the mechanical faults of the machine. It was found that machine has no major faults. Fine-tuning is going on. The performance test of the machine will be done thoroughly in the up-coming season.

A battery operated small size reaper was developed in Zomzom workshop, Pabna. The machine consists of main body, power transmission system and cutter bar. The machine was tested at the farmers' field at Pabna. The wide of the cutter bar was 45 cm. The average forward speed of the machine was 2.8 km/h and capacity was 0.09 ha/h.

The effects of tillage depths on the productivity of paddy were determined in field experiments in Aman 2019 and Boro 2020 at BRRI RS, Rajshahi and Rangpur in different tillage depths. There were five tillage depths i.e. 2-3, 3-4, 4-5, 6-7 and 7-8 inches. Tillage depths affected tiller, panicle number and yield of BRRIdhan34 in Aman 2019, BRRIdhan28 at Rajshahi and BRRIdhan63 at Rangpur in Boro 2020 season. Tiller and panicle number of plant also increased with the increase of tillage depth. These were found highest in 6-7 inches depth of tillage and nearly same as 7-8 inches depth of tillage. The highest grain yield was found 2.50 t ha^{-1} and 5.18 t ha^{-1} in the tillage depth of 6-7 inches and lowest yield was found 2.02 t ha^{-1} and 4.00 t ha^{-1} in the tillage depth of 2-3 inches in Aman 2019 and Boro 2020 respectively at RS, Rajshahi. At Rangpur the highest grain yield was found 8.05 t ha^{-1} in the tillage depth 7-8 inches and lowest yield was found 7.33 t ha^{-1} in the tillage depth of 2-3 and at 6-7 inches the yield was found 7.99 t ha^{-1}. Number of tiller, panicle, yield of both varieties were found more or less same in both seasons at 6-7 and 7-8 inches tillage depth. Farmers of Bangladesh practiced usually 4-5 inches depth of tillage for paddy cultivation.

A survey was conducted using semi-structure questionnaire on machinery used in farmer's field at Botiakhali and Hazratala in SreepurUpazila of Magura district. A little number of machinery was used in these villages and these were power tiller, shallow tube well, engine operated pedal thresher and sprayer. There were no rice transplanter, reaper, combined harvester at the farm level of these areas. So, there is a scope to introduce these machinery in these areas. The problem was that the operator of the machine is not skilled and they never follow proper machinery maintenance schedule which increase their operation time and repair cost. So, proper training should be arranged for the machinery operator.

A survey was conducted on potentiality of engineering workshop for enhancing farm mechanization in Rangpur district by the developed semi-structure questionnaire. Different kinds of farm machinery have been used in the farmers' field. Some of them were imported and rest of these was made by the local workshops. The facilities of machinery of the workshops were lathe, shaper, drill, grinding and welding machine.

There were different kinds of vehicles and farm machinery at BRRI head quarter which repairs and maintenance works were done by WMM Division. The total cost of major and moderate/minor repair and maintenance was Tk64,52,379.00from July 2019 to June 2020. Among these major repair and maintenance cost was Tk 49,61,676.00 and moderate/minor repair and maintenance cost was Tk 14,90,703. The major repair and maintenance work was done by direct cash purchase, direct contracting through work order and RFQ (Request for quotation). On the other hand, the moderate/minor repair and maintenance work was done only by using the revolving fund.

The aim of this study was to determine the percentage of milling effect on weight loss, head rice recovery, and zinc (Zn) loss of rice at Farm Machinery and Postharvest Technology (FMPHT) division, BRRI, Gazipur. Three most popular rice varieties such as BRRI dhan28, BRRI dhan42 and BRRI dhan74 (Zn enriched bio-fortification) were used to conduct the study. In this study, grain Zn content was estimated in the brown rice (dehusked unpolished grain) and different degrees of polished rice (7.5, 10, 12, 13.75 and 15%) by the atomic absorption spectrophotometer (AA-7000). It was carried out in three factor Randomized Complete Block (RCB) design with three replications. It was observed that the zinc content of three varieties decreased with the increasing of the degree of milling (DoM). It was revealed that there had negative relationship between DoM and head rice yield. The zinc content of three varieties was varied up to 12% DoM and after 13.75% DoM there have no difference in Zn content, both bio-fortification and not Zn enriched varieties. During the milling process, the broken percentage increases with increasing of DoM, due to low surface hardness which leads to low quality and recovery of milled rice. The DoM affects not only the quality but also the appearance of rice kernels. The whiteness value of each variety was the lowest in the brown rice stage, followed by different degree of milling (7.5<10.0<12.0<13.75<15%) in both parboiled and unparboiled condition. This study showed that the DoM and whiteness are positive correlated. It can be concluded from these results that over DoM affect the losses of Zn content as well as lower head rice yield. It was clearly shown that more food loss occurred due to more degree of milling, which is greatly, hampered the food security of the nation.

The experiment of recirculating dryer was conducted during Boro season 2020 at the FMPHT divisional workshop using BRRIdhan28 with different load capacity. The modified dryer was run in no load, half load and full load condition. Drying air temperature distribution through grain bin was uniform throughout the dryer during drying operation. The paddy was dried from 28.7 to 18.9%, 28.5 to 14.2% and 29.4 to 13.6% during Boro season 2020 within the range of 4.5 to 10.0 hrs, respectively. The drying rate was found to be varied between 1.6 to 2.2% which is directly depends on initial moisture content of paddy and drying air temperature. The range of drying efficiency was ranged from 24.9% to 51.6% during Boro season for different dryer capacity.

FMPHT Division modified rubber roll de-husker for improving the performance of rice processing. Husking efficiency of modified rubber roll de-husker was around 90% for BRRI dhan84. Milling recovery of BRRI dhan84 was 64 % polished in MNMP - 15 type polisher followed by de-husking. The average head rice recovery based on input paddy was 54.0 %, which is promising for processing of premiere quality rice. Engelberg huller may replace with one rubber roll de-husker and polisher for better quality rice. Beside this, rubber roll de-husker separate husk and friction type polisher separate bran. Separately collected husk and bran is suitable for briquette and edible oil production.

Parboiled BRRI dhan71 with six different moisture contents was processed in the air blow type engelberg huller to find out the optimum moisture content of milling. Milling yield for moisture content of 9.1%, 10.2%, 11.3%, 12.3%, 13.2% and 13.9% (wb.) were found 67.5%, 68.0%, 68.6%, 69.2%, 70.0% and 70.5% respectively and head rice recovery (based on input paddy) were 59.0%, 63.0%, 62.5%, 60.0%, 58.8% and 56.6% respectively. Higher head rice recovery was observed in 63.0% and 62.5% in 10.2% and 11.3% moisture content (wb.) respectively. Broken rice percentage (based on input Paddy) was found lower (5.0%) in 10.2% moisture content (wb.). It may be concluded that, around 10-11% moisture content (wb.) is suitable for milling of parboiled paddy processed in the air blow type engelberg huller in terms of head rice recovery and less broken percentage.

A study was conducted in haor ecosystem of Bangladesh to investigate the rental charges and operational management of the combine harvester in a competitive way. The data collected in Mithamainupazilla under the Kishoreganj district covering *haor* region of Bangladesh from 86 rice fields, harvested by the whole-feed combination of harvesters (Model: Zoomlion). The size of land, operative time, loss time, repair time and idling time were also recorded to predict the business sustainability of combined harvester. Daily area coverage and harvester constraints were also recorded. In keeping with the standard protocol, the renting and payback period is determined to make businesses profitable. It was found that the combine harvester becomes profitable only after 40 hectares of paddy field harvested at a harvesting capacity of 0.20 ha h^{-1} for the rental charges of Tk 10,000 ha^{-1}.

MACHINERY DEVELOPMENT AND TESTING

Development and fabrication of a whole feed combine harvester

A prototype of whole feed combine harvester was fabricated using locally available materials in the FMPHT divisional workshop, BRRI, Gazipur. The faults of first version were taken in consideration to fabricate the second version. The important functional elements are cutter bar, reel, grain screw conveyer, feeding conveyer, threshing drum, blower fan, paddy screw conveyer and driving power of the combine. The grain holding tank and bagging system are also considerable parameters to design a combine harvester.

Design considerations of whole feed combine harvester

Government and non-government organization imported combine harvest (head feed and whole feed) which are not affordable for the farmers due to high cost. Moreover, the imported combine are big in size, those are tough to handle in small and fragmented land. The most of farm land have no road for easy accessibility of machines. Considering the above point, BRRI took initiatives to fabricate combine harvester at the FMPHT divisional workshop, Gazipur.For easy fabrication, low cost, high capacity and easy repair& maintenance the following criteria were considered:

- Use cutter bar from the reaper, which is available in local markets
- Use close drum thresher, which is commonly used for threshing in Bangladesh
- Locally available materials for conveyer, gear box, belt pulley, etc
- Locally available materials should be used to minimize the fabrication cost
- It should be easy to repair and maintenance
- The cost of harvester must be within the capacity of small and medium farmer
- It should be suitable for operation by 2-3 person

As per design, specifications, identified problems of the 1st version and recommendations were considered. The 2nd version of whole feed combine harvester was fabricatedat FMPHT divisional workshop (Fig.1 & 2). Initial performance test was done to find out the faults of the machine (Plate 1). After fine tuning, the performance test will be done in up-coming Amanseason to find out the performance, efficiency and operational faults.

Cutting part. The part is consisted of cutting blade (serrated blade), cutting blade holder, cutter bar, cutting teeth, reel assembly, paddy separator and hydraulic system. The reel assembly was the one most important part of the cutting system and the component were reel bar, reel peg, reel frame.

Conveyer part. There have conveyer cylinder, conveyer belt with peg, helical conveyer part. The conveyer part is one kind of box type, remain closed. The conveyer belt would be made by nylon.

Threshing part. The thresher main part was threshing drum,drum shaft, peg tooth, stripper bar assembly, rasp bar, straw thrower and concave assembly. Also the main component of blower was blower cover assembly, cover assembly with louver, blower blade assembly, blower shaft, oscillating arm assembly, oscillating screen assembly, grain chute.

***Design and drawing of some fabricated parts of the machine** (All dimensions in mm)*

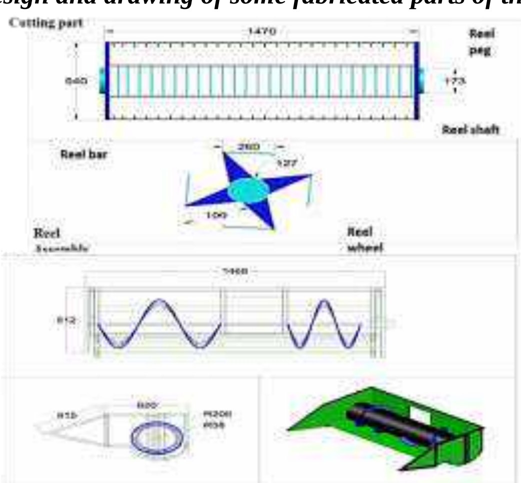


Fig.1 (a). Cutting parts of the combine

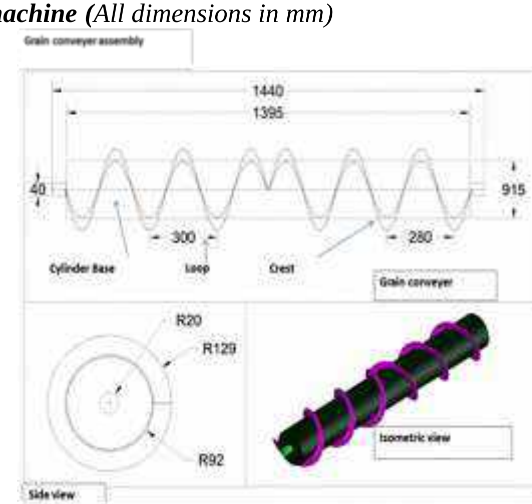


Fig. 1 (b). Grain conveyer assemble of the combine

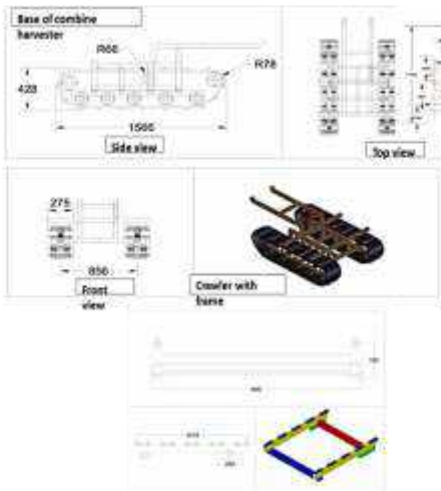


Fig. 1 (c). Basement/platform of combine

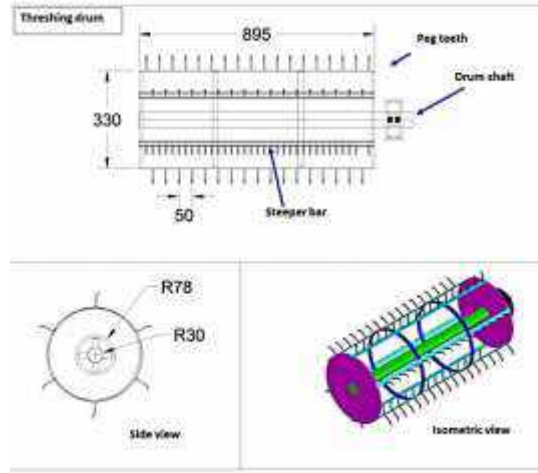


Fig. 1 (d). Thresher assemble

Fig. 1. Drawing of some fabricated parts of the machine

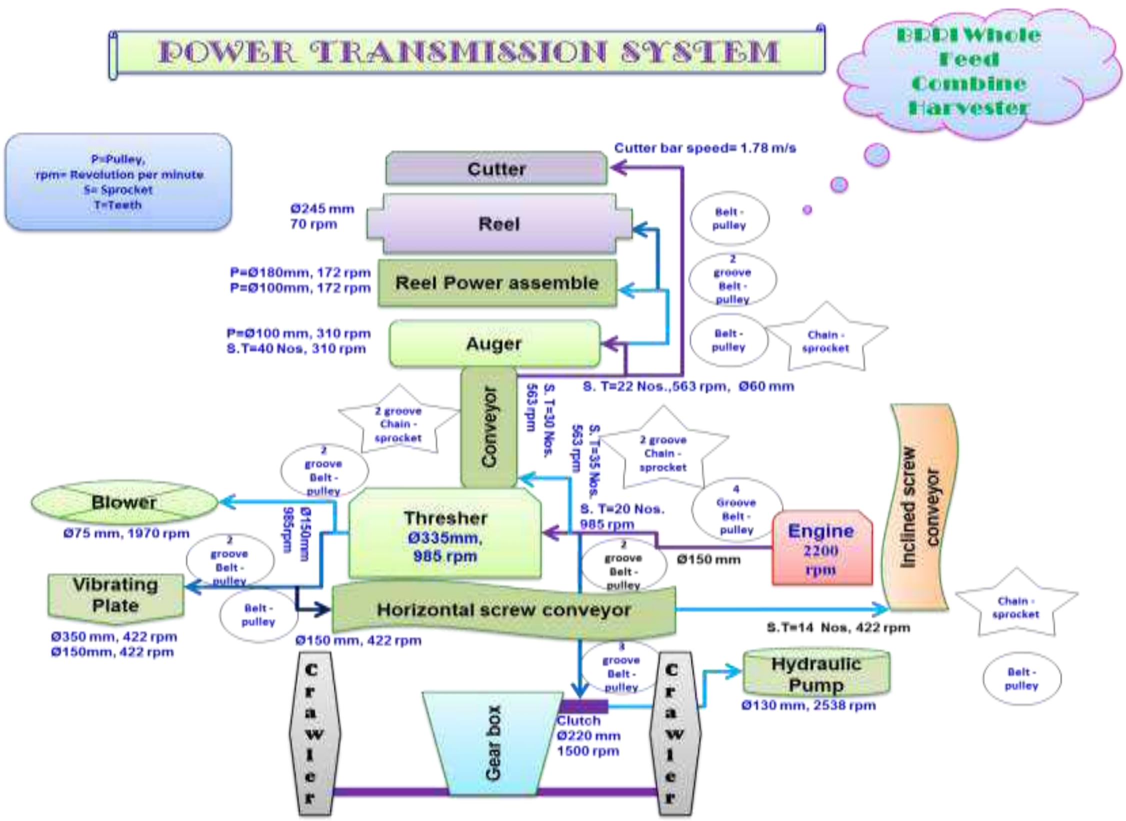


Fig. 2. Power transmission system of the newly developed BRRI whole feed combine harvester. Design and fabrication of whole feed combine harvester was finished at the FMPHT divisional workshop using locally available materials. Fine tuning is going on. Some parts of the machine such as crawler, gear box, hydraulic systems etc. were procured from local market. Maximum parts of the machine were manufactured in the divisional workshop and some of the parts of the machine were fabricated in the local workshop as well.

Plate 1. Whole feed combine harvester

Bagging part. The major component of the bagging part is grain tank, conveyer panel, screw conveyer and bagging place.After threshing the grain gather in the grain chute and screw conveyer carry the gain to the grain tank and stored.

Combine base. The thresher, engine, steering system, hydraulic system was placed on the base and operator sit will be also placed on the base. Moreover the cutting part will be connected to the base. In addition the driving system attached to the base for movement.

Engine. 32 Hp diesel engine was used for this whole feed type combine harvester; the main power will be distributed through belt-pulley, ideal pulley, chain and shaft to thresher, cutting part, cleaning blower, driving wheel. The self-starting will be incorporated to run the engine.

Driving system. The main part of the driving system is wheel/crawler, differential shaft and gear arrangement. The power was transferred from engine. The driving system and others control system connected with lever by rod and shaft.

Modification of the fertilizer deep placement mechanism for existing rice transplanter

A study was conducted to modify the BRRI developed mixed fertilizer deep placement mechanism for existing rice transplanter under the program based research grants, NATP-2, Bangladesh Agricultural Research Council (BARC). Mixed fertilizer deep placement mechanism was incorporated in the walking (ARP-4UM) and riding type (S3-680) rice transplanter. Both the technology improved based on problems identified during field trials inBoro 2018-19 and Aman 2019 seasons. In both type of rice transplanters, spiral type mechanism was incorporated as metering device to receive and dispense desired amount of mixed fertilizer.

DESIGN CONSIDERATIONS

- Fertilizer deep placement (FDP) should be in between two rows and before the rotary picker,
- FDP technology should be operated with the existing power of the transplanter,

- Depth of fertilizer placement should be in between 80 to 100 mm,
- Uniformity of fertilizer dispensing should be maintained to keep the desired dose of fertilizer,
- Power transmission system should be simple with engage and disengage facility,
- Locally available materials should be used to minimize the fabrication cost.

Design steps

- Belt-pulley arrangement with tension pulley was designed to transmit power from engine shaft to an additional shaft attached in the same axis with engage and disengage facility.
- A simple gear box incorporating worm and bevel gears was designed and attached to the rice transplanter to reduce rpm at the ratio of 35:1 and transmit at 90° directions.
- Spiral type fertilizer metering device was designed and attached in front of seedling holding tray to collect and dispense fertilizer at desired rate.
- Skid in between two rotary picker was attached with variable depth control mechanism to place the dispensed fertilizer in the furrow and covered properly,
- All components of the mixed fertilizer deep placement mechanism was fabricated and attached in the transplanter as per design.

Power transmission from engine to the mixed fertilizer applicator

Necessary modification of the rice transplanter was done to receive engine power for FDP technology. Engine power available at high rpm (more than 1800 rpm of the walking type rice transplanter) was conveyed to the applicator with the arrangement of a belt-pulley, worm gearing, shaft, bevel gear and universal joint mechanism with engage-disengage facility resulting 23 rpm of the main shaft of the applicator (Fig. 3). For whom, farmers can choose the transplanter either for both operation or only for seedling transplanting. Power transmission mechanism is shown in following flow chart.

Engine power of the selected transplanter transmitted to the hydraulic pump, driving wheels & rotary picker and water pump of the transplanter with the belt-pulley arrangement. To convey the engine power to the applicator, engine pulley and main gear pulley were modified by adding one additional grove to the main gear pulley. This is the first stages of power reduction from 1800 rpm to 810 rpm. From main gear pulley, power transmitted to the worm gear to reduce rpm at a ratio of 1:35. Bevel gear also used in the applicator shaft to change the direction of power at 90 degree intersecting shaft at the same velocity ratio. In the 2nd stage, power reduced from 810 to 23 rpm. From output shaft of the gear box, power transmitted to the main shaft of the applicator using universal joint shaft.

Worm and bevel gearing

Worm gears are widely used for transmitting power at high velocity ratio between non-intersecting shafts that are generally at right angles. In the developed rice transplanter cum mixed fertilizer applicator, straight face single start worm gear was used to reduce engine rpm at the velocity ratio of 20:1. Number of teeth of the worm wheel-20, circular pitch was assumed 10 mm during design and actual was found 10.21 mm. Worm and worm wheel was fabricated using high carbon and phosphorus bronze materials. Size of the gear box is 140 × 85 × 120 mm, material-cast iron and thickness-4 mm. Detail design of the worm gears is given in figure 4, 5, 6 and 7 and plate 2.

Bevel gear was also used in the gear box to convert the rotation at 90 degree to the intersecting shaft. The bevel gears, made of cast steel material (untreated), were used for transmitting power at a constant velocity ratio between shafts whose axes at a same angle. Bevel gears were used to transmit power to the intersecting shaft. In the developed rice transplanter cum mixed fertilizer applicator, bevel gear of equal teeth was used in the gear box.

Universal joint shaft. A universal joint is a mechanical device that allows one or more rotating shafts to be linked together, allowing the transmission of torque and/or rotary motion. It also allows for transmission of power between two points that are not in line with each other. In the developed rice transplanter, universal joint shaft was used to transmit power and rotation from incorporated gear output shaft to the applicator shaft.

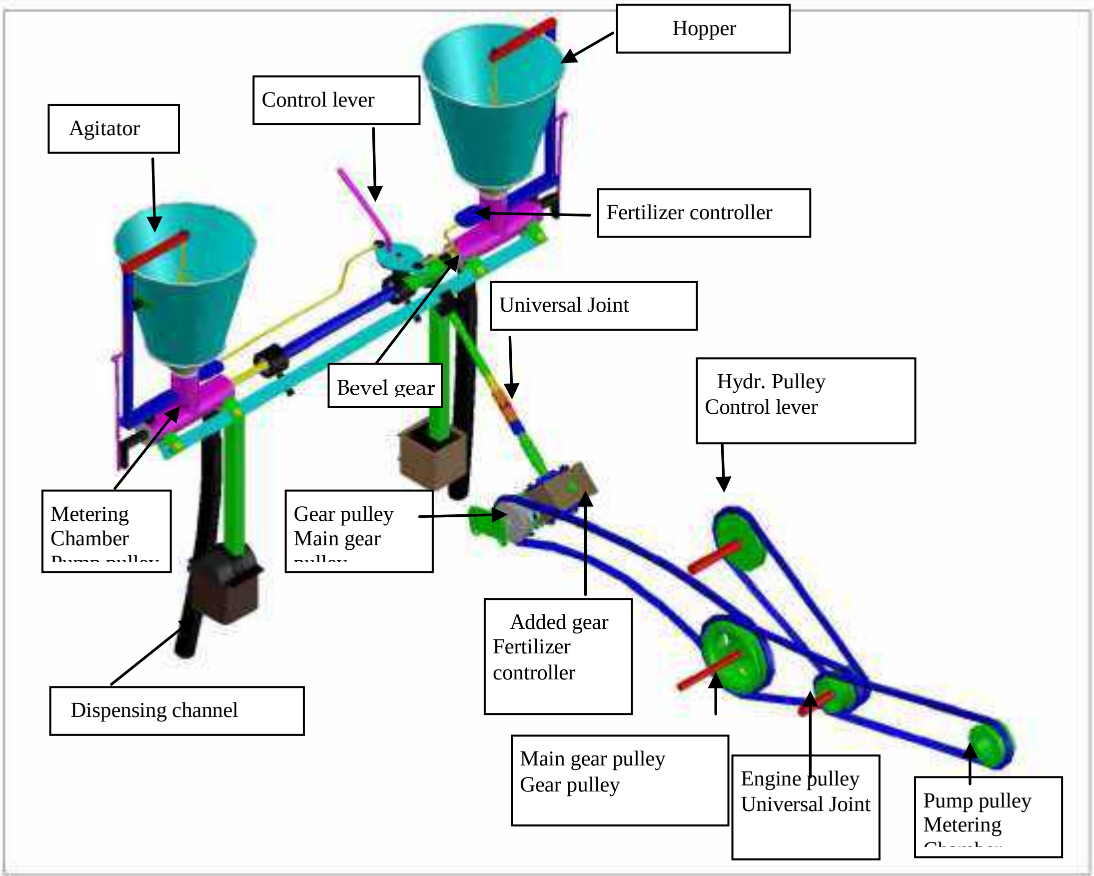


Fig. 3. Power transmission from engine to the mixed fertilizer applicator.

Power transmission flow chart

In walking type rice transplanter, power conveyed to the applicator from engine while it was conveyed in the riding type rice transplanter from rear wheel. Flow chart of power transmission is presented below:

Prime mover : 1800 rpm ⇩ RT Main gear shaft : 810 rpm ⇩ Gear output shaft : 23 rpm ⇩ Applicator main shaft : 23 rpm	Rear wheel: Synchronized with transplanting speed ⇩ Additional shaft: (1:1) ⇩ Applicator shaft: (1:1) ⇩ Metering shaft: (3:1)
Power transmission flow chart of WRT	Power transmission flow chart of RRT

Metering device. Spiral conveying type metering device was used in the developed rice transplanter. Mixed fertilizer dispensed to the inner chamber of the metering device due to continuous agitation of the agitator. Spiral conveyor of the metering device conveyed fertilizer mixture from inner chamber to the outlet pipe connected with the chamber. Fertilizer dispensing rate increased with the increase of opening in between fertilizer hopper and fertilizer metering chamber which can be control by a lever. Rate of fertilizer dispensing can be controlled by adjusting the lever based on season and variety.

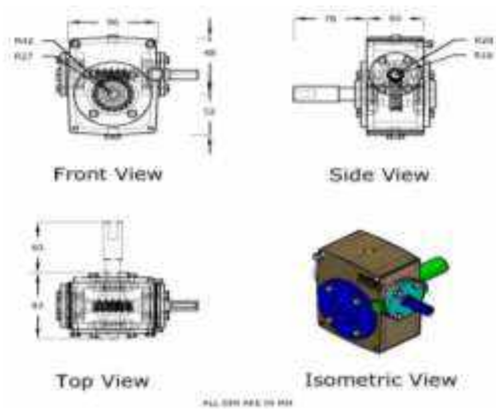


Fig. 4. Single start worm gear

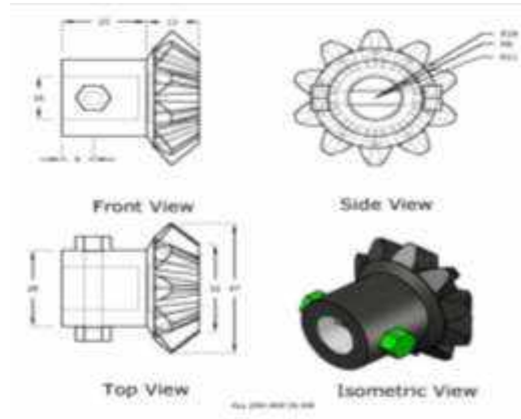


Fig. 5. Bevel gear

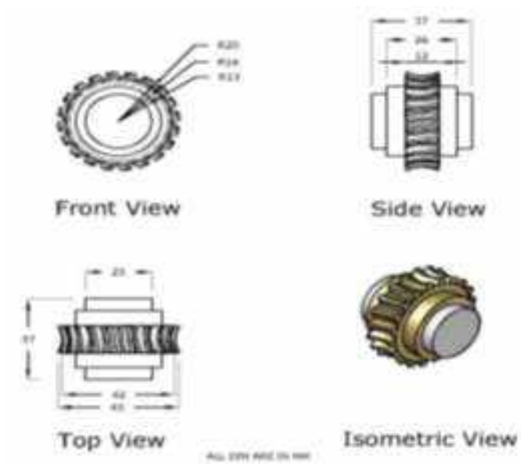


Fig. 6. Worm wheel

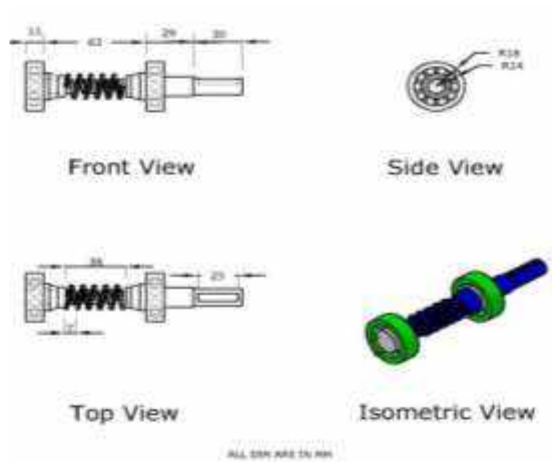


Fig. 7. Worm screw

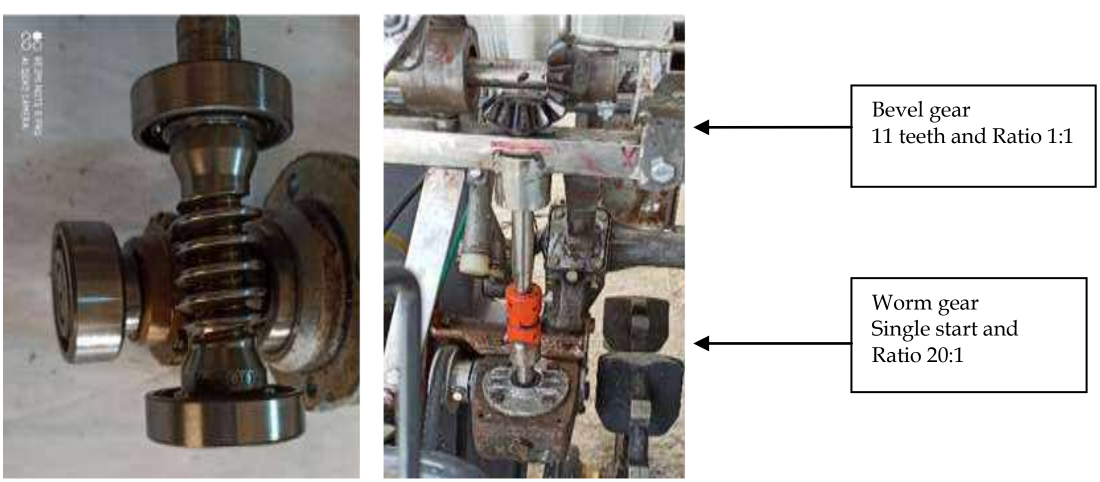


Plate 2. Gear box incorporating with warm gearing

Skid. Skid was designed considering space in between two rows of the transplanter and maximum depth of penetration of the transplanter skids during field operation. The bottoms of the applicator and transplanter skids were maintained same height horizontally. Depth of fertilizer placement and covering mechanism was taken in consideration to design the skids.

Operational procedure

The walking type rice transplanter was modified to incorporate mixed fertilizer deep placement mechanism. During transplanter operation, the following procedure needs to follow for successful placement of mixed fertilizer.

- Disengage the power of the applicator gear box before start engine and transplanting.
- Lubricant and grease need to be checked of the applicator gear and chain-sprocket before operation.
- Tension of the belts also needs to be checked before operation.
- Power of the applicator gear box engaged with the start of seedling transplanting.
- At the end of field, during turning, again disengage the power of the applicator gear box for avoiding un-necessary loss of fertilizer.
- Time to time re-filled the hopper by mixed fertilizer.
- Some amount of mixed fertilizer need to be carried like seedling mat for re-filing in the field as and when necessary.

Field evaluation of the BRRI rice transplanter cum mixed fertilizer applicator

A study was conducted to evaluate the field performance of the BRRI rice transplanter cum mixed fertilizer applicator in different locations during Boro and Aman season. In Aman 2019 season, the developed machine was evaluated in 07 different locations of the country while it was evaluated in 02 locations during Boro 2018-19 season. RCB design was followed in both the seasons with three replications. Treatments of the studies were mechanical transplanting along with mixed fertilizer deep placement simultaneously (T_1), mechanical transplanting and hand broadcasting of fertilizer (T_2) and traditional transplanting and hand broadcasting of fertilizer (T_3).

Locations

This study was conducted to evaluate the performance of BRRI developed rice transplanter cum mixed fertilizer applicator (RTFA) in the farmers' field at Kushtia and Habigonj during irrigated dry Boro season 2018-2019. It was also evaluated in different 07 locations (Sadar, Rangpur-BRRIdhan71; Sadar, Gazipur-BRRIdhan71; Mirpur, Kushtia-BRRIdhan87, Kumarkhali, Kushtia 1-BRRIdhan75; Kumarkhali, Kushtia 2-BRRIdhan87; Purbadhala, Netrakona-BRRIdhan71; Shaistaganj, Habiganj-BRRIdhan71) during Aman 2019 season.

Field capacity of the RTFA

Field capacity of the developed rice transplanter cum mixed fertilizer applicator was measured with and without fertilizer deep placement mechanism in 02 locations during Boro 2018-19 and in seven locations during Aman 2019 seasons (Table 1 and 2). Theoretical field capacity varied with forward speed of machine operation whereas actual field capacity varied with forward speed, turning time loss, seedling and fertilizer re-filling time etc. Average of locations and replications, actual field capacity of the rice transplanter was found 0.12 and 0.13 ha hr^{-1} with and without fertilizer deep placement mechanism in Boro season while it was 0.19 and 0.21 ha hr^{-1} in Aman 2019 season, respectively.

Table 1. Field performance of the RTFA in Boro 2018-19 Season

Treat.	Area decimal (Decimal)	Time of operation (min)	Forward speed (km h^{-1})	Actual field capacity (ha h^{-1})	Theoretical field capacity (ha h^{-1})	Efficiency (%)
			Mirpur, Kushtia			
T_1	33	73	1.5	0.11	0.19	57.9
T_2	40	67	1.62	0.12	0.19	63.2
T_3	32	-		0.006		
			Shaistaganj, Habiganj			
T_1	20	67	1.63	0.12	0.20	60.0
T_2	26	62	2.69	0.13	0.20	65.0
T_3	27	-		0.006		
		Average: T1	1.57	0.12	0.20	58.95
		T2	2.16	0.13	0.20	64.10

Note: Average value of three replications, width covered per pass of the applicator is 1.2 m. FDP-Fertilizer deep placement

However, field efficiency was obtained 58.95 and 64.10% with and without fertilizer deep placement mechanism in Boro season whereas it was 80.66 and 80.60 in Aman season, respectively. Actual and theoretical field capacity as well as field efficiency of the developed rice transplanter cum fertilizer applicator was found higher in Aman season due to improvement of the technology, good seedling and field quality. Field capacity and field efficiency was higher to some extent without fertilizer deep placement mechanism during transplanting due to extra fertilizer re-filling time and slow of operation.

Actual amount of fertilizer application

Before field operation of the machine, it was calibrated to apply desired amount of fertilizer based on recommended dose of mixture fertilizer. During field operation, actual dispending amount of fertilizer was calculated to determine percentage of deviation (Table 3). In Boro season, calibrated rate of fertilizer was 67.98 and 68.03 g/rotation of the rice transplanter driving wheels for Kushtia and Habiganj while actual rate was 67.39 and 63.56 g/rotation, respectively. Fertilizer dispensing rate was found less compared to calibrate rate in both locations during Boro season due to frequent clogging of the output channel of fertilizer. It was improved based on field problems in Boro season and again evaluated in Aman season. In Aman season, calibrated rate of fertilizer was 37.72 g/rotation while actual dispensing rate was 39.62, 40.51, 38.73, 39.11, 38.73, 40.81 and 39.54 g/rotation in Rangpur, Gazipur, Mirpur-Kushtia, Kumarkhali-Kushtua (1), Kumarkhali-Kushtia (2), Purbadhala-Netrakona and Habiganj, respectively. Vibration of the machine, turning losses of fertilizer and slippage of the driving wheels might be the causes of more dispensing rate of fertilizer compared to calibration.

Table 2. Field performance of the RTFA in Aman 2019 Season

Treat.	Area decimal (Decimal)	Time of operation (min)	Forward speed (km/h)	Actual field capacity (ha/h)	Theoretical field capacity (ha/h)	Efficiency (%)
			Sadar, Rangpur			
T_1	22	26	1.92	0.21	0.23	89.18
T_2	40	44	2.1	0.22	0.25	87.60
T_3	20	-		0.006		
			Sadar, Gazipur			
T_1	18	27	1.79	0.16	0.21	75.36
T_2	20	23	1.92	0.21	0.23	91.64
T_3	28	-		0.006		
			Mirpur, Kushtia			
T_1	22	32	1.7	0.17	0.20	81.83
T_2	80	98	1.85	0.20	0.22	89.29
T_3	20	-		0.006		
			Kumarkhali, Kushtia (1)			
T_1	20	24	2.1	0.20	0.25	80.30
T_2	40	44	2.6	0.22	0.31	70.75
T_3	22	-		0.006		
			Kumarkhali, Kushtia (2)			
T_1	22	26	2.2	0.21	0.26	77.83
T_2	30	32	2.4	0.23	0.29	79.04
T_3	20	-		0.006		
			Purbadhala, Netrakona			
T_1	28	36	2.1	0.19	0.25	74.94
T_2	40	51	2.2	0.19	0.26	72.14
T_3	20	-		0.006		
			Shaistaganj, Habiganj			
T_1	13	16	1.93	0.20	0.23	85.19
T_2	26	32	2.23	0.20	0.27	73.73
T_3	25	-		0.006		
		Average: T_1	1.96	0.19	0.23	80.66
		T_2	2.19	0.21	0.26	80.60

Note: Average value of three replications, width covered per pass of the applicator is 1.2 m. FDP-Fertilizer deep placement

Table 3. Percent of deviation from calibrated amount of fertilizer as affected by soil condition and location in Boro 2018-19 and Aman 2019 season

Treat.	*Area in Deci	Recommended amount of fertilizer (kg/ha)					Actual amount of dispensed (kg)	Dispensing rate (g/rotation)		% of deviation
		Urea (80%)	TSP	MOP	Gyp	Total		Calibrated	Actual	
Boro 2018-19 season										
Kushtia (BRRIdhan58)	33	29.9	13.4	22.1	14.9	80.3	79.6	67.98	67.39	+0.87
Habiganj (BRRIdhan58)	20	18.1	8.1	13.4	9.1	48.7	45.5	68.03	63.56	+6.57
Aman 2019 season										
Rangpur (BRRIdhan71)	22	11.9	5.5	7.4	5.0	29.7	31.2	37.72	39.62	-5.05
Gazipur (BRRIdhan71)	18	9.7	4.5	6.1	4.1	24.3	26.1	37.72	40.51	-7.41
Mirpur, Kushtia (BRRIdhan87)	22	11.9	5.5	7.4	5.0	29.7	30.5	37.72	38.73	-2.69
Kumarkhali Kushtia1 (BRRI dhan75)	20	10.8	5.0	6.7	4.5	27.0	28.0	37.72	39.11	-3.70
Kumarkhali Kushtia2 (BRRI dhan87)	22	11.9	5.5	7.4	5.0	29.7	30.5	37.72	38.73	-2.69
Netrakona (BRRIdhan71)	28	15.1	7.0	9.4	6.3	37.9	40.9	37.72	40.81	-7.92
Habiganj (BRRIdhan71)	13	7.0	3.3	4.4	2.9	17.6	18.4	37.72	39.54	-4.55

Note: Average value of three replications, width of covered per pass of the machine is 1.2 m. *Area of mechanical transplanting along with fertilizer deep placement (T_1) is presented only.

Transplanting cost under different methods of seedling transplanting

Transplanting cost of the transplanter depends on machine life, annual operating use, field capacity, operator cost and fuel-oil and maintenance cost. Transplanting cost of the walking type rice transplanter with and without fertilizer deep placement mechanism as well as manual transplanting cost is presented in the Table 4.

Table 4. Transplanting cost under different methods

	Transplanting cost (Tk h^{-1})			Time of transplanting (h ha^{-1})			Transplanting cost (Tk ha^{-1})		
Location	T1	T2	T3	T1	T2	T3	T1	T2	T3
Boro Season 2018-19									
Kushtia	339.8	335.2	50.0	9.1	8.3	166.7	3089.1	2793.0	8333.3
Habiganj	349.1	340.7	50.0	8.3	7.7	166.7	2908.9	2621.0	8333.3
Aman Season 2019									
Rangpur	333.3	270.3	50.0	4.8	4.5	166.7	1587.2	1228.5	8333.3
Gazipur	342.6	335.2	50.0	6.3	4.8	166.7	2141.1	1596.0	8333.3
Mirpur	333.3	324.0	50.0	5.9	5.0	166.7	1960.7	1620.2	8333.3
Kushtia-1	330.5	325.9	50.0	5.0	4.5	166.7	1652.7	1481.3	8333.3
Kushtia-2	325.9	321.3	50.0	4.8	4.3	166.7	1551.9	1396.8	8333.3
Netrakona	330.5	325.9	50.0	5.3	5.3	166.7	1739.6	1715.2	8333.3
Habiganj	339.8	337.0	50.0	5.0	5.0	166.7	1699.0	1685.1	8333.3

Note: 1. Average annual use of rice transplanter (assumed) 70 days considering Aus (15 days), Aman (20 days) and Boro (35 days). Considering 8 working hours per day, average annual use in h/yr is 560.
2. Labor cost as operator,Tk h^{-1}=75 and helper cost, Tk h^{-1}=50. Total cost, Tk h^{-1}=125, and Agricultural labour cost, Tk h^{-1}=40,
3. Fuel cost, Tk lit^{-1}=90.00 (Octan) and
4. Manual transplanting capacity, 1.5 decimal/h including seedling uprooting.

Crop performance

Plant height and number of tiller were measured at every 15 days after transplanting in both Boro and Aman seasons to evaluate the crop performance under different methods of transplanting and fertilizer application which is presented in the figures 8, 9, 10 and 11. In all cases, plant height and number of tiller were found significantly higher for the treatment of mechanical transplanting along with fertilizer deep placement.

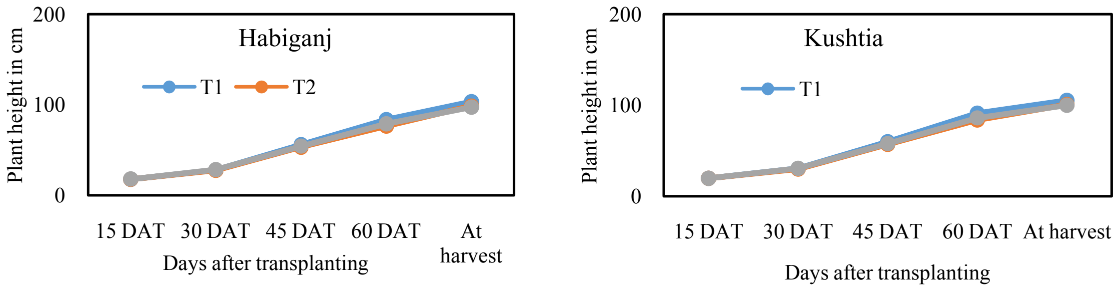
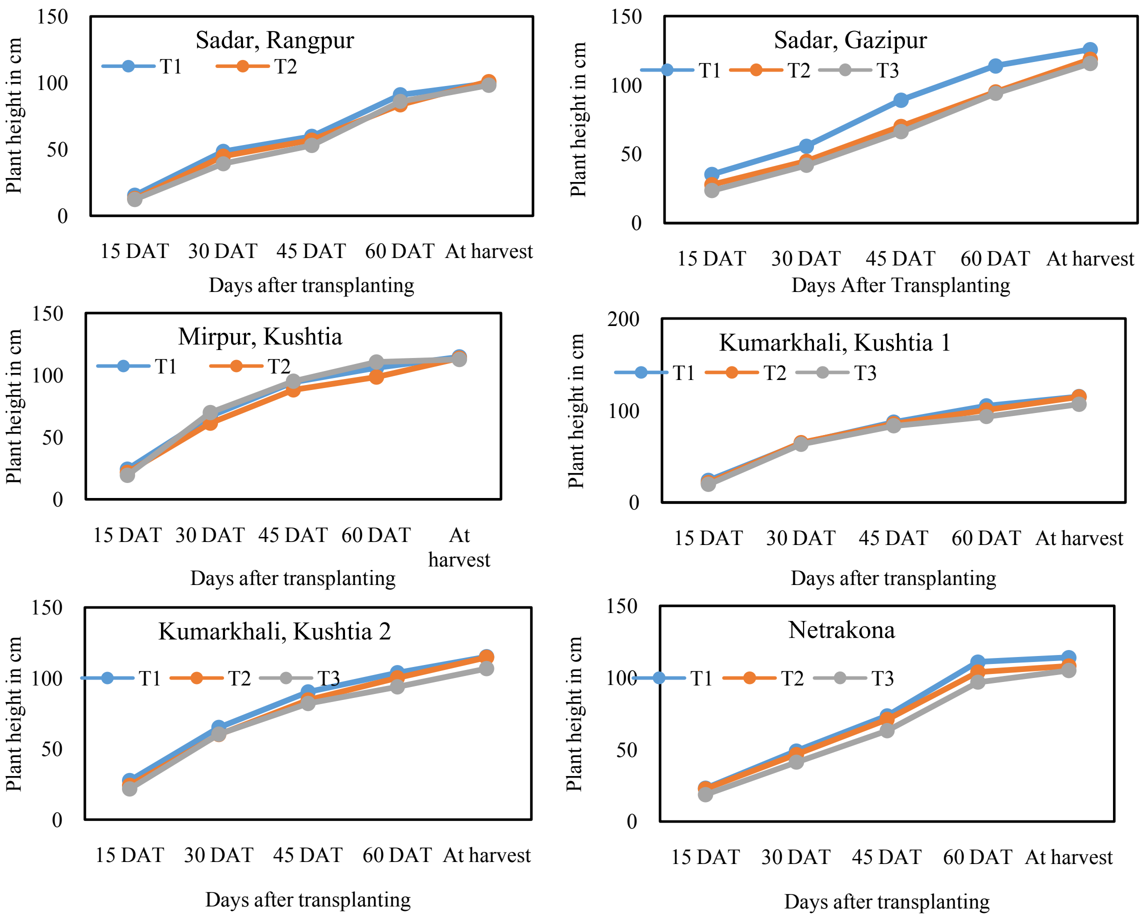


Fig. 8. Plant height at different date after transplanting in Boro season 2018-19 season.



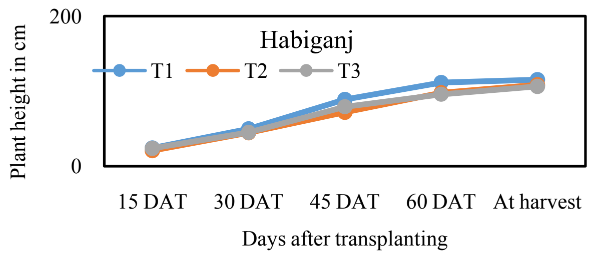


Fig. 9. Plant height at different date after transplanting in Aman season 2019.

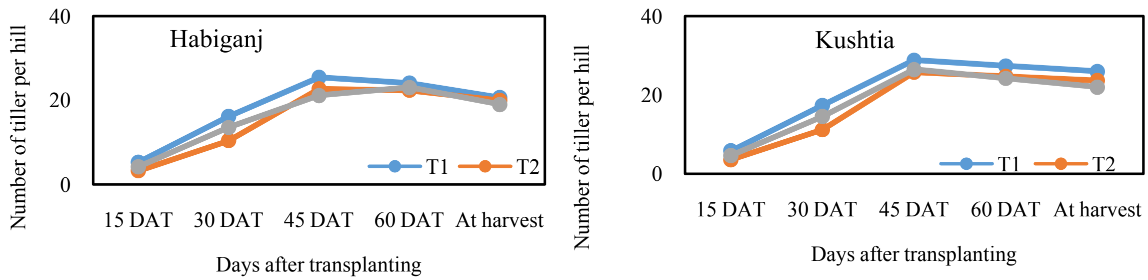
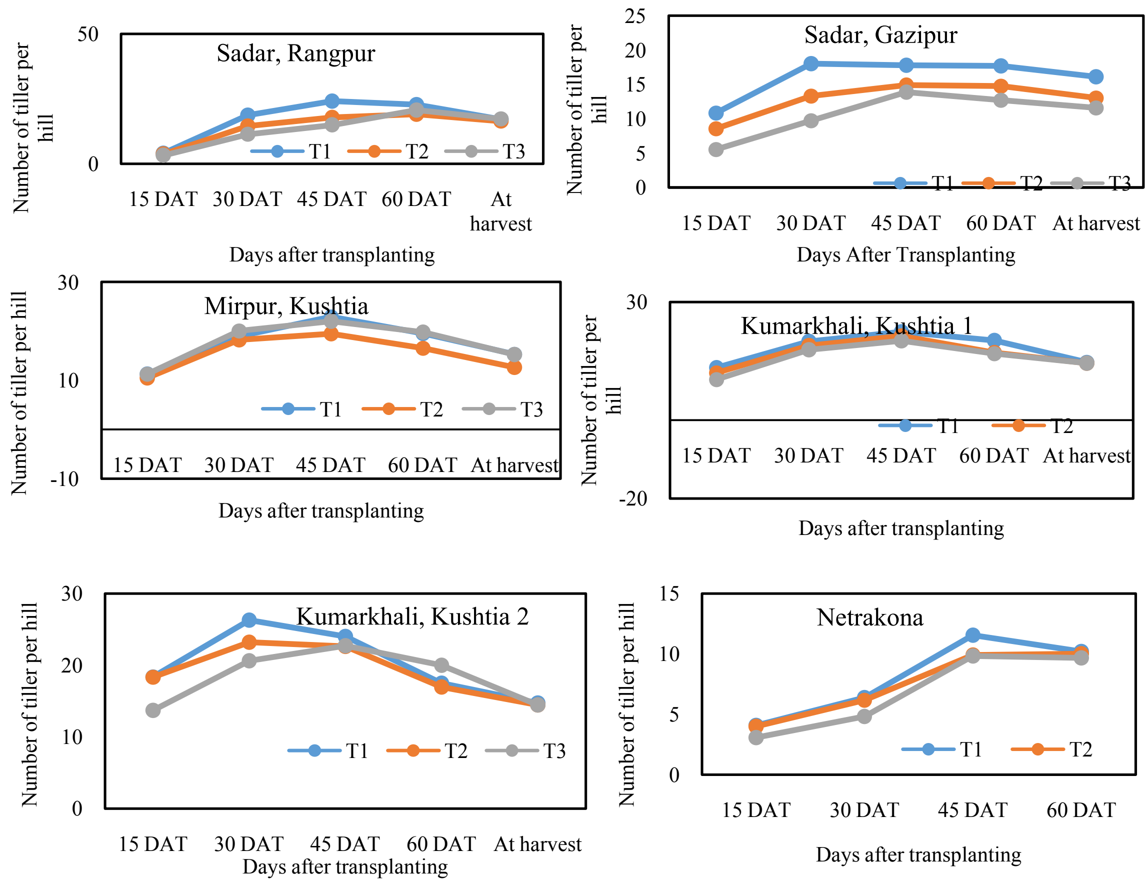


Fig. 10. Number of tiller at different date after transplanting in Boro season 2018-19.



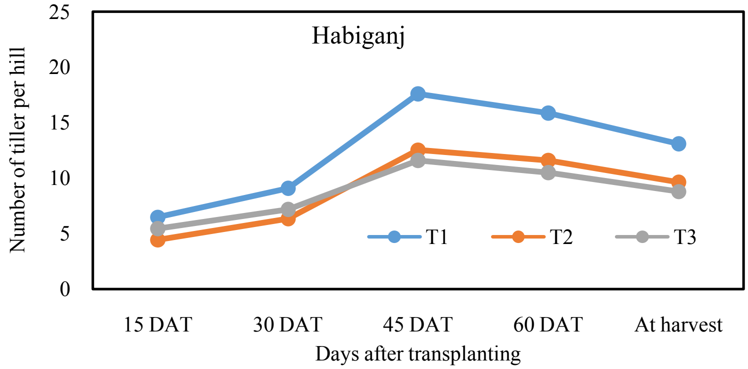


Fig. 11. Number of tiller at different date after transplanting in Aman season 2019.

Yield performance

Paddy and straw yield in Boro 2018-19 season

Transplanting and fertilizer application methods influenced significantly on grain and straw yields in both locations during Boro season (Table 5). In both locations, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments while lower grain yield was found for manual transplanting along with fertilizer hand broadcasting method.

Paddy yield in Aman 2019 season

Transplanting and fertilizer application methods also influenced significantly on grain yields in all seven locations during Aman season (Table 6). In all locations, mechanical transplanting along with fertilizer deep placement produced significantly higher yield compared to the other two treatments while lower grain yield was found for manual transplanting along with fertilizer hand broadcasting method except Habiganj.

Table 5. Paddy yield performance as affected under different transplanting and mode of fertilizer application (Boro 2018-19).

Treat	Paddy yield @ 14% m.c (t ha^{-1})		Straw yield (t ha^{-1})	
	Kushtia	Habiganj	Kushtia	Habiganj
T_1	7.96 a	6.15 a	9.90 a	8.17 a
T_2	6.81 b	5.52 b	9.27 b	6.94 b
T_3	6.68 b	5.05 c	8.79 c	6.40 c
LoS	*	**	**	**
CV (%)	1.75	1.57	1.70	3.30
$LSD_{0.05}$	0.28	0.20	0.36	0.54

Paddy yield in Aman 2019 season

Table 6. Paddy yield performance as affected under different transplanting and mode of fertilizer application (Aman 2019).

Treat	Yield @ 14% m.c (t ha^{-1})						
	Sadar, Rangpur	Sadar, Gazipur	Mirpur, Kushtia	Kumarkhali, Kushtia 1	Kumarkhali, Kushtia 2	Purbadhala, Netrakona	Shaistaganj, Habiganj
T_1	4.89 a	4.83 a	5.77 a	5.94 a	6.12 a	4.52 a	4.77
T_2	4.51 b	3.66 b	4.91 b	4.89 b	5.64 b	3.92 b	3.94
T_3	4.14 c	3.81 b	4.44 c	4.84 b	5.05 c	3.67 b	4.02
LoS	**	**	**	*	**	**	ns
CV (%)	3.39	4.23	1.46	5.14	3.38	3.03	8.34
$LSD_{0.05}$	0.35	0.39	0.17	0.61	0.43	0.28	0.80

Straw yield

Straw yield varied significantly with the transplanting and fertilizer application methods in all seven locations during Aman season (Table 7). In all locations, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments while lower grain yield was found for manual transplanting along with fertilizer hand broadcasting method except Habiganj and MirpurKushtia.

Economic analysis

Cost-analysis of rice production is shown in Table 8 as affected under different rice seedling transplanting and fertilizer application methods during Boro/2018-19 and Aman/2019 season. During Boro/2018-19 season, T_1 gave the highest BCR in both Kushtia (1.72) and Habiganj (1.32) whereas T_2followed by T_3 gave lower BCR in both the locations (Table 8). Averaged for locations, BCR of T_1 (1.52) was higher in Boro season compared to T_2 (1.31) and T_3 (1.20). Variation of BCR was observed due to yield effect on gross margin and to some extent from input costs (e.g., labor, fuel, time, etc.). In Aman/2019 season, T_1gave the highest BCR in all locations compared to T_2 and T_3 whereas lower BCR was observed in T_3. Averaged of 7 locations, BCR of T_1, T_2 and T_3 were found 1.42, 1.24 and 1.10, respectively. Overall BCR was higher in Boro season due to higher yield. Benefit-cost ratio calculation is presented in Appendix II and III.

Table 7. Straw yield performance as affected under different transplanting and mode of fertilizer application (Aman 2019).

Treat	Straw yield @ 14% m.c (t ha^{-1})						
	Sadar, Rangpur	Sadar, Gazipur	Mirpur, Kushtia	Kumarkhali, Kushtia 1	Kumarkhali, Kushtia 2	Purbadhala, Netrakona	Shaistaganj, Habiganj
T_1	5.20 a	4.99 a	7.79	4.71 a	5.04 a	4.45 a	5.45
T_2	4.44 b	4.35 ab	7.61	4.67 a	4.67 b	3.88 b	4.16
T_3	4.05 c	3.85 b	6.81	4.21 b	3.67 c	3.04 c	4.11
LoS	**	*	ns	*	**	**	ns
CV (%)	2.28	6.92	5.55	3.67	3.29	5.96	14.25
$LSD_{0.05}$	0.2361	0.69	-	0.38	0.33	0.51	-

Crop and yield performance, yield contributing parameters, harvest Index and economic performance calculation is under process. All data will be processed, analyzed and interpreted after harvesting of the tested crops.

Table 8. Cost analysis of rice production as affected under different transplanting and fertilizer application methods during Boro 2018-19 and Amanm 2019 season.

Locations	Input cost, Tk ha^{-1}			Gross return, Tk ha^{-1}			Gross margin, Tk ha^{-1}			BCR			Avg. BCR
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	
Boro 2018-19													
Mirpur, Kushtia	99978	101658	105113	171575	147788	144588	71597	46130	39475	1.72	1.45	1.38	1.52
Habiganj	100576	101740	106163	133213	119075	109000	32636	17335	2837	1.32	1.17	1.03	1.17
Average	100277	101699	105638	152394	133431	126794	52117	31732	21156	1.52	1.31	1.20	1.34
Aman 2019													
Rangpur	77798	79026	84307	97800	96700	88350	20002	17674	4043	1.26	1.22	1.05	1.18
Gazipur	78379	78887	84281	101663	79438	81638	23283	551	-2643	1.30	1.01	0.97	1.09
Mirpur, Kushtia	76772	77862	83756	120213	107938	98313	30076	14557	51283	1.57	1.39	1.17	1.38
Kumar. Kushtia-1	76029	76929	82181	127313	103688	102638	51283	26759	20457	1.67	1.35	1.25	1.42
Kumar. Kushtia-2	77026	77470	82968	127663	119100	106838	50637	41630	23869	1.66	1.54	1.29	1.49
Purba. Netrakona	76120	76754	81341	94988	83963	78250	18867	7208	-3091	1.25	1.09	0.96	1.10
Habiganj	78440	79505	84800	99200	85613	85600	20760	6107	800	1.26	1.08	1.01	1.12
Average	77224	78062	83376	109834	96634	91661	30701	16355	13531	1.42	1.24	1.10	1.25

Mechanical rice transplanter is a promising technology considering the present labor crisis in Bangladesh. Mixed fertilizer deep placement technology successfully incorporated with the walking type rice transplanter with proper design and found suitable in operation under laboratory, research field and farmers' field condition. Fertilizer deep placement technology also incorporated in the riding type rice transplanter which is under evaluation. Mechanical transplanting using walking type rice transplanter along with mixed fertilizer deep placement gave significantly higher yield as well as higher benefit compare to the traditional practices.

Design and development of walking type power operated rice transplanter

A study was conducted to develop a walk behind type power operated rice transplanter suitable for Bangladesh condition in the FMPHT Divisional research workshop. The following methodology was applied to design and develop the technology.

- Different components/parts of the walking type transplanter studied in laboratory condition. These parts were used as reference parts to develop the rice transplanter.
- Power transmission system was studied for designing different components.
- Engineering drawing was done with the help of three dimensional AutoCAD tools to develop the mechanical rice transplanter.
- On the basis of design, fabrication works was conducted in BRRI research workshop
- The fabricated transplanter will be tested in the field during Aman season, 2020 and data to be collected.
- Main frame with engine, gear box, propeller shaft and picker, handle with operating lever, Picker with chain cover, Seedling rack, Seedling rack moveable channel, Wheel with chain box, Ordinary stand , Seedling tray slider, Additional rod of seedling rack , Floating skid, Lever with stand, Spare seedling tray, Marker with furrow closer, Engine cover, seedling tray or mat were fabricated and assembled in the research workshop..

Design consideration

- Line to line spacing should be 30 cm
- Plant to plant spacing should be in between 15 to 20 cm
- Rotary picker should be operated smoothly receiving power from main gear
- There should be simple mechanism to control depth of seedling placing and plant to plant distance
- Uniformity of spacing should be maintained by adding simple mechanism of power distribution in between driving wheels and rotary pickers
- Locally available materials should be used to minimize the fabrication cost.

Power transmission analysis

Power transmission analysis (Fig. 12) is the crucial part of the design. It was analyzed for design and fabrication of the gears (Spur, worm, bevel, spiral bevel), pulley, chain-sprocket, spline shaft etc.

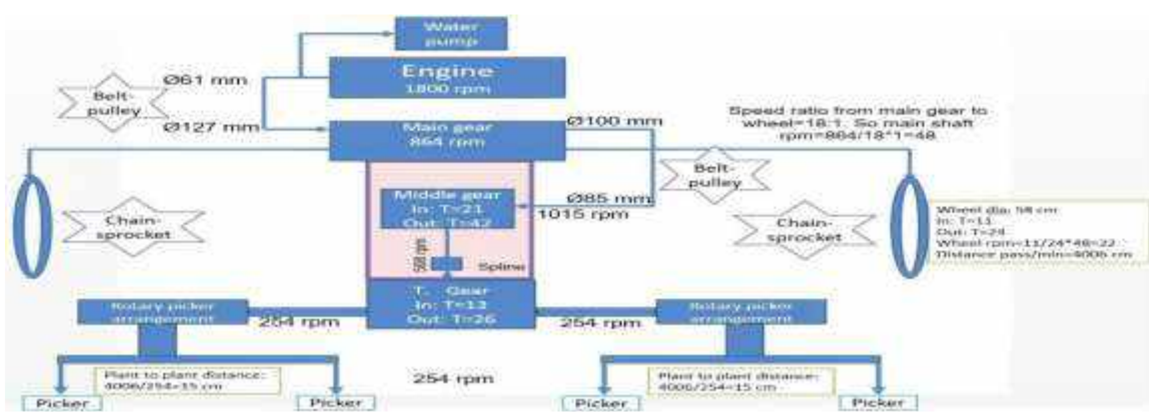


Fig. 12. Power transmission system of the developed rice transplanter.

Jigs and fix for fabrication

The jig is used for guiding the cutting tool, and for doing so, jigs have components, which comes in contact with the cutting tool. On the other hand, a fixture is used to maintain the accuracy components as per design (Plate 3).

Analysis, material selection, drawing, jigs and fixtures preparation, fabrication, no-load test, soil bin test, lab test, etc has been completed. Complete report will be submitted in the annual research review workshop.

Design and development of a head feed power thresher

A study was undertaken to design and development of a head feed thresher using locally available materials in Nayem Engineering workshop, Modan, Netrokona under private public partnership (PPP). The use of thresher increased day by day and most of the farmers wanted to keep the straw intact for their domestic use. BRRI developed Open Drum Thresher (ODT) and Close Drum Thresher (CDT) thresher worked effectively in farmers' field. However, the straw remained intact in ODT but there is no cleaning facility in it. So farmers are needed more time in cleaning the threshed paddy. On the other hand, CDT has cleaning facility but straw are crashed away and could not use in their desire purpose. Therefore, one attempt is taken to overcome the existing problem where cleaning facility will be available and straw remain in intact condition.

The head feed thresher was designed and fabricated at Nayem Engineering workshop, Modan, Netrokona. The thresher has the provision of threshing, cleaning and straw remain intact after threshing (Table 9). It has also whole feed threshing facility (Plate 4).Materials used to fabricate a prototype of head feed thresher.

- MS sheet, flat bar, angle bar, shaft bar, GI pipe, Nuts and Bolts, Gear, belts, pulley
- Wire-loop threshing drum
- Feeding mechanism
- Belt-pulley/gear arrangement to transmit engine power

Plate 3. Jigs and fix of the main frame of the transplanter, side cover and tray holder

Plate 4. Head feed thresher.

Design consideration

For design of the head feed thresher considered the mechanism of threshing part of the head feeds combine harvester and Korean thresher. The designed thresher has two function (a) head feed mechanism for remaining straw intact and (b) whole feed mechanism, where straw may be damage. Also the thresher has the provision of cleaning, less dust, easy handling and movability.

Design components of the thresher

The thresher was designed as per following considerations:

- Both function of head and whole feed mechanism
- Easily threshed small bundled paddy
- Two man 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 minimize the fabrication cost
- Capacity should be accepted by the farmers
- Trouble free operation

In first stage, engine power shifted in idle pulley. In second stage, the threshing drum and cleaning blower gets power from idle pulley using different sizes pulley through B-type V belt. Schematic diagram of power transmission system of thresher was shown in Fig 13.

Performance evaluation of battery operated reaper

A battery operated small size reaper was developed in Zomzom workshop, Pabna. The machine consists of main body, power transmission system and cutter bar. A motor (1 hp, 48V) was used as power transmission system. A total of 4 batteries were used (96W, 48V) as power supplier and each battery was 24 W and 12 volt. A charger was used to charge the battery by using electricity. The reaper can be operated 6 hours continuously by the fully charged battery. A controller was used to control the forward and backward speed and goes to the neutral position. On the other hand, gearbox is needed for the forward and backward speed of the engine which increased the total weight of the machine. Flat bar, angle bar, SS rod, chain and sprocket were the common materials to manufacture the machine. Plate5 shows the fabricated battery operated reaper.The machine was tested at the farmers' field at Pabna (Plate 5). The wide of the cutter bar was 45 cm. The average forward speed of the machine was 2.8 km/h and capacity was 0.09 ha h^{-1}.

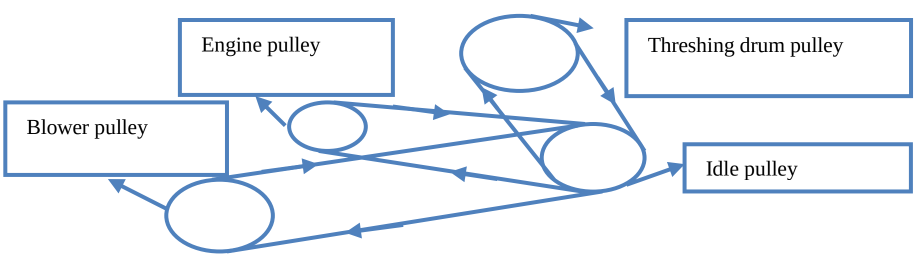


Fig. 13. Schematic diagram of power transmission system.

Table 9. The general features.

Item	Features	Item
Engine type	8 hp Diesel engine	Threshing drum length
Operator requirement (labour)	2 nos.	Threshing drum dia.
Operation	Head feed and whole feed	Feeding chain length
Cleaning facility	Blower	Feeding chain width
Grain collector	Auger	Feeding height
Power transmission system	Belt pulley	Machine height
Threshing teeth	loop type	Machine width

Plate 5. Field test of battery operated reaper.

Determination of tilling efficiency of power tiller at selected areas of Bangladesh

Experiments were conducted in Aman 2019 at BRRI R/S, Rajshahi and Boro 2020 at BRRI R/S, Rajshahi and Rangpur to determine paddy yield as influenced by different tillage depths. There were five different tillage depths such as: 2-3, 3-4, 4-5, 6-7 and 7-8 inches. Land preparation and the tillage depths were maintained by a power tiller. All sorts of weeds were removed from the field before transplanting of seedling. Seedlings were transplanted at 20 cm apart from rows maintaining 20 cm hill to hill distance and three seedlings per hill. Necessary gap filling was done eight days after transplanting. Applying irrigation, weeding and other intercultural operations were done as and when necessary. Paddy was harvested at full maturity. Harvesting, threshing, cleaning and drying of grain were done plot-wise separately. The weights of paddy were also recorded plot-wise. Tiller and panicle number were increased over tillage depth as shown in Tables 10 and 11. Grain yield of BRRIdhan34 in Aman 2019 and BRRIdhan28 in Boro 2020 seasons were varied from different tillage depths in Rajshahi and BRRIdhan58 in Rangpur. Plant height of cultivated paddywas increased with tillage depth at Aman and Boro seasons as shown in Table 12. These were found highest in 6-7 inches depth of tillage and nearly same as 7-8 inches depth of tillage.

Table 10. Tiller and panicle number of cultivated paddy at Aman season 2019 and Boro 2020 in Rajshahi region.

Tillage depth (Inch)	Aman 2018 (BRRIdhan34)		Boro 2020 (BRRIdhan 28)	
	Tiller no./12 hill	Panicle no./12 hill	Tiller no./12 hill	Panicle no./12 hill
2-3	105	98	155	150
3-4	111	107	180	172
4-5	118	117	185	178
6-7	123	120	212	209
7-8	123	121	215	209

Table 11. Tiller and panicle number of cultivated paddy at Boro 2020 in Rangpur region.

Tillage depth (Inch)	Boro 2019 (BRRI dhan63)	
	Tiller no. /12 hill	Panicle no. /12 hill
2-3	148	135
3-4	161	150
4-5	164	157
6-7	197	179
7-8	200	189

Table 12. Plant height at Aman season 2019 and Boro 2020.

Tillage depth (Inch)	Aman 2019 (Rajshahi)	Boro 2020 (Rajshahi)	Boro 2020 (Rangpur)
	Average plant height (cm)	Average plant height (cm)	Average plant height (cm)
2-3	100.00	87.20	93
3-4	107.50	89.00	93.5
4-5	113.50	90.60	94
6-7	117.00	93.30	94.5
7-8	114.00	92.80	94.5

The highest grain yield was found 2.50 t ha^{-1} and 5.20 t ha^{-1} in the tillage depth of 6-7 inches and lowest yield was found 2.02 t ha^{-1} and 4.00 t ha^{-1} in the tillage depth of 2-3 inches in Aman 2019 and Boro 2020 respectively at RS Rajshahi (Table 13). At Rangpur the highest grain yield was found 8.05 t ha^{-1} in the tillage depth 7-8 inches and lowest yield was found 7.33 t ha^{-1} in the tillage depth of 2-3 but the yield was more or less same at 6-7 inches and 7-8 inches tillage depth (Table 14).

Table 13. Yield of paddy with different tillage depths in Rajshahi.

Paddy	Tilling depth (inch)	Paddy yield (t ha^{-1})
	BRRI dhan34	
Aman 2019	2-3	2.02
	3-4	2.08
	4-5	2.30
	6-7	2.50
	7-8	2.50
	BRRI dhan28	
Boro 2020	2-3	4.00
	3-4	4.35
	4-5	4.73
	6-7	5.20
	7-8	5.18

Table 14. Yield of paddy with different tillage depths in Rangpur.

Paddy	Tilling depth (inch)	Paddy yield (t ha^{-1})
	BRRI dhan58	
Boro 2020	2-3	7.33
	3-4	7.67
	5-6	7.80
	6-7	7.99
	7-8	8.05

Deep tillage improved the soil physical environment. It made the soil softer, which was indicated by reduced bulk density, penetration resistance and encouraged root growth and increased the moisture retention capacity of the soil. This might have favored the roots to proliferate down into the deeper layers of the soil profile to extract more nutrients and moisture that has led to higher growth and yield of the crops. Higher tillage depth favorably influenced the soil-water-plant ecosystem, thereby improved crop yields and quality. Higher tillage depth also reduced weed infestation.

Survey on status and constraint of farm machinery used in farmer's field at selected areas

A survey was conducted in Botiakhali and Hazratala in SreepurUpazila of Magura district based on machinery used in the farmers' field. Different kinds of farm machinery had been used in these villages and these machinery were power tiller, shallow tube well, sprayer, pedal thresher and open drum thresher. Some farmers were the owner of these machinery and some others used these machinery by custom hire service. Table 15 shows that power tiller, shallow tube well, sprayer, pedal thresher and open drum thresher were mostly popular agricultural machinery used in these areas. All the farmers used sickle for harvesting paddy, wheat and other crops. Power tiller is very popular for cultivation of land in these areas. Irrigation and threshing are also fully mechanized in these villages. All the farmers of theses village used power tiller, shallow tube well and pedal or open drum thresher. Land was irrigated by custom-hire service or the farmers have to pay 1/5th of the total yield/production in Aman season and 1/4th of the total production in Boro season. Custom-hire service or share of total production and fuel consumption of power tiller, shallow tube well and thresher in these areas are shown in Table 15.

Potentiality of engineering workshop for enhancing farm mechanization in selected areas of Bangladesh

Different kinds of farm machinery are used from land preparation to threshing/winnowing crops in the farmers' field. Most of the machinery were imported and costly which were used in our agricultural sector but now-a-days, lot of engineering workshops have been developed at different places in our country for manufacturing those agricultural machinery using the locally available materials. So, the farmers are getting these machineryin their locality with low cost. It is necessary to investigate the capacity, limitations and prospects of the engineering workshops at farm level, and quality, production and use level of machinery at different farm operations.

Potentiality of engineering workshopswas surveyed at Rangpur in Bangladesh. There are twenty five engineering workshops in Rangpur town. Among them six workshops are selling farm machinery such as power thresher and pedal thresher. They purchased these from farm machinery manufacturing workshops from Dinajpur and Netrokona. In a year, they can sell near about 140 pedal and 60 power threshers. They

Table 15. Rent and fuel consumption of different machineries.

Variable cost			
	Power tiller		
Rent of tiller (Taka/bigha)	Fuel requirement/bigha (Liter)	Time requirement/ bigha (hr)	Fuel consumption (Liter /hr)
660.00	5-6	2.00-2.50	2.50-3.00
	Shallow tube well		
Rent of shallow (Taka/hr)	Rent in Aman season (share of total production)	Rent in Boro season (share of total production)	Fuel consumption (Liter /hr)
100.00	1/5	1/4	0.50
	Pedal thresher		
Rent of thresher (Taka/day)	--	--	Fuel Consumption (lit/hr)
100.00	--	--	0.50
	Close drum thresher		
	1/8	1/8	1.00

usually repair farm machinery, motor, pump etc. Door, window, household furniture's are also produced in these workshops. The facilities of the workshops are foundry, lathe machine, shaper machine, drill machine, milling machine, grinding machine, welding machine, metal cutting and power press. They have technical knowledge how to manufacture these machinery. Lack of capital, seasonality of demand and scarcity of skilled labour are the key constraints of farm machinery manufacturing, they mentioned. Spare parts for servicing of threshers are locally available. Sometimes they produced unavailable spare parts in their workshops. They have not got modern farm machinery such as reaper, combine harvester and transplanter yet to repair. Sale of Pedal thresher is decreasing while sale of power thresher is increasing due to its better performance.

Local workshops can play an important role to reach the agriculture machinery at farm level if they use the locally available material to manufacture the machinery. As a result, the manufacturing cost of the machinery will be low. Then the farmers can buy the machinery from the manufacturers at a cheaper rate. Lack of fund is the main problem to the manufacturer to produce machinery. They need subsidy and proper support from the government, which will help them to produce the machinery by improving their workshop.

Repair and maintenance works of transports/vehicles and different farm machinery

Different kinds of transport/vehicles and farm machinery are at BRRI. WMM Division of BRRI does repair and maintenance works of different kinds of transport/vehicles and farm machinery. There were 47 vehicles (4-wheeler), 110 motor cycles, 4 tractors with accessories (one scrapper, three harrows, five rotaries, three discs and three scissors), 21 power tillers, 13 hydro-tillers, one reaper, 4 BRRI field mower, 22 pumps, 13 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
- 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 was totally done outside BRRI. A total of 45 vehicles (4-wheeler) in 1124 times, 110 motor cycles and other farm machineries in 22 times were repaired and changed of spare parts under moderate/minor repair and maintenance work.

Major repair and maintenance work

There are 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 RupantoritoPrakritic 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. The major repair and maintenance cost and times of work of individual vehicles (4-wheeler), motor cycles, tractor/ power tiller/hydro-tiller from July 2019 to June 2020 is given in Table 10. A total of 45 vehicles (4-wheeler) in 1124 times, tractor in 72 times, power tiller in 139 times, hydro tiller in 33 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 Tk64,52,379.00from July 2019 to June 2020. Major repair and maintenance cost was Tk 49,61,676.00 and moderate/minor repair and maintenance cost was Tk 14,90,703.00. The moderate/minor repair and maintenance work was done only by using the revolving fund.On the other hand, the major repair and maintenance work was done by direct cash purchase, direct contracting through work order, RFQ (Request for quotation) and OTM (Open tender method).

MILLING AND PROCESSING TECHNOLOGY

Study the effect of polishing on rice grains quality

The milling research was conducted in semi-auto rice mill at Farm Machinery and Postharvest Technology (FMPHT) division in BRRI head quarter, Gazipur. Three most popular rice varieties such as BRRI dhan28, BRRI dhan42 and BRRI dhan74 (Zn enriched bio-fortification) were used to conduct the study. There were used both parboiled and unparboiled type condition paddy. The experiment was carried out in three factor Randomized Complete Block (RCB) design with three replications. The treatments sequences for milling were T_1 = 1 pass (Near about 7.5), T_2 = 2 pass (Near about 10), T_3 = 3 pass (Near about 12), T_4 = 4 pass (Near about 13.5) and T_5 = 5 pass (Near about 15).

Degree of milling (DoM)

Degree of Milling (DoM) is measured suing the following equation (Mohapatra and Bal, 2007).

$$\text{DoM}=\left(1-\frac{\text{Wt. of milled rice}}{\text{Wt. of brown rice}}\right)\times 100$$

The unpolished rice was milled to produce white (polished) rice by friction type polisher machine. The polishing kinetics of three different varieties of rice is presented in figure 14. As the number of pass increased the degree of milling increased. It observed that the initial slope of the curve was higher which remained almost near about constant afterwards. During the initial pass of polishing, higher bran removal indicated that the germ was also removed within 3 pass of milling and the degree of milling almost stabilized during 5 pass of milling for each variety in both parboiled and unparboiled rice.

Effect on head rice yield

Head rice yield(HRY) is one of the most important criteria for measuring milled rice quality. HRY is measuredin percentage by using the following equation (Roy*et al*., 2008).

$$HRY=\left(\frac{Wt.\ of\ milled\ \ head\ rice}{Wt.\ of\ rough\ rice\ or\ paddy}\right)*100$$

Figure 15 indicates that there had negative relationship between DoM and head rice yield both parboiled and unparboiled condition. The head rice percentage was maximum in brown rice and DoM increased the percentage of head rice gradually decreased in both parboiled and unparboiled condition.

Effect on whiteness of rice grain

Color of the rice kernels varies according to variety, conditions of environment and pre and post harvesting conditions. The whiteness was determined by Kett Instant Whiteness Tester (Model: C600). These meters measure the kernel whiteness in range, from 0-84, generally termed as Whiteness Index. The yellowness and the redness levels decreased from outer surface to middle endosperm of brown rice at DoM (0-15%). The whiteness value of each variety was the lowest in the brown rice stage, followed by different degree of milling (1 pass<2 pass< 3 pass< 4 pass < 5 pass) in both parboiled and unparboiled condition. Fig. 16 shows that the DoM and whiteness are positively correlated. Therefore, at near about 15% of degree of milling the whiteness values of BRRI dhan28, BRRI dhan42 and BRRI dhan74 were 30.53, 37.9 and 40.23 in parboiled rice and 54.67, 59.1 and 57.93 in unparboiled rice, respectively. However, the effect of cultivars and over all degree of milling on whiteness value was found to be highly significant.

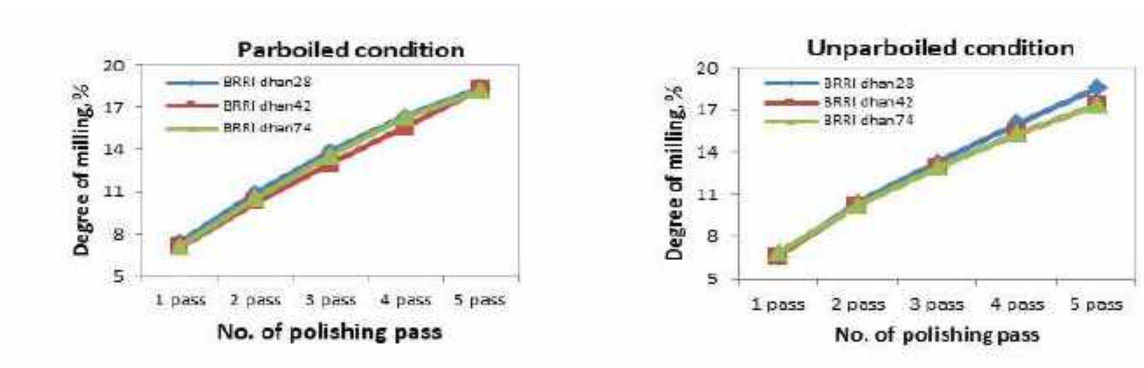


Fig.14. Relationship between no. of polishing pass and degree of milling%.

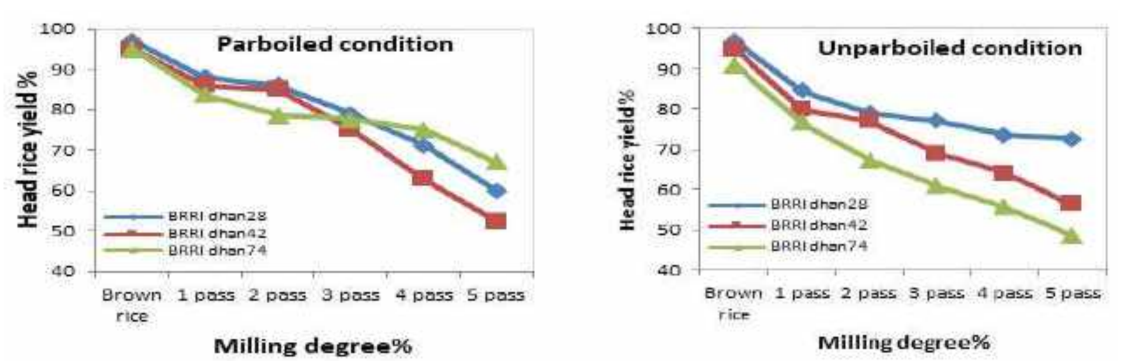


Fig. 15. Relationship between head rice yield % and degree of milling%.

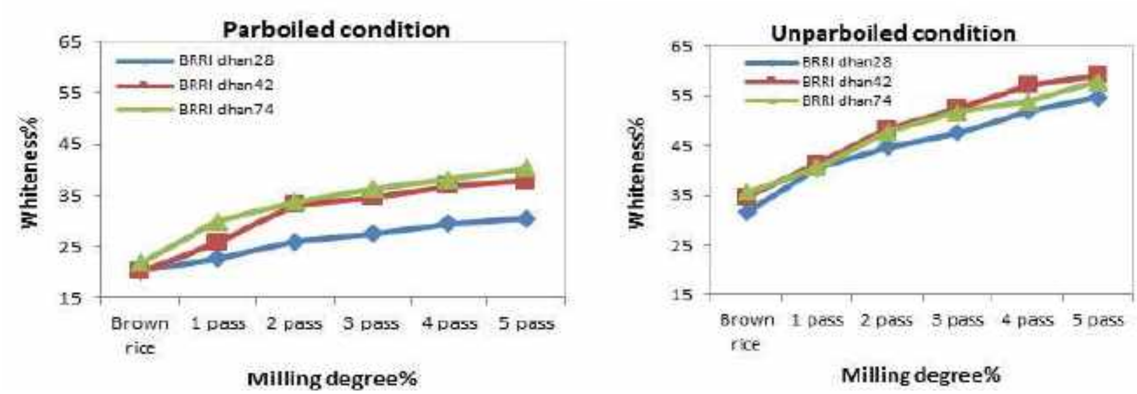


Fig. 16. Relationship between whiteness and degree of milling.

Effect on weight loss

Rice breakage was quantified as the weight of broken rice expressed as a percentage of the total weight of milled rice. In general, de-husk brown rice exhibited more weight compared to polished rice (Fig. 3). This was due to increase of DoM decrease in size of individual grain. The standard degree of milling is 8-10% and it goes more termed as over polished (FAO). The brown rice and below 7.5% DoM is problematic for digest as a daily consumption. It is clearly shown in figure 17 that more food loss occurred due to more degree of milling, hampers the food security of a nation.

Estimation of Zn content (ppm)

Grain zinc content was estimated in polished rice near about 7.5, 10, 12, 13.75 and 15% of degree of milling from the selected variety. Sample were digested and estimated by the method of the Association of Official Agricultural Chemists (AOAC, 1995). About 0.5 g rice powder was taken into a 25mL conical flask and then for extraction of minerals, 5mL mixture of nitric acid: perchloric acid (5:2) was added to the flask. The samples were heated at 350°C for digestion until the color became clear. Then the digested sample were cooled and filtered through a Whatman filter paper No. 1 and the volume was made up to 25mL with de-ionized distilled water. The zinc content in these samples was determined by the atomic absorption spectrophotometer (AA-7000).

After polishing, large variation in zinc content was observed among the verities. It was observed that the zinc content of three varieties decreased with the degree of milling (passing number 1 to 5) indicating that the zinc is reduced during milling (Fig. 18). Statistically significant difference in zinc content of three varieties was found up to 12% DoM.

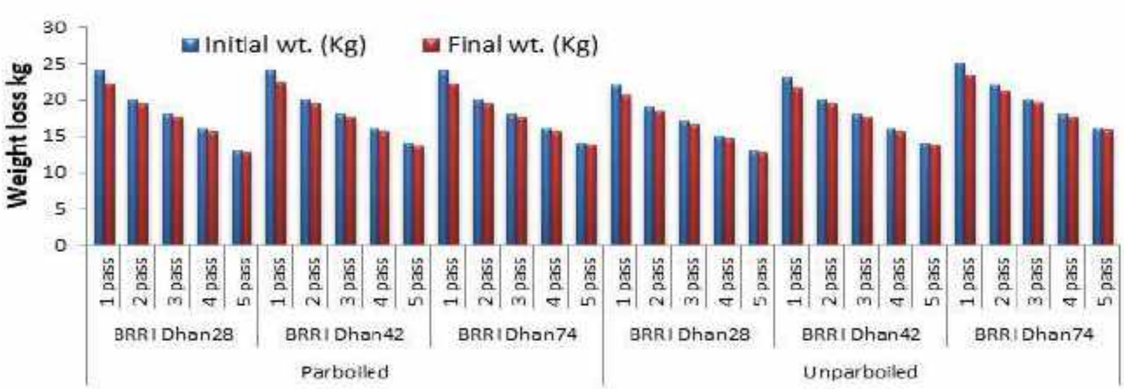


Fig. 17. Relationship between weight loss (kg) and degree of milling%.

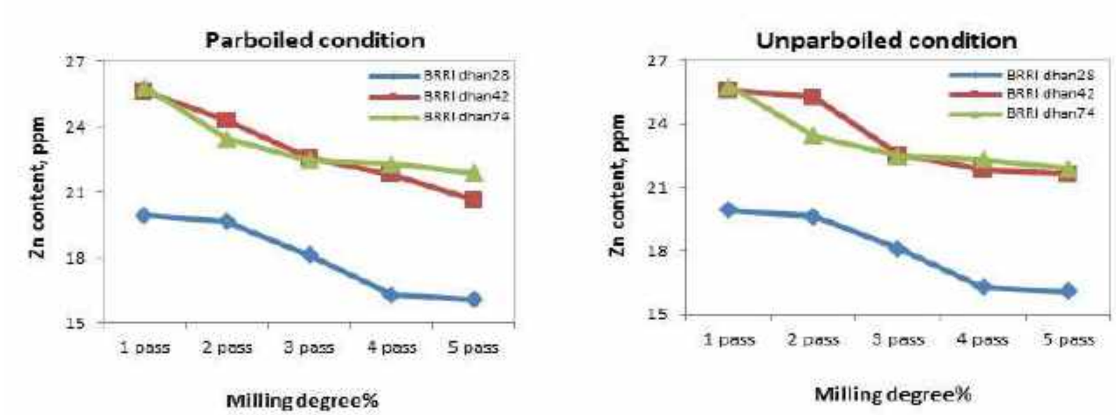


Fig. 18. Relationship between Zn content and degree of milling.

Different degree of milling substantially affected the milling recovery, head rice yield and nutritional properties of the examined rice varieties. Increase in DoM resulted in further reduction of zinc content, milling recovery and head rice yield in both parboiled and unparboiled condition. A positive correlation between DoM and kernel whiteness was observed. It is suggested that adopting up to 10% DoM for commercial milling of rice might help to prevent quantitative, qualitative and nutritional loss along with retention of good cooking characteristics.

Design and development of a small scale recirculating type dryer

The dryer is consists of a burner, suction mood blower, two screw type conveyor and a bucket elevator. One screw type conveyor placed in the lower part of grain bin was used to collect paddy from grain hopper and transport to bucket elevator chamber. Bucket elevator was used to circulate paddy from lower portion to upper portion of the dryer. Another screw type conveyor was used to transport paddy from bucket elevator to drying chamber. Grains are distributed on the top of the grain divider and falling down over a perforated screen. Suction mood blower was used to pull hot air from burner through perforated drying chamber (Fig. 19).

Dryer components

Drying bin. The function of the drying bin is to hold the grain for drying. Drying bins are made of hexagonal shape with a perforated metal screen inner bin and a solid sheet outer bin according to the requirements of the design of the dryer.

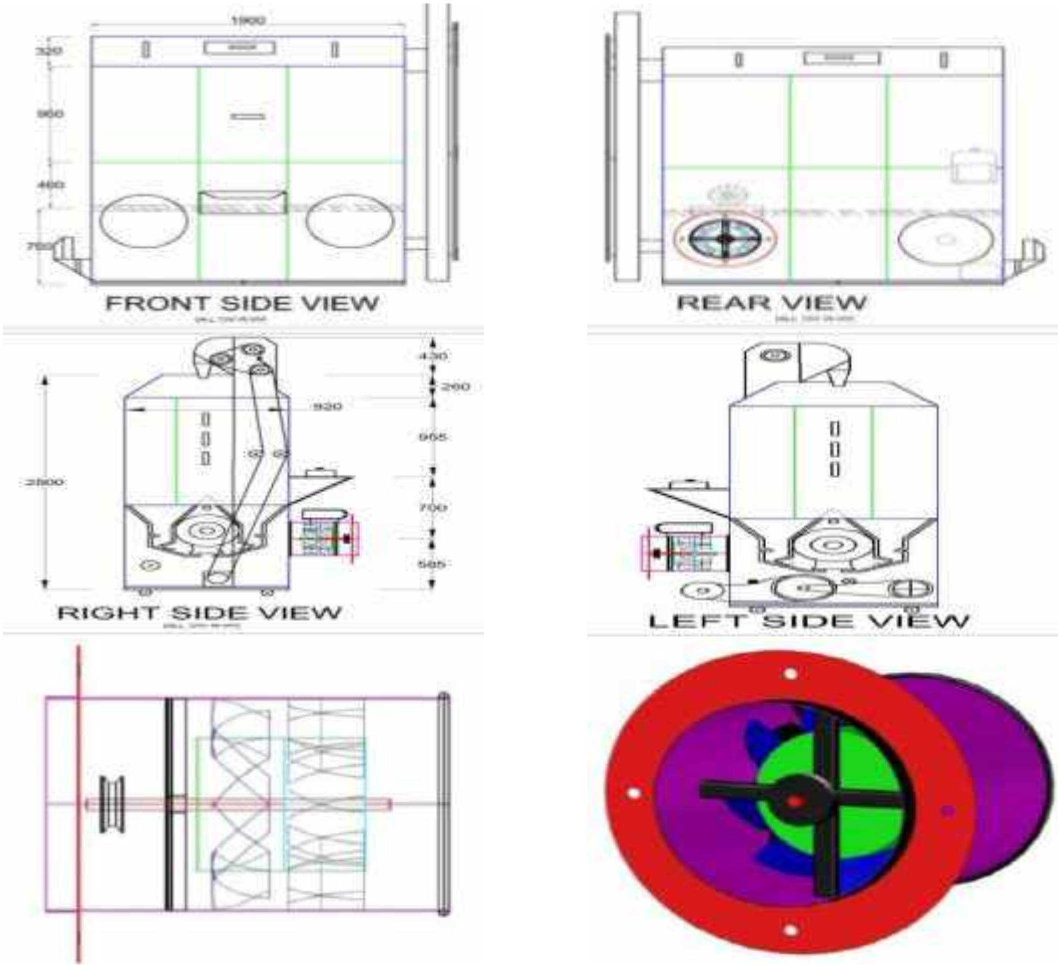
Blower. The blower is the most critical component of a dryer. A suction mood axial-flow blower is used to pull heated air from heat source through perforated drying chamber designed on the required airflow rate (30 m/s) and the needed pressure creation. Axial-flow blower was used to provide a higher airflow rate at lower pressure creation and shallow bed batch dryers with low resistance to airflow. A 1.5 hp with 1500 rpm electric motor was attached with blower.

Conveyors and Elevator. Two screw type conveyors and elevator was used for horizontal and vertical transport of grains to load, circulate or discharge grains which will improve the efficiency of the drying operation and reduce labor costs. Elevators are designed properly so that they match the capacity of the dryer.

Evaluation of dryer in loading condition

The trial of recirculating dryer was conducted during Boro season 2020 at the FMPHT divisional workshop using BRRI dhan28 with different dryer capacity.Drying air temperature distribution through grain bin was uniform throughout the dryer during drying operation. The drying temperature increased rapidly within one hour and then increasing rate was nearly steady or slowed down till the completion of drying depending on fuel supply. It proves that hot air temperature uniformly distributed to all over the drying section of dryer.

The general trend, moisture level of grain was decreased with the drying time. The drying rate is



Drawing of recirculating dryer
Fig. 19. Schematic view of recirculating dryer.

dependent on initial moisture content and drying temperature. The initial moisture content of paddy and drying air temperature directly affect the drying time. The moisture content of paddy was decreased rapidly at first but slowed down as drying progress. The dying rate decreased with moisture content and increased with drying air temperature. Finally, the grain was dried uniformly and reached same and desired moisture level in 4.5 to 10.0 hours depending on the initial moisture content of paddy and drying air temperature.

The performance of recirculating dryer was satisfactory at laboratory level in terms of drying rate, drying capacity and drying efficiency. The paddy was dried from 28.7 to 18.9%, 28.5 to 14.2% and 29.4 to 13.6% during Boro season 2020 within the range of 4.5 to 10.0 hrs, respectively (Table 16). The results showed that the drying rate was found to be varied between 1.6 to 2.2% which is directly depends on initial moisture content of paddy and drying air temperature. The drying time was also varied for initial moisture content, drying air temperature and dryer capacity. The range of drying efficiency was ranged from 24.9% to 51.6% during Boro season for different dryer capacity. The dryer used energy efficiently with full load condition and high initial moisture content of paddy compared to half load condition and low initial moisture content. Therefore, the drying efficiency of trial 3 (51.6%) is much higher compared to others because of low energy loss.

Table 16. Performance of dryer during Boro 2020 season.

Treat	Initial MC (%)	Final MC (%)	Initial wt. of paddy, kg	Final wt. of paddy, kg	moisture removed, kg	Hot air temp. °C mean±std	Drying time, hr	Drying rate, (% mc/hr)	Drying efficiency, %
T_1	28.7	18.9	165	145.0	20.0	62.6±2.9	4.5	2.2	24.9
T_2	28.5	14.2	500	416.7	83.3	58.7±3.1	9.0	1.6	46.2
T_3	29.4	13.6	528	431.4	96.6	60.1±3.7	10.0	1.6	51.6

Problem identifications during drying operation

Various problems were encountered during drying operation of the dryer. Significant among them are:-

1. Fuel consumption is high which leads the operating cost of dryer.
2. Variety mixture due to lower part screw conveyor inefficiency.
3. Frequent clogging in recirculating unit due to extra dust with paddy.

Test, evaluation and modification of rubber roll de-husker and MNMP - 15 type polisher

Modified rubber roll de-husker was used to improve the performance of rice processing operates with 4 kW (3-phase 4 wire 1440 rpm) electric motor. Fixed and adjustable rubber roll diameter and length is 230 mm and 154 mm respectively. The RPM of the fixed rubber roll is 1051 rpm. andthe RPM of the adjustable rubber roll is 790 rpm. The adjustable rubber roll rotates 24.83% less RPM than fixed roller. The blower runs at 1028 rpm. 50 × 50 mm angle bar and 16 BWG sheet was used to fabricate stairway for facilitate carrying paddy in the hopper. Bottom end of the de-husker connected with a husk aspirator through a pipe (dia. 200 mm). Aspirator fan (dia.330 mm) operates by 1.5 kW (2840 rpm) motor (Plate 6). A cyclone separator attached in the de-husker for collecting husk. Previously, husk was directly collected from aspirator discharge outlet with gunny bag thus created huge amount of dust in the working area. An airstream is blown over the grains and immature grains drop into the separate hopper for discharge. The paddy and husk discharged separately. BRRI dhan84 (un-parboiled) was used in this experiment. The moisture content was 11.2% (wb.) and each sample size was 20 kg. De-husked paddy was processed in MNMP-15 type polisher to evaluate the milling parameter.

The average de-husking capacity of the husker was 678 kg/h and husking efficiency was about 90% (Table 17). Husking efficiency can be increased by closing the adjustable roller which increases the broken rice (brown rice). The average brown rice percentage was found 77.3% and rest of was husk and embryo.

Adjustable rubber roll rotate 24.83 % 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.

Evaluation of milling parameter of BRRI dhan84 processed in MNMP-15 type polisher

Brown rice of BRRI dhan84 from rubber roll de-husker was polished in MNMP-15 type polisher (Plate 7). The average capacity of the polisher was 681 kg/h and the average milling recovery was 64 %. The average head rice recovery (based on input paddy) was 54.0 % and head rice recovery (based on total milled rice) was 84.10% (Table 18).

Plate 6. Husker in operation.

Table 17. Husking performance of developed husker.

Sl. no.	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
1.	675	89	77.0	788	1048	24.81
2.	678	89	78.0	792	1052	24.71
3.	680	91	78.0	790	1053	24.97
Av.	678	90	77.3	790	1051	24.83

Table 18. Milling parameter of BRRI dhan84 processed in friction type polisher.

Sl. no.	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)
1.	680.0	64	55.0	85.94	9.0	14.1
2.	675.0	65	54.0	83.10	11.0	16.9
3.	688.0	64	53.2	83.13	10.2	16.87
Av.	681.0	64.3	54.0	84.10	10.0	15.90

The broken rice percentage was 8.4 % (based on input paddy) and 13.3% (based on total milled rice).

Plate 7. Polisher in operation

Husking efficiency was found around 90% of BRRI dhan84 de-husking in rubber roll de-husker. Milling recovery of BRRI dhan84 was 64 % polished in friction type polisher followed by de-husking. The average head rice recovery based on input paddy was 54.0 %, which is promising for processing of premiere quality rice. Engelberg huller may replace with one rubber roll de-husker and polisher for better quality rice. Beside this, rubber roll de-husker separate husk and friction type polisher separate bran. Separately collected husk and bran is suitable for briquette and edible oil production.

Study on milling recovery of BRRI dhan71under different moisture content

Parboiled BRRI dhan71 with different moisture content was processed in modified air blow type engelberg huller to find out optimum moisture content for higher milling yield and head rice recovery. Initially paddy was winnowing through BRRI winnower and soaked in the drum for 36 hours. Every 10 hours of interval soaked water changed by clean water for produce quality rice. After 36 hours water was removed from the tank and steaming in the small container with local *chula*. Drying was done in the drying floor of BRRI. Samples were collected with the moisture content of 9.1%, 10.2%, 11.3%, 12.3%, 13.2% and 13.9% (wb.). Drying was done in effective sun-shine days maintaining 2-4 cm of grain thickness layer. Steering of paddy continued at 30 minutes interval. After drying in the specified moisture content paddy sample was heaped for tempering in room temperature. Sample size was 20kg with three replications.

Milling parameters of parboiled BRRI dhan71 under different moisture content

The milling capacity of air blow type engelberg huller was ranged from 350 to 380 kg/hr for parboiled BRRI dhan71(Table 19). Milling yield for moisture content of 9.1%, 10.2%, 11.3%, 12.3%, 13.2% and 13.9% (wb.) were 67.5%, 68.0%, 68.6%, 69.2%, 70.0% and 70.5% respectively. Head rice recovery (based on input paddy) for moisture content of 9.1%, 10.2%, 11.3%, 12.3%, 13.2% and 13.9% (wb.)were 59.0%, 63.0%, 62.5%, 60.0%, 58.8% and 56.6% respectively. Higher head rice recovery was observed in 63.0% and 62.5% in 10.2% and 11.3% moisture content (wb.) respectively. Broken rice percentage (based on input Paddy) was found lower (5.0%) in 10.2% moisture content (wb.) and highest (19.80%) in 13.9% moisture content. No un-hulled paddy found in the milled rice processed by the air blow type engelberg huller.

Table 19. Milling capacity, milling yield and head rice recovery of parboiled BRRI dhan71 processed in the air-blow engelberg huller.

Milling Parameter	Moisture content (wb.)					
	9.1%	10.2%	11.3%	12.3%	13.2%	13.9%
Capacity, kg/h	350	357	364	370	374	380
Milling yield, %	67.5	68.0	68.6	69.2	70.0	70.5
Head rice, % (Based on input paddy)	59.0	63.0	62.5	60.0	58.8	56.6
Head rice, % (Based total milled rice)	87.4	92.60	91.10	86.7	84.00	80.20
Broken rice, % (Based on input paddy)	8.5	5.0	6.1	9.2	11.2	13.9
Broken rice, % (Based on Total milled rice)	12.6	7.40	8.9	13.3	16.00	19.80
Paddy remain, %	0	0	0	0	0	0

Parboiled BRRI dhan71 (six different moisture content) was processed in the air blow type engelberg huller to find out the optimum moisture content of milling. Higher head rice recovery was found in moisture content of 10.2% and 11.3% which were 63.0% and 62.5% respectively. Lower broken rice percentage was also observed at this moisture content. It may be concluded that, around 10-11% moisture content (wb.) is suitable for milling of parboiled paddy processed in the air blow type engelberg huller in terms of head rice recovery and less broken percentage.

INDUSTRIAL AND FARM LEVEL EXTENSION OF BRRI MACHINERY

Custom hire service business of rice combine harvester in haor basin of bangladesh

Rice cultivation in the haor region is often affected by early floods due to heavy rainfalls and water from the upstream Meghalayanmountains of India. Hence, it is important to find ways to rapidly harvest the crop so that the damage can be reduced to a minimum level. However, Bangladesh faces a serious labor crisis in the rice harvesting season including in haor region. Combine harvester is the only option to mechanize rice harvesting system. Custom hiring is the best alternative to utilize machine in the paddy fields to harvest paddy in time. However, no scientific study has been undertaken yet to assess the business viability of small size combine harvesters, particularly in *haor* ecosystem of Bangladesh. Therefore, the study was undertaken to explore the rental charge and operational management of combine harvester in a profitable manner. Data were collected from 86 rice fields harvested by a whole-feed combine harvester (Model: Zoomlion; Specification: Table 20) in Mithamainupazilla under the Kishoreganj district representing *haor* area of Bangladesh (Fig. 20). Land size, operational time, loss time, repair time, idle time, daily area coverage and constraints of harvester machine were also recorded to predict the business viability of combine harvester. The rental charge and payback period was calculated following standard protocol to make business venture profitable. The perception of farmers regarding the prospect of using combine harvester in harvesting has been recorded through personal interviews.

Rental charge calculationand assumptions

The rental charge for unit (1 ha) area depends on machine price, fuel, labour, transport cost, annual usage and profit.

Following assumptions are taken for calculating rental charge of combine harvester;

- Purchase price of the combine harvester is Tk 20,00,000
- Government assistance is 70% of the purchase price in *haor* area (MoA, 2020)

- The machine is in good condition to perform its task in same rate (ha hr^{-1}) without varying over its lifetime
- The bank rate for interest on investment is 12%
- The repair and maintenance cost of rice harvester is taken as 5% of its purchase price
- The life of the harvester is considered 8 years
- Fuel price is taken as Tk 70 l^{-1}
- Operator charge is considered Tk 900 day^{-1}
- Cost of manual harvesting and threshing was Tk 16,500 ha^{-1}

The average field capacity of combine harvester was observed as 0.20 ha hr^{-1} (Fig.21). Field efficiency of combine harvester depended on the land size. The daily area coverage can be increased after careful selection of the plots. Fuel consumption was found 4.18 l ha^{-1}. Operational consolidation is the best approach to reduce the time of movement resulting in increased daily area coverage. Seasonal use of combine harvester in one locality of the study area was observed for 22 days. The rental charge of the machine was estimated as 10,000 Tk ha^{-1} and payback period was 3.5 years for the area coverage of 40 ha rice fields (Fig. 22 and 23). Farmers would be able to save 40% harvesting cost for the rental charge of Tk 10,000 ha^{-1}.Combine harvester rental service has emerged as a viable business model in the *haor* basin. Whole-feed (Zoomlion model) combine harvester appeared as an effective, economical, and labor-saving harvesting machine in the *haor* region land tenure system.

Fig. 20. Location Map of study area.

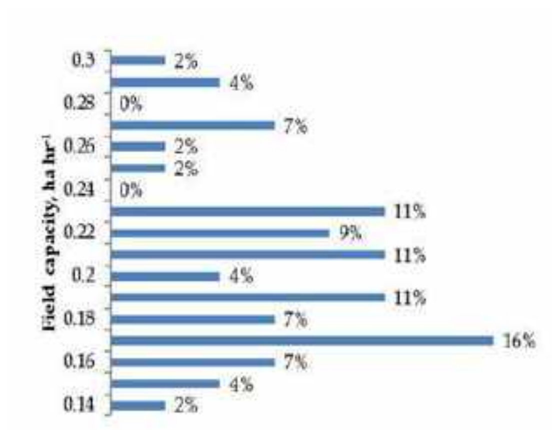


Fig. 21. Percentage of field capacity in different plots in haor areas.

Table 20. Technical specifications of Zoomlion combine harvester.

Item	Specification	Item	Specification
Model	4LZT-4.0ZD	Fuel tank capacity, l	40
Country of origin	China	Cutting width, m	2.0
Price, Tk	20,00,000	Feed quantity, kg s^{-1}	4.0
Max power, kW	67	Grain tank capacity, kg	650
Rated speed, rpm	2400	Unloading discharge, kg s^{-1}	3.6
Total weight, kg	3260	Header auger	Spiral blade+ Eccentric telescopic rod rack
Tracking tire	Full track	Bagging facility	No
Minimum ground clearance, mm	325	Grain cleaning (depending on moisture level)	Good
Fuel type	Diesel	Worker	1-2 Person

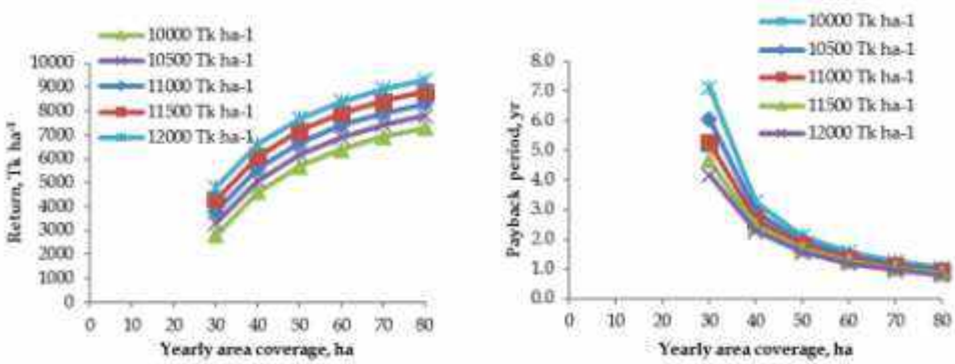


Fig. 22. Return and payback period of combine harvester

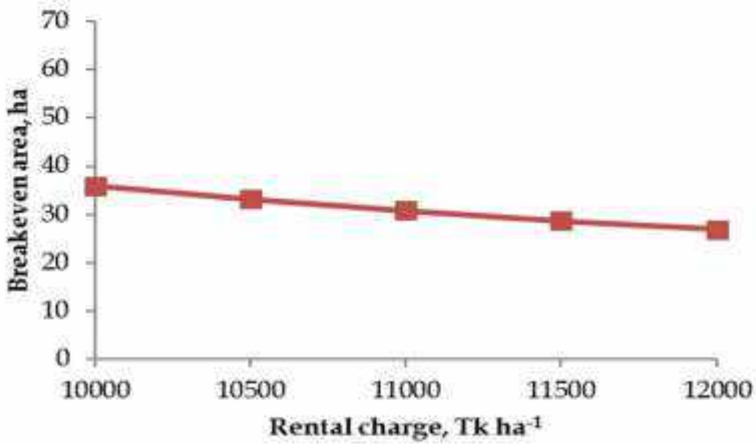


Fig. 23. Break-even area with respect to rental charge

Adaptive Research Division

SUMMARY

During the reporting period (2019-2020), 25 advanced breeding lines for different seasons were evaluated by conducting 10 advanced line adaptive research trials (ALART) at farmers' field in different agro ecological regions of Bangladesh. Considering specialty on some important characteristics and farmers' opinion, three advanced breeding lines for different characteristics in different seasons were recommended for proposed variety trial (PVT). During Aus 2019, one broadcast Aus variety BRRI dhan83 was found suitable for transplanting condition in T. Aus ecosystem and recommended for PVT. No advanced line was recommended for PVT during T. Aman 2019. During Boro 2020, one zinc enriched line and one bacterial blight resistant rice genotype were recommended for PVT.

Seed Production and Dissemination Programmes (SPDP) were conducted by using BRRI varieties (BRRI dhan27, BRRI dhan48, BRRI dhan49, BRRI dhan58, BRRI dhan71, BRRI dhan72, BRRI dhan74, BRRI dhan75, BRRI dhan79, BRRI dhan81, BRRI dhan82, BRRI dhan84, BRRI dhan87 and BRRI dhan89) and other technologies under GoB and different projects (SPIRA, TRB and HNRP) A total of 566 demonstrations were conducted in 157 upazilas of 62 districts, from which about 302.33 tons of paddy were produced and 51 tons were retained as seeds by the farmers for next year cultivation. About 46 thousand farmers gained awareness and knowledge about BRRI varieties through demonstrations, knowledge sharing, field days, field visit and interactions with farmers and extension personnel. Among them, about nine thousand farmers were motivated to adopt BRRI varieties.

A total of 400 Head to Head Adaptive Trial (HHAT) were conducted through public private partnership during the reporting period (200 HHAT in Aman 2019 and 200 in Boro 2020). From the interaction of genotypes and environments, BRRI dhan87 was found the most suitable variety for Aman season and varietal preferences were BRRI dhan87> BRRI dhan71> BRRI dhan75> BRRI dhan52> BRRI dhan76> BRRI dhan79> BRRI dhan80> BRRI dhan49> BRRI dhan73. In Boro 2020, BRRI dhan88 and BRRI dhan92 showed higher potentiality throughout the country for BRRI dhan28 and BRRI dhan29 growing areas, respectively. BRRI dhan67 also found suitable for throughout the country although it was released for coastal saline environment. BRRI dhan58 have good potentiality only in the fish culture land (*Gherland*) of southwest region. BRRI dhan81 suggested to grow in northwest to northern region as these varieties were highly infected by neck blast disease in other regions of the country.

During Aman 2019 and Boro 2020, ARD conducted seed support program to farmers and different stakeholders in different locations of Bangladesh under TRB project to enhance rapid dissemination of newly released BRRI varieties. A total of 91 farmers' training programmes at different locations of the country in which 2,730 trainees participated on modern rice production technologies.

Fifty field days at different locations of the country were arranged. Nearly, 7,000 participants including farmers, local leaders and DAE personnel participated in the field days. In BRRI farm, quality seeds of recently released varieties were produced during T. Aman 2019 and Boro 2020 seasons. Seven tons quality seeds of BRRI varieties were produced. The seeds were used to conduct research activities and dissemination programme.

TECHNOLOGY VALIDATION

Advanced line adaptive research trial (ALART)

T. Aus 2019. Three BRRI released broadcast Aus rice varieties i.e., BRRI dhan42, BRRI dhan43 and BRRI dhan83 along with BRRI dhan48 as checks were tested at farmers' field in ten locations under T. Aus ecosystem. The tested BRRI released B. Aus varieties i.e., BRRI dhan42 and BRRI dhan43 produced lower yield than the check variety BRRI dhan48 and they didn't have any special characters over the check variety (Table 1). On the other hand, the tested variety BRRI dhan83 produced similar yield with almost similar growth duration to that of check variety BRRI dhan48 and it was lodging tolerant in all the locations. Phenotypic acceptance of BRRI dhan83 was also better than the other tested varieties. Disease infection in BRRI dhan83 was found lower than the other varieties. Considering the above information and farmers' opinion, the tested B. Aus variety BRRI dhan83 may be suitable for T. Aus ecosystem. Therefore BRRI dhan83 was recommended for further trial as T. Aus variety in PVT.

Table 1. Grain yield, growth duration, 1000-grain weight (TGW) and plant height of some B. Aus varieties under ALART, T. Aus 2019.

Genotype	Location											GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
BRRI dhan42	3.82	4.04	1.19	3.30	2.87	4.05	4.08	3.30	3.30	2.40	3.24	104	21.20	113
BRRI dhan43	3.70	3.79	1.25	3.08	2.58	4.82	4.09	3.50	3.37	1.70	3.19	106	21.25	107
BRRI dhan83	4.83	4.84	1.75	4.41	2.08	5.73	4.84	4.38	3.67	3.06	3.96	110	23.17	112
BRRI dhan48 (ck)	5.21	4.03	2.63	4.43	2.51	6.32	3.52	4.36	4.13	3.13	4.03	108	22.86	101
$LSD_{0.05}$					0.56						0.56	1.67	NS	5.05

L1-Barishal, L2-Cumilla, L3-Faridpur, L4-Feni, L5-Gazipur, L6-Habiganj, L7-Kushtia, L8-Mymensingh, L9-Rajshahi, L10-Rangpur

T. Aman 2019, ALART, rainfed lowland rice (RLR). Four advanced lines: BR8521-30-3-1, BR8441-38-1-2-2, BR8526-38-3-2-1-HR2 and BR8526-38-3-2-1-HR8 along with BRRI dhan49 (ck) and BRRI dhan87 (ck) as checks were tested at farmers' field in ten locations. But the trial at Khulna and Habiganj was damaged due to heavy rainfall just after transplanting and severe occurrences of sheath blight disease. Therefore, the results of these two locations were excluded from the report. The average yield performances (4.13-5.00 t/ha) of the tested advanced lines were significantly lower than the check variety BRRI dhan87 (5.57 t/ha) (Table 2). Although, yield performance of BR8521-30-3-1 was similar to BRRI dhan49 and grain size was fine and 1000-grain weight (TGW) was less than the all other genotypes, it was not considered for PVT for its slightly irregular flowering and maturity. Moreover, all the tested entries had the same irregularity problem. Considering all the necessary characteristics and farmers' opinion, no advanced line was found suitable for PVT.

T. Aman 2019, ALART, zinc enriched rice (ZER). Three zinc enriched advanced rice genotypes BR8436-7-4-2-3-1, BR8442-12-1-3-1-B7, IR90210-100-2-3-1-P4 along with BRRI dhan49, BRRI dhan72 and BRRI dhan87 as checks were tested at farmers' field in nine locations. Check variety BRRI dhan87 produced higher grain yield than the other check varieties and the tested advanced lines (Table 3). BR8442-12-1-3-1-B7 produced similer yield with other two ckeck varieties BRRI dhan49 and BRRI dhan72. However, the growth duration of BR8442-12-1-3-1-B7 had no advantage over the checks. Growth duration of tested entry no. 1 and 3 was lower than three check varieties (Table 3) but yield was lower and flowering was irregular. Based on overall performance, yield, duration, grain type; farmers did not prefer any of the tested lines over BRRI dhan87. So, none of the tested entries was found suitable for proposed varietal trial (PVT).

Table 2. Grain yield, growth duration, TGW and plant height of the rice genotypes, ALART (RLR) during T. Aman 2019.

Genotype	Location									GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR8521-30-3-1	5.01	5.30	4.28	3.93	5.96	5.47	4.56	5.48	5.00	125	17.0	120
BR8441-38-1-2-2	5.72	6.05	4.41	3.85	5.71	5.71	4.37	3.74	4.95	125	24.6	118
BR8526-38-3-2-1-HR2	4.73	4.40	3.37	2.74	5.16	5.03	4.76	2.88	4.13	129	18.9	124
BR8526-38-3-2-1-HR8	4.88	4.86	4.14	3.48	5.80	5.09	5.06	3.72	4.63	128	18.8	112
BRRI dhan49 (ck)	4.81	5.42	4.17	4.78	5.75	5.25	5.55	4.86	5.08	130	20.0	102
BRRI dhan87 (ck)	5.80	6.14	4.91	5.48	5.98	6.62	5.84	3.77	5.57	126	24.5	123
$LSD_{0.05}$				0.71					0.25	1	0.8	2

L1-Barishal, L2-Gopalganj, L3-Kushtia, L4-Rajshahi, L5-Rangpur, L6-Feni, L7-Mymensingh, L8-BRRI, Gazipur

Table 3. Grain yield, growth duration, TGW and plant height of the rice genotypes, ALART (ZER) during T. Aman 2019.

Genotype	Location										GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t/ha)												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean	Mean	Mean	Mean
BR8436-7-4-2-3-1	3.37	4.16	3.43	4.26	4.33	5.25	5.12	5.50	3.71	4.35	119	23.97	110
BR8442-12-1-3-1-B7	4.01	5.33	3.34	5.41	4.30	6.14	5.52	5.79	3.81	4.85	125	21.74	113
IR90210-100-2-3-1-P4	3.42	4.99	3.00	4.29	4.11	4.72	5.34	5.85	3.52	4.36	117	23.41	116
BRRI dhan49 (ck)	3.43	6.31	3.47	4.52	5.00	5.63	5.48	5.98	3.54	4.82	128	19.92	104
BRRI dhan72 (ck)	3.75	5.55	3.56	5.31	5.19	4.53	5.65	5.35	4.15	4.78	127	27.53	116
BRRI dhan87 (ck)	4.10	6.08	3.57	5.76	6.30	5.77	6.71	5.95	3.70	5.33	125	23.15	122
$LSD_{0.05}$					0.64					0.21	1	1.24	2

L1-Barishal, L2-Faridpur, L3-Kushtia, L4-Jashore, L5-Rajshahi, L6-Rangpur, L7-Feni, L8-Mymensingh, L9-BRRI Gazipur

T. Aman 2019, ALART, Rainfed lowland rice (RLR), Biotechnology, (RLR-Bio). Two advanced lines developed by Biotechnology Division of BRRI for rainfed lowland rice ecosystem i.e., BR (Bio) 9786-BC2-161-1-2, BR (Bio) 9786-BC2-80-1-1 along with BRRI dhan71 and BRRI dhan87 as checks were tested at farmer's field in ten locations. The trial conducted under BRRI RS, Habiganj was severely affected by sheath blight disease and the data was not suitable for representation as actual/normal condition. Therefore, the result of Habiganj location was not shown here. Both the advanced lines yielded lower than the check variety BRRI dhan87 (Table 4). Although, mean grain yield of BR (Bio) 9786-BC2-161-1-2 was statistically similar with the check variety BRRI dhan71. The advanced line BR (Bio) 9786-BC2-80-1-1 performed the lowest among the tested entries. The mean growth duration of BR (Bio) 9786-BC2-161-1-2 and BR (Bio) 9786-BC2-80-1-1was found four and two days earlier than the check variety BRRI dhan87. But mean growth duration of the two advanced lines were 2-4 days higher than the other check variety BRRI dhan71 (Table 4). Considering the above results and phenotypic acceptance, grain type, disease reaction, insect infestation, lodging tendency, and farmers' opinion, none of the advanced lines was found suitable for PVT.

T. Aman 2019, ALART, rainfed lowland rice (RLR), Rangpur, (RLR-Rang). Two advanced lines: BR8189-10-2-3-1-5, BR10238-5-1 along with BR11(ck) as check was tested in seven locations of greater Rangpur region and BRRI, Gazipur. On average of eight locations, the check variety BR11 produced a little bit higher yield (4.95 t ha^{-1}) than the tested two entries BR10238-5-1 and BR8189-10-2-3-1-5 (4.91 and 4.57 t ha^{-1}) (Table 5). However, the yield of above three entries was statistically similar to each other. The mean growth duration of the advanced line BR8189-10-2-3-1-5 (entry no.1) was 142, ranged from 128 to 147 days. Whereas, the mean growth duration of another advanced line BR10238-5-1 (entry no.2) was 146 days, ranged from 133-151. Check variety BR11 was found to be matured within the earliest mean growth duration of 139 days (Table 5). Compared to check variety BR11, farmers did not show interest about the advanced lines. Based on overall performances and farmers' preference, none of the genotypes was found suitable for proposed variety trial (PVT).

Boro 2020, ALART premium quality rice (PQR). Two advanced lines: BR8862-29-1-5-1-3 and BR8995-2-5-5-2-1 along with BRRI dhan50 as check were tested at farmers'field in ten locations. The tested genotypes have no advantage in respect to yield and duration over the check variety BRRI dhan58 (Table 6). Flowering and maturity of the genotypes were irregular. Higher pest incidence was found in the genotypes. Grain shape, size and TGW of the genotypes were not superior to the check varieties BRRI dhan50. Based on overall performances, the tested genotypes of PQR were not recommended for proposed variety trial (PVT).

Table 4. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (RLR-Bio) during T. Aman 2019.

Genotype	Location										GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	Mean	Mean	Mean	Mean
BR(Bio)9786-BC2-161-1-2	4.77	4.87	3.49	6.83	5.67	5.25	3.95	3.81	4.92	4.84	121	23.85	111
BR(Bio)9786-BC2-80-1-1	4.28	4.35	3.92	6.56	4.93	4.73	4.30	4.08	5.07	4.69	123	23.47	117
BRRI dhan71 (ck)	4.85	5.21	4.10	5.67	3.96	4.87	5.10	4.00	5.66	4.82	119	24.08	118
BRRI dhan87 (ck)	6.01	6.02	4.60	7.02	5.43	5.41	5.37	4.29	6.09	5.58	125	23.58	123
$LSD_{0.05}$										0.57	0.98	NS	4.16

L1-Barishal, L2-Feni, L3-BRRI, Gazipur, L4-Gopalganj, L5-Jashore, L6-Kushtia, L7-Mymensingh, L8-Rajshahi, L9-Rangpur

Table 5. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (RLR-Rang) during T. Aman 2019.

Genotype	Location									GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})											
	L1	L2	L3	L4	L5	L6	L7	L8	Mean	Mean	Mean	Mean
BR8189-10-2-3-1-5	4.71	5.06	5.08	5.42	3.20	4.68	3.22	5.16	4.57	142	27	126
BR10238-5-1	5.61	5.22	5.29	5.76	3.24	5.18	3.58	5.42	4.91	146	28	128
BR11 (ck)	5.62	5.55	5.40	5.84	3.12	5.21	3.96	4.93	4.95	139	26	111
$LSD_{0.05}$									0.59	0.97	1.69	3.9

L1-Thakurgaon (Sadar), L2-Dinajpur (Birganj), L3-Rangpur (Taraganj), L4-Dinajpur (Nawabganj), L5-Gaibandha (Sundarganj), L6-Kurigram (Rajarhat), L7-Kurigram (Nageswari), L8-BRRI Gazipur

Table 6. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (PQR) in Boro 2020.

Genotype	Location											GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
BR8862-29-1-5-1-3	7.14	7.47	5.89	6.12	6.45	5.54	6.77	4.57	5.87	5.24	6.11	158	21.8	95
BR8995-2-5-5-2-1	6.24	6.91	5.56	5.93	5.96	6.57	6.47	4.10	5.58	5.05	5.84	160	21.2	109
BRRI dhan50 (ck)	5.95	6.79	6.08	5.76	6.51	5.89	6.73	5.28	5.68	5.72	6.04	158	18.0	86
$LSD_{0.05}$						0.54					0.17	0.4	0.7	1.0

L1-Barishal, L2-Faridpur, L3-Feni, L4-Rajshahi, L5-Rangpur, L6-Habiganj, L7-Jashore, L8-Kushtia, L9-Sherpur, L10-BRRI, Gazipur

Boro 2020, ALART zinc enriched rice (ZER). One zinc enriched advanced rice genotype IR99285-1-1-1-P2 along with BRRI dhan29 and BRRI dhan84 as checks were tested at farmers'field in ten locations. On average of ten locations, the entry IR99285-1-1-1-P2 obtained higher yield (7.37 t ha^{-1}) than the zinc enriched check variety BRRI dhan84 (5.94 t ha^{-1}) and it was statistically similar to that of the check variety BRRI dhan29 (7.43 t ha^{-1}) (Table 7). Mean growth duration of the advanced line was two days earlier than the check variety BRRI dhan29. Besides, uniformity of flowering and maturity were observed in the advanced line IR99285-1-1-1-P2. Grain type of the line is long slender and it was zinc enriched. Considering all the above characteristics and farmers' opinion, the entry IR99285-1-1-1-P2 was recommended for PVT.

Boro 2020, ALART insect resistant rice (IRR). One advanced rice genotype BR8340-5-6-1, resistant to BPH along with BRRI dhan58 (ck) and T27A (R. ck) were tested at farmers 'field in ten locations. The Average yield of the entry BR8340-5-6-1 was lower than the standard check BRRI dhan58. No significant difference was observed in case of insect's infestation and disease incidence. Moreover, all tested genotypes were infested by brown plant hopper (BPH) in two experimental sites of Tarash and Sirajganj upazila in Sirajganj district. All replications of tested entry BR8340-5-6-1 was damaged by rats about 10-60% in Tarash and Royganj upazila under Sirajganj district. No other advantages were observed in entry BR8340-5-6-1 compared to the check variety BRRI dhan58. Considering all the above characteristics, the entry BR8340-5-6-1 was not found suitable for PVT.

Table 7. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (ZER) during Boro 2020.

Genotype	Location											GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
IR99285-1-1-1-P2	7.42	9.12	7.8	6.72	7.12	6.62	7.46	7.32	7.00	6.39	7.37	160	22.42	103
BRRI dhan29 (ck)	7.52	9.03	7.26	6.47	7.28	7.62	7.66	8.23	6.63	6.76	7.43	162	21.95	103
BRRI dhan84 (ck)	5.93	5.07	6.12	4.57	6.51	3.01	6.57	6.61	6.27	5.83	5.94	147	22.03	103
LSD0.05					0.52						0.17	0.21	0.74	1.0

L1-Jhalokathi, L2-Faridpur, L3-Feni, L4-Rajshahi, L5-Rangpur, L6-Habiganj, L7-Satkhira, L8-Kushtia, L9-Sherpur, L10-BRRI, Gazipur

Table 8. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (IRR) during Boro 2020.

Genotype	Location											GD (day)	TGW (g)	Plant height (cm)
	Grain yield (t ha^{-1})													
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
BR8340-5-6-1	4.20	4.52	7.58	6.50	7.81	6.70	7.29	5.43	5.71	4.05	6.19	162	20.0	108
BRRI dhan58 (ck)	7.88	8.03	7.87	6.19	6.77	7.28	6.97	6.85	5.50	4.02	6.74	160	21.3	98
T27A (R.)	2.49	4.37	3.09	2.84	3.10	-	-	5.89	4.23	3.18	3.85	169	25.1	125
LSD0.05					0.73						0.29	6.52	3.06	7.92

L1-Sirajganj (Tarash), L2-Sirajganj (Royganj), L3-Natore, L4-Dinajpur, L5-Thakurgaon, L6-Satkhira, L7-Feni, L8-Habiganj, L9-Sherpur, L10-BRRI Gazipur. "–"= Experiment damaged due to failure of seed germination.

Boro 2020, ALART blast resistant rice (BRR). Three advanced lines: HR (Path)-11, Path 2,441 and BR (Path)12,452-BC3-16-19 along with BRRI dhan58 and BRRI dhan29 as standard checks were tested at farmers'field in ten locations. (Table 9). On average, none of the tested lines showed yield advantage over the check varieties. All of the tested lines as well as the check varieties were prune to diseases. Though entry no.1 HR (Path)-11 was less susciptible to blast disease, it was more susceptible to bacterial disease. Moreover, due to its taller plant height HR (Path)-11 became more prune to lodging. Considering yield, growth duration and disease reactions, none of the tested lines found suitable for PVT.

Boro 2020, ALART bacterial blight resistant rice, Plant Breeding (BBRR-PB). Two advanced lines: BR8938-19-4-3-1-1-P2-HR3 and BR9651-15-2-1-4 from Plant Breeding division along with BRRI dhan28 (Sus ck) and BRRI dhan58 (Std ck) were tested at farmers' field in ten locations. The entry BR8938-19-4-3-1-1-P2-HR3 obtained a little higher yield compared to both the standard checks. The entry was less attacked by bacterial leaf blight disease. Growth duration of the entry BR8938-19-4-3-1-1-P2-HR3 (150 days) was three days longer than BRRI dhan28 (147 days) but six days earlier than BRRI dhan58 (156 days). Grain type is attractive like BRRI dhan28. In maximum cases, farmer, scientists and SA/SAAO chose the entry BR8938-19-4-3-1-1-P2-HR3 as their first choice. Considering all the above characteristics, the entry BR8938-19-4-3-1-1-P2-HR3 could be recommended for PVT.

Boro 2020, ALART bacterial blight resistant rice, Biotechnology (BBRR-Bio). Two advanced lines: BR (Bio) 11447-1-28-14-3 and BR (Bio) 11447-3-10-7-1 from Biotechnology Division along with BRRI dhan28 (Sus) and BRRI dhan58 (Std) were tested at farmers' field in ten locations. Though the entries showed resistance over BLB in some extent, the tested entries produced much lower yield compared to the BRRI dhan58 (Table 11). The tested entries were not uniform in flowering and maturity. Most of the locations reported slightly irregular to irregular flowering and maturity. Though one of the tested entry, BR (Bio) 11447-1-28-14-3 gave a little higher yield compared to the check BRRI dhan28, its grain type was not as good as the check (little bit bolder). Considering all the above characteristics, no entry of BBRR was recommended for PVT.

Table 9. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (BRR) during Boro 2020.

Genotype	Location: Grain yield (t ha^{-1})											GD (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
HR (Path)-11	3.18	5.35	7.48	4.59	4.49	6.46	5.57	7.87	4.66	3.09	5.27	156	24.69	128
Path 2441	3.34	5.87	7.89	4.55	4.57	7.38	6.24	7.43	4.14	2.07	5.35	159	21.39	102
BR (Path)12452-BC3-16-19	3.25	4.85	7.16	4.63	4.34	7.19	5.87	8.06	3.98	2.10	5.14	159	17.45	96
BRRI dhan58 (Std Ck)	3.51	5.22	7.56	5.28	6.27	7.04	6.26	7.07	4.32	3.49	5.60	155	20.93	99
BRRI dhan29 (Std Ck)	2.83	5.69	7.30	4.83	5.74	7.23	6.94	7.05	4.28	3.21	5.51	162	19.32	99
LSD$_{0.05}$						0.82					0.25	0.4	1.0	1.5

L1-Cumilla,L2-Jhalokathi, L3-Bogura, L4-Rangpur, L5-Satkhira, L6-Feni, L7-Habiganj, L8-Bandarban, L9-Sherpur, L10-BRRI, Gazipur

Table 10. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (BBRR-PB) during Boro 2020.

Genotype	Location: Grain yield (t ha^{-1})											GD (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
BR8938-19-4-3-1-1-P2-HR3	5.93	7.65	7.01	7.02	6.76	6.53	7.39	7.11	6.38	5.88	6.77	150	23.12	107
BR9651-15-2-1-4	5.22	7.20	6.80	6.92	6.57	6.47	6.57	6.40	6.49	5.85	6.45	155	21.87	93
BRRI dhan28 (Sus. ck)	5.37	6.21	6.87	6.38	6.27	6.88	5.97	5.95	6.90	5.21	6.20	147	22.81	101
BRRI dhan58 (Std. ck)	6.00	7.21	5.79	7.23	7.31	6.91	7.09	6.26	6.58	6.36	6.67	156	22.26	100
LSD$_{0.05}$						1.20					0.41	0.33	0.7	2

L1-Cumilla, L2-Jhalokathi, L3-Bogura, L4-Rangpur, L5-Satkhira, L6-Feni, L7-Habiganj, L8-Bandarban, L9-Sherpur, L10-BRRI Gazipur

Table 11. Grain yield, growth duration, TGW and plant height of the rice genotypes under ALART (BBRR-Bio) during Boro 2020.

Genotype	Location: Grain yield (t ha^{-1})											GD (day)	TGW (g)	Plant height (cm)
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Mean	Mean	Mean	Mean
BR(Bio)11447-1-28-14-3	5.89	7.06	6.27	6.96	6.61	6.17	6.98	5.41	5.81	5.78	6.29	148	24.7	101
BR(Bio)11447-3-10-7-1	5.90	5.84	6.25	6.83	6.37	5.63	7.23	5.73	5.19	5.23	6.02	147	24.8	103
BRRI dhan28 (Sus. ck)	5.37	6.21	6.87	6.38	6.27	6.88	5.97	5.95	6.90	5.21	6.20	147	22.8	101
BRRI dhan58 (Std. ck)	6.00	7.21	5.79	7.23	7.31	6.91	7.09	6.26	6.58	6.36	6.67	156	22.3	100
LSD$_{0.05}$														

L1-Cumilla, L2-Jhalokathi, L3-Bogura, L4-Rangpur, L5-Satkhira, L6-Feni, L7-Habiganj, L8-Bandarban, L9-Sherpur, L10-BRRI, Gazipur

TECHNOLOGY DISSEMINATION

Seed production and dissemination programme (SPDP) and adaptive trial (AT)

For rapid dissemination of newly released BRRI varieties among the farmers through seed production, Adaptive Research Division (ARD) conducted seed production and dissemination programme (SPDP) in all rice growing seasons in different locations of the country.

SPDP during T. Aus 2019 under GoB. Trials were conducted at 12 upazilas of six districts such as Narsingdi, B. Baria, Sylhet, Chattogram, Chuadanga and Barguna. BRRI dhan27, BRRI dhan48, BRRI dhan82 and BRRI dhan85 were used in the programme. Varieties were demonstrated in area of 3 bigha in a cluster in each upazila. Among the varieties, BRRI dhan48 produced the highest mean grain yield 4.83 t ha^{-1}-1followed by BRRI dhan 85 (4.23 t ha^{-1}) and the lowest yield (4.152 t ha^{-1}) was in BRRI dhan82. A total of 19,980 kg grains were produced from all demonstrated plots and 3950 kg quality seeds were retained by the farmers for the next year use.

SPDP in Jhum during Aus 2019 under HNRP. These SPDPs were conducted in Jhum cultivation at three hilly districts such as Khagrachari, Bandarban and Rangamati. Each SPDP was consists of two varieties, BRRI dhan48 and BRRI dhan83 covering four bigha of land. SPDPs were executed in six sites of six upazilas in Khagrachari, two sites in two upazilas of both Rangamati and Bandarban. BRRI dhan48 (2.84 t ha^{-1}) yielded higher than BRRI dhan83 (2. 65 t ha^{-1}) and farmers choose BRRI dhan48 for their higher yield. Some farmers also choose BRRI dhan83 for their Jhum cultivation. Total 515 kg seeds of BRRI dhan48 and 225 kg seeds of BRRI dhan83 were retained by Jhumian farmers.

Adaptive trial (AT) in Jhum during Aus 2019 under HNRP: Experiments were carried out in six upazilas in three hilly districts (Bandarban, Rangamati and Khagrachari) using four high yielding modern rice varieties (BRRI dhan27, BRRI dhan48, BRRI dhan82 and BRRI dhan85) and one local check were planted in one bigha land. Considering all the situations, BRRI dhan48 and BRRI dhan82 might be suitable for hilly areas. Some newly released varieties might be included in the programme in next season.

SPDP during T. Aman 2019 under GoB. SPDPs in T. Aman 2019 were conducted in 25 upazilas of 12 districts (Tangail, Gazipur, Netrakona, Mymensingh, Kishoreganj, Sherpur, Dinajpur, Chattogram, Jashore, Khulna, Jhinaidah and Bagerhat) under GoB. Nine modern rice varieties (BRRI dhan49, BRRI dhan70, BRRI dhan71, BRRI dhan73, BRRI dhan75, BRRI dhan76, BRRI dhan79, BRRI dhan80 and BRRI dhan87) were used as cultivars in the programme. Among the varieties, BRRI dhan87 produced the highest mean grain yield 5.97 t ha^{-1} followed by BRRI dhan76 (5.72 t ha^{-1}) and the lowest yield (4.39 t ha^{-1}) was in BRRI dhan70. A total of 46,109 kg grains were produced from all demonstrated plots and 7,643 kg quality seeds were retained by the farmers for the next year cultivation.

SPDP in T. Aman 2019 under TRB project. A total of 20 SPDPs were conducted in 16 upazilas of 12 districts (Netrakona, Mymensingh, Kishoreganj, Jashore, Khulna, Naogaon, Bogura, Chapai Nawabganj, Gaibandha, Sylhet, Bandarban and Cox's Bazar. BRRI dhan49, BRRI dhan52, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan79, BRRI dhan80 and BRRI dhan87 were demonstrated in the SPDPs. Area of each SPDP was 3 bigha and total area of SPDP was 60 bigha. The programme was executed in collaboration with DAE. TRB-BRRI provided quality seeds, fertilizer and signboard. Irrespective of varieties and locations, BRRI dhan87 produced the highest mean grain yield (6.16 t ha^{-1}) followed by BRRI dhan71 (5.94 t ha^{-1}). Across the locations, BRRI dhan87 produced the highest grain yield (6.91 t ha^{-1}) at Keshabpur, Jashore while the lowest yield (4.71 t ha^{-1}) obtained in BRRI dhan75 at Nachole, Chapai Nawabganj. Total production of all the varieties was 47,056 kg from which 8,905 kg was retained as seeds (14% of total production) by the farmers for next season cultivation.

Head to head adaptive trial (HHAT) during Aman 2019 under TRB project

HHAT in Aman 2019. A total of 200 HHAT were conducted under TRB project through public private partnership (PPP) in T. Aman 2019 throughout the country. BRRI released ten varieties BRRI dhan49, BRRI dhan52, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76, BRRI dhan79, BRRI dhan80 and BRRI dhan87 were used in the HHATs. Area of each HHAT was 1 bigha (0.13 ha) and total area of HHAT was 200 bigha (26.75 ha). Uniform management practices were followed for all the varieties in each trial. Genotypes by environments interaction had significant effect on grain yield, growth durations and the overall performances of the varieties (Fig. 1). Performances of the varieties varied from location to location due to environmental effect. Among the varieties, BRRI dhan87 produced the highest grain yield (7.30 t ha^{-1}) followed by BRRI dhan71 (7.16 t ha^{-1}) at Puthia, Rajshahi and BRRI dhan75 (6.60 t ha^{-1}) at Kumarkhali Kushtia. Irrespective of locations, BRRI dhan87 gave the highest mean grain yield (6.02 t ha^{-1}) while the lowest (4.55 t ha^{-1}) was BRRI dhan73. BRRI dhan72 was the second highest yielder (5.52 t ha^{-1}) followed by BRRI dhan71 (5.31 t ha^{-1}), which was at par with BRRI dhan52 (5.25 t ha^{-1}). BRRI dhan52 and BRRI dhan79 produced better yield with tolerance to flash flood. BRRI dhan87 performed excellent throughout the country. Farmers preferred this variety for its higher grain and straw yield and long slender grain.

BRRI dhan71 performed excellent in both the drought prone environment and also favorable environment. BRRI dhan72 produced higher yield but most of the farmers don't like for its bold grain. It could be suitable for Barishal region. BRRI dhan73 produced good yield in saline environment but it lodged in some locations especially after depression of October. BRRI dhan75 performed excellent in the Rainfed lowland environment in all over the country. Farmers preferred this variety for its higher yield with shorter growth duration, long slender grain having bit aroma, Rabi crop easily can be grown after harvesting. BRRI dhan76 gave higher yield than local varieties like DudKalam, Sadamota etc. So that farmers preferred BRRI dhan76 than the local varieties. BRRI dhan79 has better yield with flash flood tolerance, but it was infected by false smut disease in some locations. BRRI dhan80 produced good yield, it could be popularize in high and medium high land. Finally, the preferences of the varieties were BRRI dhan87> BRRI dhan71> BRRI dhan75> BRRI dhan52> BRRI dhan76> BRRI dhan79> BRRI dhan80> BRRI dhan49> BRRI dhan73. Moreover, the farmer's preference varied from environments to environment.

HHAT in Boro 2020. A total of 200 HHATs were conducted throughout the country during Boro 2020 under TRB project through PPP. BRRI released nine rice varieties were used in the HHATs. The trials were divided into two groups like short duration (SD) group (BRRI dhan28 (check), BRRI dhan67, BRRI dhan81, BRRI dhan84 and BRRI dhan88) having growth duration below 150 days and the long duration (LD) group (BRRI dhan29 (check), BRRI dhan58, BRRI dhan89 and BRRI dhan92) having duration more than 150 days. Area of each HHAT was one bigha (0.13 ha) and total area of HHAT was 200 bigha (26.75 ha). Uniform crop management practices were followed for all the varieties in each trial. Grain yield, growth durations and the overall performances of modern varieties were significantly affected by the interaction of genotypes by environments (Fig. 2). Among the varieties across the locations, the highest grain yield of BRRI dhan88, BRRI dhan67, BRRI dhan81 and BRRI dhan84 and BRRI dhan28 was recorded 8.24, 8.10, 7.95, 7.74 and 7.52 t ha^{-1} at Dinajpur, Faridpur, Rajshahi and Meherpur, respectively. Among the long duration varieties, BRRI dhan92 provided the highest grain yield (9.85 t ha^{-1}) at Sadar upazila of Faridpur district that was followed by BRRI dhan89 (9.70 t ha^{-1}) and BRRI dhan29 (9.63 t ha^{-1}) and the lowest yield (8.98 t ha^{-1}) was in BRRI dhan58. BRRI dhan88 and BRRI dhan92 showed potentiality throughout the country for BRRI dhan28 and BRRI dhan29 growing areas, respectively. BRRI dhan67 was also found suitable for throughout the country although it was released for coastal saline environment. BRRI dhan58 have good potentiality only in the non-saline fish culture land (Gherland) of southwest region. BRRI dhan81 would be suggested to grow in northwest to northern region as the variety was highly infected by neck blast disease in other regions of the country. BRRI dhan89 produced competitive yield along with BRRI dhan29. However some famers disappointed for its medium bold grain compared to BRRI dhan29 and BRRI dhan92.

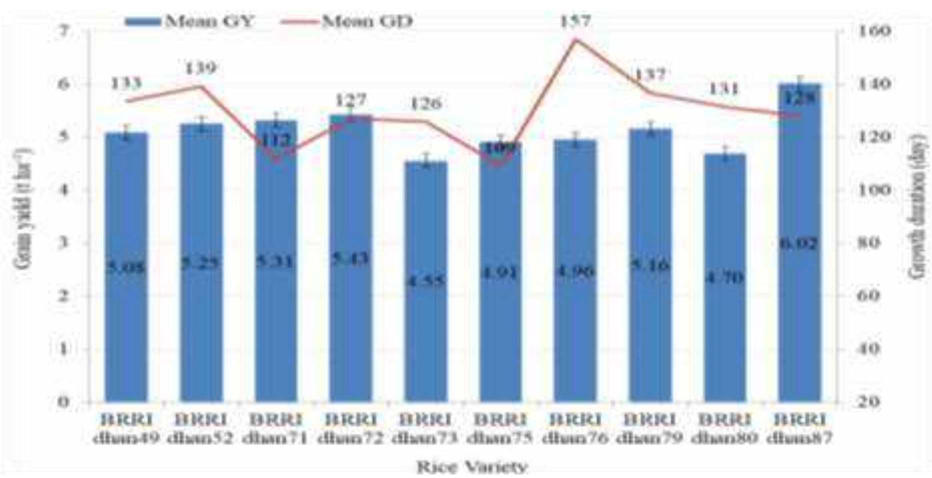


Fig 1. Mean grain yield and growth duration of modern rice varieties in HHAT Aman 2019.

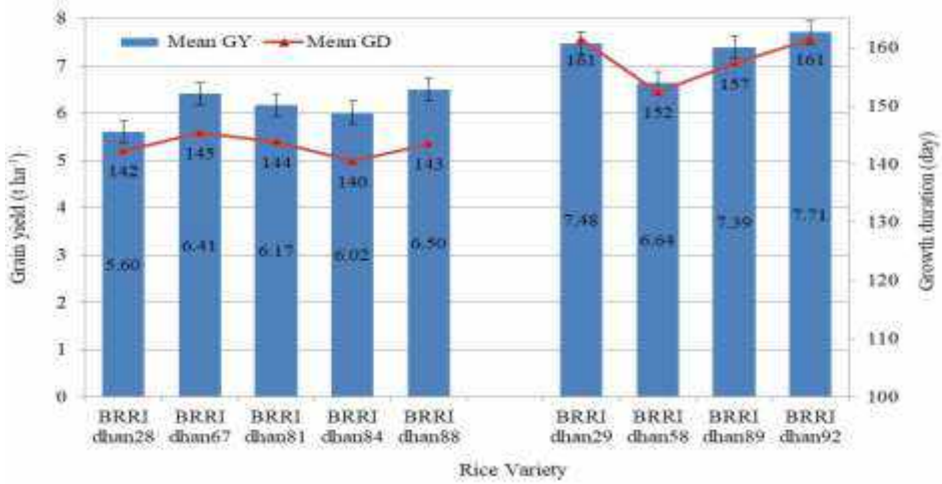


Fig 2. Mean grain yield and growth duration of modern rice varieties in HHAT Boro 2020.

SPDP during T. Aman, 2019 under SPIRA. SPDPs in T. Aman 2019 were conducted in nine upazilas of six districts (Tangail, Gaibandha, Jashore, Naogaon, Patuakhali and Bagerhat) under SPIRA Project. Eight modern rice varieties (BRRI dhan52, BRRI dhan71, BRRI dhan72, BRRI dhan73, BRRI dhan75, BRRI dhan76, BRRI dhan80 and BRRI dhan87) were used as cultivars. Plot size of each variety was one bigha and three varieties were demonstrated in 3 bigha area in a cluster in each upazila. Among the varieties, BRRI dhan87 produced the highest mean grain yield 5.86 t ha^{-1}followed by BRRI dhan76 (5.20 t ha^{-1}), BRRI dhan72 (5.18 t ha^{-1}) and BRRI dhan52 (5.17 t ha^{-1}). A total of 29,900 kg grains were produced from all demonstrated plots and 3,883 kg quality seeds were retained by the farmers. A total of 747 farmers were motivated and showed their interest to cultivate these varieties.

SPDP during T. Aman 2019 at Tangail as a special activity. SPDPs in T. Aman 2019 were conducted in Dhanbari and Madhupur upazilas of Tangail district under GoB. Six modern rice varieties (BR22, BR23, BRRI dhan71, BRRI dhan72, BRRI dhan75 and BRRI dhan87) were used in the programme. Plot size of each variety was one bigha and 3 varieties were demonstrated in 3 bigha area in a cluster in each upazila. Among the varieties, BRRI dhan87 produced the highest mean grain yield 5.96 t ha^{-1} followed by BRRI dhan75 (4.97 t ha^{-1}) and the lowest yield (4.39 t ha^{-1}) was in BR22. A total of 46,727 kg grains were produced from all demonstrated plots and 5,125 kg quality seeds were retained by the farmers for the next year use. About 3,937 farmers acquired awareness and knowledge about the varieties through field visits, discussion and knowledge sharing. A total of 1,213 farmers were motivated and showed their interest to cultivate these varieties in the next year.

Adaptive trial (AT) in valley during T. Aman 2019. The experiments were conducted at valley of hill in farmers' field of Khagrachari, Bandarban and Rangamati districts. The trial was non-replicated in six sites of six different upazilas in Khagrachari, two sites in two upazilas of Rangamati and five sites in four upazila of Bandarban. Five high yielding modern T. Aman rice varieties (BRRI dhan71, BRRI dhan72, BRRI dhan75, BRRI dhan80 and BRRI dhan87) and one local check were cultivated side by side in one bigha of land. Among the varieties, BRRI dhan87 yielded the highest (5.25 t ha^{-1}) followed by BRRI dhan80 (4.31 t ha^{-1}) with similar growth duration (126 days). These varieties might be suitable for hill areas in T. Aman season. Rice varieties in most of the locations were affected by sheath blight disease. BRRI dhan72 were mostly affected one.

SPDP in valley during T. Aman 2019. The demonstrations were conducted at farmers' field of Khagrachari, Bandarban and Rangamati districts. Each SPDP was consists of two variety cultivated in two bigha of land. The SPDPs were executed in six sites of six different upazila in Khagrachari, two sites in two upazila of Rangamati and five sites in four upazila of Bandarban. Two high yielding modern T. Aman rice varieties, BRRI dhan49 and BRRI dhan87 were used as cultivar. BRRI dhan87 (5.78 t ha^{-1}) showed much higher yield compared to BRRI dhan49 (4.99 t ha^{-1}) with one-week growth duration advantage. Total 848 and 360 kg seeds of BRRI dhan87 and BRRI dhan49, respectively were retained for seed purpose for use in the next year.

SPDP during T. Aman 2019 under TTFP. Four demonstrations with BRRI released rice varieties were established in farmer's field at Valuka and Muktagacha upzillas of Mymensingh; Sadar and Sarisabari upazilas of Jamalpur district funded by transfer of agricultural technologies to farmers' level for increasing farm productivity (TTFP) project with funding source of NATP-2. BRRI dhan70, BRRI dhan71, BRRI dhan75, BRRI dhan79, BRRI dhan80 and BRRI dhan87 were used in Aman 2019. Six farmers were selected in each location. Land area of each location was 6 bighas (2 acre) having 1 bigha of land for 1 farmer. Therefore, total no. of farmers was 24 and total demonstration area was about 24 bigha. Total paddy production was 16,181 kg from which farmers retained 2,877 kg as seed for the next year cultivation. A considerable number of farmers observed the performance of the six BRRI released recent rice varieties and among them 642 farmers were motivated for the next year cultivation.

SPDP in Boro 2020. On-farm demonstrations were conducted in different Agro Ecological Zones (AEZ) of the country covering 36 upazilas of 15 districts. Eight varieties like BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan88 and BRRI dhan89 suitable for favourable and stress prone rice growing eco-system were cultivated. The demo areas were three bigha with three varieties having one bigha of land for each variety. Among the varieties, BRRI dhan89 produced the highest grain yield 7.45 t ha^{-1} followed by BRRI dhan58 (6.39 t ha^{-1}) and BRRI dhan81 (6.28 t ha^{-1}). A total of 12,989 kg seeds were retained by the involved and neighboring farmers for next year cultivation.

SPDP in Boro 2020 under the TRB project. Thirty-eight SPDPs were conducted in 24 upazilas of 17 districts under TRB project. Seven modern rice varieties BRRI dhan58, BRRI dhan67, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88 and BRRI dhan89 were demonstrated in the SPDPs. The programme was executed in collaboration with farmers, Department of Agricultural Extension (DAE) and non-government organizations. Across the locations, BRRI dhan89 produced the highest grain yield followed by BRRI dhan74. Total production of all the varieties was 1,01,568 kg from which 9,535 kg was retained as seeds for next season cultivation.

SPDP in valley during Boro 2020 under HNRP. SPDPs were conducted at the valley of hills in three hilly districts of Bangladesh (Bandarban, Rangamati, and Khagrachari) in Boro 2020. BRRI developed Boro rice varieties BRRI dhan58, BRRI dhan67, BRRI hybrid dhan3 and BRRI hybrid dhan5 were used in the demonstration. A total of 9,715 kg seeds were produced and the amount of retained seeds was 1,445 kg by 281 motivated farmers**.**

SPDP during Boro 2020 under TTFP. Four demonstrations with BRRI released rice varieties were established in farmer's field at Valuka and Muktagacha upazilas of Mymensingh; Sadar and Sarisabari upazilas of Jamalpur district funded by TTFP project of NATP-2. BRRI dhan58, BRRI dhan67, BRRI dhan81, BRRI dhan84, BRRI dhan88 and BRRI dhan89 were demonstrated in Boro 2020. Total paddy production from these six rice varieties was 19,839 kg from which farmers retained 3,486 kg as seed for the next year cultivation. A considerable number of farmers observed the performance of varieties and 619 farmers were motivated for the next year cultivation.

FARMERS TRAINING AND PROMOTIONAL ACTIVITIES

Farmers' Training. During the reporting period, ARD conducted 91 farmers' training at different locations of the country under GoB and different projects (20 from HNRP and 18 from TRB) from which 2,730 trainees (2,128 male farmers, 397 female farmers and 205 SAAOs of DAE) participated on modern rice production technologies.

Field day. ARD conducted 50 Field days at different locations of the country under GoB and different projects (SPIRA, TRB and HNRP/PPNB).

Around 7,000 participants including farmers, local leaders and DAE personnel participated in the field days. These programmes also generated much enthusiasm about modern rice production technologies and BRRI varieties, which helped rapid dissemination of technologies.

Seed Production at BRRI farm. Quality seeds of recently released promising and potential rice varieties were produced during T. Aman 2019 and Boro 2020 seasons. A total of 7.0 tons quality seeds of BRRI varieties were produced. The seeds were used to conduct research activities and dissemination programme.

Seed support to farmers and stakeholders under TRB project. Adaptive Research Division distributed 3.15 and 3.35 tons of truthfully labeled seeds (TLS) of 24 modern rice varieties to farmers and stakeholders with free of cost in Aman 2019 and Boro 2020 respectively among the farmers.

Establishment of farmer's seed center under TRB project. Two seed centers for farmers were established at Palashbari and Gobindaganj upazilas of Gaibandha district. Six plastic drums were provided in each center. Around 80 kg seeds were preserved in each drum.

Training Division

SUMMARY

Training Division has conducted 31 training programmes in the reporting year with course duration from two days to two months. Need based course curriculum was developed for these courses. Total number of participants was 635. The participants were Agriculture Extension Officers and Sub-Assistant Agriculture Officers (SAAO) of the Department of Agriculture Extension (DAE), BRRI Scientists, ACI field level extension workers and IRRI officials. The highest number of participants was from the DAE. The overall improvement of knowledge for SAAOs in 1-week Rice Production Training (RPT) was 186% with wide range from 120% to 490%. Knowledge improvement of DAE officers in two-month long rice production technologies training course 214% items were in theory and 119% of them were practical evaluations. The results indicate the significance of rice production training for extension personnel. Effectiveness of imparted training was determined on the basis of feedback response on different aspects. Most of the trainees expressed positive views about the course content and method of training. However, participants of the 1-week course suggested for increasing duration of the course from 1-week to at least 2-3 weeks. Most of the BRRI's speakers' performance was very good to excellent.

TRAINING NEED ASSESSMENT

A need assessment session was conducted at the beginning of each batch of training to know the expectation of the trainees. A total of 683 responses on different issues were received from the trainees. Out which 505 were from one week modern rice production training for the SAAOs and 178 were from the two-month long modern rice production technologies for DAE officers. Though the participants were of different categories, their expectations were very much similar. SAAOs showed high expectation about disease and insect management followed by variety related issues. Participants of DAE officers also showed similar expectations like the SAAOs. High expectation of participants, in case of two-month RPT course for DAE officers was on insect, disease and variety related issues followed by soil and fertilizer management techniques (Table 1).

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

Training on rice physiological development through trait discovery

A training programme on 'Rice physiological development through trait discovery' under the project of Physiological Development through Trait Discovery for Boosting Rice Yield in Changing Climatic Conditions was conducted in 2019-20. Duration of the course was five days. A total of 28 participants were trained through this course. The participants of this course included scientific officers (SO) and senior scientific officers (SSO) of BRRI. Table 2 presents the particulars of the trainings.

Training on Agricultural Research Methodology

A training programme on 'Agricultural Research Methodology' for BRRI scientists was conducted in 2019-20. Duration of the course was five days. A total of 50 participants were trained in two batches through this course. The participants of these course were Scientific Officers and Senior Scientific Officers of BRRI. Table 3 presents the particulars of the trainings.

Training on modern rice production technologies (Regular)

Twenty training courses on modern rice production technologies were conducted during the reporting period. The main objective of the course was to train the grass root level extension workers (SAAO) of DAE. The course curriculum was designed based on the priority of field problems related to rice production and rice based technologies. Lecture and discussion, field visit, hands-on practical session, review session etc were the leading training methods in this course. Duration of the course was one week. A total of 394 SAAOs were trained. Among the participants 367 and 27 were male and female respectively (Table 4).

Benchmark and final evaluation tool was applied to assess the knowledge improvement of individual participants. The average knowledge gain and improvement of the participants were 45% and 186% respectively (Table 5).

Table 1. Expectations of the SAAO and DAE officers on different subjects in need.

Subject/Issue	SAAO Expectation (%)	Rank	Subject/Issue	DAE Officer Expectation (%)	Rank
Disease	26	1	Insect	21	1
Insect	24	2	Disease	21	1
Variety	18	3	Variety	15	2
Seed	14	4	Soil and fertilizer management	12	3
Plant physiology	11	5	Cultivation and weed management	10	4
Cultivation and weed management	6	6	Plant physiology	6	5
Others	1	7	Irrigation	6	5
-	-	-	Seed and seedbed	3	6
-	-	-	Farm machinery	3	7
Total	100	-	Total	100	-
Response no.	505	-	Response no.	178	-

Table 2 . Training on rice physiological development through trait discovery.

Duration	Participants (no.)			Designation	Organization
	Total	Male	Female		
29 Dec 2019-2 Jan 2020	28	20	8	SO, SSO	BRRI

Table 3 . Training on agricultural research methodology for BRRI scientists.

Duration	Participants (no.)			Designation	Organization
	Total	Male	Female		
16-20 Nov 2019	25	15	10	SO	BRRI
22-26 Dec 2019	25	21	4	SSO	
Total	50	36	14		

Table 4. Particulars of one-week modern rice production training for SAAO of DAE.

Duration	No. of participants		
	Total	Male	Female
24-29 Aug 2019	20	20	0
24-29 Aug 2019	20	20	0
31Aug-5 Sep 2019	20	20	0
31Aug-5 Sep 2019	20	18	2
7-12 Sep 2019	20	18	2
7-12 Sep 2019	20	20	0
14-19 Sep 2019	17	17	0
14-19 Sep 2019	20	20	0
21-26 Sep 2019	19	19	0
21-26 Sep 2019	20	20	0
28 Sep-3 Oct 2019	20	16	4
28 Sep-3 Oct 2019	20	18	2
12-17 Oct 2019	20	20	0
12-17 Oct 2019	20	18	2
19-24 Oct 2019	19	18	1
19-24 Oct 2019	20	14	6
26-31 Oct 2019	20	16	4
26-31 Oct 2019	20	19	1
2-7 Nov 2019	19	17	2
2-7 Nov 2019	20	19	1
Total	394	367	27

Table 5. Knowledge gain, improvement and performance status of one week modern rice production training.

Evaluation Score (%)		Gain	Improvement (%)	Performance		
Benchmark	Final			Distinction	Satisfactory	Participatory
22	70	48	218	7	8	5
29	73	44	152	9	7	4
30	66	36	120	7	8	5
30	66	36	120	5	10	5
27	67	40	148	7	9	4
28	73	45	161	10	8	2
26	66	40	154	5	7	5
26	71	45	173	6	12	2
10	59	49	490	0	13	6
24	71	47	196	5	13	2
25	67	42	168	6	9	5
21	69	48	229	7	10	3
24	63	39	163	4	9	7
25	71	46	184	7	9	4
25	68	43	172	6	10	3
23	72	49	213	8	10	2
20	72	52	260	5	13	2
24	79	55	229	10	10	0
16	59	43	269	2	8	9
26	72	46	177	4	15	1
Av. 24	69	45	186	120	198	76

Two-month long rice production technologies training course for DAE Officers

The main objectives of the course were to train the DAE officers so that they can acquire and enrich knowledge on:

- Modern rice production technologies
- Identification of field problems of rice cultivation and its solutions and
- Quick dissemination of rice production technologies in the field

The course curriculum was designed as per requirement and objectives of the course. Enhanced lectures and discussions followed by group discussion, individual presentations, practical session, field visit, review and feedback etc were the predominant training methods in this course. Two batches of the training were arranged during the reporting period. Total participants were 60. Out of which 47 were male and 13 were female. Table 6 presents the particulars of the participants.

Improvement of knowledge was measured on the basis of marks obtained in the benchmark and final evaluation of individual participant. Knowledge improvement through this training was very attractive. It was 214% for theory and 119% for skill. (Table 7).

Modern rice production training course for ACI Officials

A training programme on modern rice production technologies for the ACI (Seed) officers was conducted during the reporting period. Duration of the course was 6 days. Twenty participants were trained through this course. Table 8 presents the particulars of the trainings.

Training on rice grain quality analysis

A training programme on rice grain quality analysis was conducted for the ACI and IRRI officers in 2019-20. Duration of the course was 12 days. Ten participants (Scientists, assistant scientists, associate scientists, senior specialists) were trained through this course. Table 9 presents the particulars of the trainings.

Modern rice production and ecofriendly insect management training

In the year 2019-20, one-week training programme on modern rice production and insect management training was conducted for the SAAOs of DAE. The training was funded by strengthening ecofriendly insect management programme to increase rice yield. The objective of the course was to train the SAAOs of project areas so that they could participate in disseminations of rice technology as well as ecofriendly insect management practices by motivating the farmers. A total of 20 SAAO were trained through this course (Table 10). Table 11 presents the knowledge gain, improvement and performance status of the imported training courses.

Training on data collection, field management and laboratory machinery handling

Three training programmes on data collection, field management and laboratory machinery handling for scientific assistants (SA), senior scientific assistant (SSA) and laboratory attendant (LA) of BRRI were conducted during the reporting period. Table 12 presents the particulars of the trainings.

Training information over all

During the reporting period, 31 training programmes have been conducted by the Training Division. Through this trainings a total of 635 participants were trained. Table 13 presents the summaries of the trainings.

Table 6. Two-month long modern rice production training course for DAE officers.

Duration	Participant (no.)			Designation
	Total	Male	Female	
17 Nov 2019 -15 Jan 2020	30	24	6	AEO
22 Feb-21 April 2020*	30	23	7	AEO
Total	60	47	13	

* Not completed due to COVID-19

Table 7. Knowledge gain, improvement and performance status of two-month long modern rice production training course.

Category of evaluation	Bench mark evaluation score (%)			Final evaluation score (%)			Improvement (%)		
	Male	Female	All	Male	Female	All	Male	Female	All
Theory	28	26	27	84	85	85	200	227	214
Skill	36	41	39	84	84	84	133	105	119

Table 8. Particulars of one-week long modern rice production training course for ACI (Seed) officer.

Duration	Participants (no.)			Designation	Organization
	Total	Male	Female		
27 July-1 August 2019	20	20	0	APO, FRO, PO, PDS officer	ACI seed

Table 9. Training on rice grain quality analysis.

Duration	Participants (no.)			Designation	Organization
	Total	Male	Female		
1-12 September, 19	10	9	1	Scientist, Assistant Scientist, Associate Scientist, Senior Specialist	ACI and IRRI Bangladesh

Table 10. Modern rice production and ecofriendly insect's management training course for SAAO of DAE.

Duration	Participants (no.)		
	Total	Male	Female
11-16 January, 2020	20	16	4

Table 11. Knowledge gain, improvement and performance status of one-week long modern rice production and eco friendly insect's management training course.

Evaluation score (%)		Gain	Improvement (%)	Performance		
Benchmark	Final			Distinction	Satisfactory	Participatory
20	78	58	287	11	9	0

Table 12. Training on data collection, field management and laboratory machinery handling.

Duration	Participants (no.)			Designation	Organization
	Total	Male	Female		
21-22 June 2020	17	12	5	SA,SSA	BRRI
23-24 June 2020	18	17	1	SA,SSA	
29-30 June 2020	18	12	6	LA	
Total	53	41	12	Total	

Table 13. Particulars of the total training courses conducted by Training Division in 2019-20.

Name of the training	No. of training	Duration	No. of participants			Designation
			M	F	Total	
Modern rice production training	20	1-week	367	27	394	SAAO, DAE
Two-month long rice production training	2	2-month	47	13	60	AEO, DAE
Training on agricultural research methodology for BRRI scientists	2	5-day	36	14	50	SO,BRRI
Training on rice physiological development through trait discovery	1	5-day	20	8	28	SO,SSO,BRRI
Modern rice production and ecofriendly insects management training course	1	1-week	16	4	20	SAAO,DAE
Training on rice grain quality analysis	1	12-day	9	1	10	ACI and IRRI Officers
Modern rice production training	1	6-day	20	0	20	ACI (Seed) Officers
Training on data collection, field management and laboratory machinery handling	3	2-day	41	12	53	SA, SSA, LA, BRRI
Total	31		556	79	635	

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

Twenty batches of one-week modern rice production training for SAAOs and one batch of two-month long modern rice production technologies for DAE officers 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

SUMMARY

Ninety-six new crosses were made, five crosses were confirmed, 4,262 plant progenies were selected from segregating populations (F_2-F_5) and 250 advanced breeding lines were bulked from F_6 generation during the reporting period. From a special segregating population, 1,350 plants were selected and 770 lines were bulked with a special thrust for the development of new generation rice (NGR). Two PYTs, one for non-saline tidal ecosystem during T. Aus 2019 and the other for FBR during Boro 2019-20 were conducted. One RYT for non-saline tidal ecosystem during T. Aus 2019, two RYTs for ZER and DRR and one special yield trial (SYT) in T. Aman 2019 and six RYTs in Boro 2019-20 were conducted. One AYT in T. Aman 2019 and five AYTs in Boro 2019-20 were conducted. A total of 369 local Aman germplasm were collected and grown in six-line plots for characterization, utilization and maintenance.

To reduce insecticides uses, zero insecticide (ZI) technology was practiced in BRRI RS, Barishal Charbadna and Sagordi farms for seed production during Boro 2019-20. About 100 perch per hectare of land were installed to facilitate birds to sit on and took randomized 20 complete sweep for counting insect pests and natural enemy and subsequently in the potentially infested plots were identified for complete sweeping for controlling insect pests. Insect pests along with natural enemy population were monitored in the light trap. Insect pests viz green leafhopper, brown plant hopper and yellow stem borer were appeared in light trap. In case of natural enemies, the highest population was staphylinid beetle followed by carabid beetle, green mirid bug and lady bird beetle. To find out the impact of lighting period on the trapping of insect, an experiment was conducted during Aman 2019. The maximum insects appeared (69.28%) during dusk to first four hours caught in the light trap experiment and 89.65% harmful insects and 10.35% natural enemies caught overnight found in the same experiment.

A screening of nine available recommended pesticides against rice blast disease was conducted. Among those, Nativo (91.10%), Difaa (76.52%), Blastin (72.27%), and Zeal (71.38%) significantly reduced neck blast (NB) disease over untreated control (plain water). Survey and monitoring of rice diseases in selected areas of Barishal were conducted during Aman 2019 and Boro 2019-20. Brown spot and bacterial leaf blight were recorded as major diseases. The management option of blast disease was demonstrated at farmers' field. About 20.44% yield reduction was observed in farmers' managed control plots compared to recommended management practiced plots. It also decreased about 81.1% disease incidence over control plots.

Breeding lines, BR8441-38-1-2-2 and BR8143-15-2-1 may be selected for proposed variety trial from ALART of RLR and ZER respectively during T. Aman 2019. In Boro 2019-20, BR8862-29-1-5-1-3 and BR8995-2-5-5-2-1 of premium quality rice (PQR), IR99285-1-1-1-P2 of zinc enriched rice (ZER), HR (Path)-11 and Path2441 of blast resistant rice (BRR), BR8938-19-4-3-1-1-P2-HR3, BR9651-15-2-1-4 and BR (Bio)11447-1-28-14-3 of bacterial leaf blight resistant rice (BBRR) trials may be selected for proposed variety trial.

During the reporting year, seven demonstrations each of two acres of land, three in Aman season and four in Boro season, were conducted under SPIRA project. Besides, 53 seed support demonstrations were also conducted. Fifteen farmers' trainings and nine field days in different locations of Barishal region were organized.

A total of 16,000 kg breeder seed and 9,733 kg TLS during T. Aman 2019 and 33,040 kg breeder seed and 24,728 kg TLS during Boro 2019-20 season were produced.

VARIETY DEVELOPMENT

Hybridization, T. Aman 2019 and Boro 2019-20

Parents were grown in three sets at seven days interval to synchronize flowering times for achieving desired cross combinations. Thirty-day-old-seedlings were transplanted in a 5.4 m x 4 rows plot with a spacing of 20 × 20 cm. Single seedlings were used for transplanting. Fertilizer doses were 280-100-165-110-10 kg/ha Urea-TSP-MOP-gypsum-ZnSO4 with split application of urea (100+100+80) kg/ha. Total amount of P K S and Zn were applied at the time of final land preparation. Crop management practices were done as and when necessary. Forty-two crosses were made using local cultivars and high yielding varieties and 1,858 F_1 seeds were obtained during T. Aman 2019 (Table 1a). Besides To introgression of dense and erect panicle gene in indica rice to improve plant architecture six crosses were made and 139 F_1 seeds were obtained (Table 1b). During Boro 2019-2020, a total of 48 crosses were made and 4895 F_1 seeds were obtained (Table 1c).

Table 1. List of F_1 seeds produced in T. Aman 2019 and Boro 2019-20, BRRI RS, Barishal.

Cross combination	No. of seeds	Cross combination	No. of seeds
	Tidal submergence		
Bashful/BRRI dhan52	17	BRRI dhan76/Muthadhan	31
BINA dhan11/Dudmona	24	BRRI dhan76/IR 64- Pish	18
BR 23/BRRI dhan87	43	BRRI dhan77/IR 14 L 395	48
BR 23/Muthadhan	27	BRRI dhan77/Kotiagoni	88
BR 23/IR 64 Piz-t	28	BRRI dhan77/Chaulamagi	45
BRRI dhan41/BRRI dhan87	27	BRRI dhan77/Muthadhan	37
BRRI dhan52/IR 13 A 515	150	BRRI dhan77/Bashful	57
BRRI dhan52/ IR 87959-6-2-1-2 B -AYB-CMU 1	49	BRRI dhan87/Lalchikon	31
BRRI dhan52/IR 13 A 515	69	BRRI dhan87/Bashful	40
BRRI dhan52/BR 10	56	Hori dhan/Kotiagoni	34
BRRI dhan52/BRRI dhan87	48	IR 103795-B-B-2-1/BINA dhan11	107
BRRI dhan52/Dudmona	86	IR 103795-B-B-2-1/Bashful	10
BRRI dhan52/Lalchikon	26	IR 18028-B-B-B-1-B-B/BINA dhan11	87
BRRI dhan76/Dudmona	57	IR 18028-B-B-B-1-B-B/Lalchikon	47
BRRI dhan52/Muthadhan	12	IR 64-Pizt/BRRI dhan34	45
BRRI dhan77/IR 13 A 515	31	IR 9831-22 BAT2-1-CMU1/BRRI dhan52	42
BRRI dhan77/IR 16 F 1045	13	IR 9831-22 BAT2-1-CMU1/BR23	31
BRRI dhan77/BR 10	65	Lalchikon/BRRI dhan76	38
BRRI dhan77/BRRI dhan87	34	Lambu IRRI/BRRI dhan76	38
BRRI dhan76/Chaulamagi	16	Pb-1 (US)/BRRI dhan52	20
BRRI dhan76/Kotiagoni	60	Pb-1 (US)/BRRI dhan34	26
	Introgression of dense and erect panicle gene		
BRRI dhan52/MK 628	32	BRRI dhan76/MK 630	7
BRRI dhan52/MK 630	5	BRRI dhan77/MK 628	23
BRRI dhan76/MK 628	45	BRRI dhan77/MK 632	26
	Favourable Boro		
BRBa 2-5-3/AKT6	82	NGR 1-5/BRRI dhan67	160
NGR 1020-1/BRRI dhan29	66	NGR 2-1/BRRI dhan67	170
NGR 105-2/BRRI dhan29	168	NGR 991-3/BRRI dhan67	161
NGR 109-1/BRRI dhan29	79	BRBa 3-2-6/BRRI dhan74	117
NGR 22-2/BRRI dhan29	160	NGR 445-2/BRRI dhan74	55
NGR 239-1/BRRI dhan29	77	BRBa 2-9-4/BRRI dhan74	68

Table 1. Continued

NGR 43-1/BRRI dhan29	126	BR 9943-35-2-1-2-B2/BRRI dhan74	10
NGR 5-1/BRRI dhan29	154	NGR 445-2/BRRI dhan86	114
NGR 99-3/BRRI dhan29	189	NGR 938-2/BRRI dhan86	114
BRBa 2-5-3/BRRI dhan47	41	NGR 445-2/BRRI dhan88	91
BRBa 3-2-6/BRRI dhan47	109	BRBa 2-5-3/BRRI dhan89	19
NGR 445-2/BRRI dhan47	47	BRBa 3-3-3/BRRI dhan89	34
NGR 105-2/BRRI dhan50	142	NGR 109-1/BRRI dhan89	183
NGR 22-2/BRRI dhan50	200	NGR 1346-2/BRRI dhan89	122
NGR 99-2/BRRI dhan50	128	NGR 2-1/BRRI dhan89	65
BRBa 2-9-4/BRRI dhan58	70	NGR 991-3/BRRI dhan89	134
BRBa 3-3-3/BRRI dhan58	23	BR 9943-35-2-1-2-B2/BRRI dhan89	9
NGR 1020-1/BRRI dhan58	63	BR (Bio) 11447-1-28-14-1/MK628	30
NGR 1-5/BRRI dhan58	146	BRBa 2-9-4/MK628	99
NGR 239-1/BRRI dhan58	72	BRBa 3-2-6/MK628	162
NGR 43-1/BRRI dhan58	99	BR (Bio) 11447-1-28-14-1/MK630	67
BR (Bio)11447-1-28-14-1/BRRI dhan67	79	BRBa 2-5-3/MK630	90
BRBa 2-9-4/BRRI dhan67	96	BRBa 2-9-4/MK630	127
NGR 1346-2/BRRI dhan67	124	BRBa 3-2-6/MK630	154

F_1 confirmation in T. Aman 2019

Nine F_1 s were grown during T. Aman 2019. Out of nine crosses, five crosses were confirmed and registered in BRRI cross list with station code BRBa73 to BRBa77 (Table 2).

Generation advance of pedigree population

During T. Aman 2019, in tidal submergence 198 F_4 plant progenies of 21 crosses were grown. And 1,962 F_6 plant progenies of eight crosses were grown. A total of 452 plant progenies were selected from 21 crosses for further generation advance as F_5 and 101 advanced lines were selected and bulked for observation of yield trial in next T. Aman 2020 season. To introgression of dense and erect panicle gene in indica rice to improve plant architecture, 22 F_2 population were grown and 418 plants were selected for further generation advance as $F_{3.}$ A total of 133 F_4 plant progenies of four crosses were grown and 266 plant progenies were selected for further generation advance as $F_{5.}$ A total of 95 F_5 plant progenies of four crosses were grown and 155 plant progenies were selected for further generation advance as $F_{6.}$

During Boro 2019-20, a total of 5 F_2 population were grown and 222 plant progenies were selected for further generation advance as $F_{3.}$ A total of 1,162 F_3 plant progenies of 22 crosses were grown and 2,346 plant progenies were selected for further generation advance. In dense and erect panicle, 240 F_5 plant progenies of four crosses were grown and 403 plant progenies were selected for further generation advance as $F_{6.}$ A total of 149 F_6 plant progenies of four crosses were grown and 149 advanced lines were bulked for further evaluation in OYT.

In a special segregation population, during Aus 2019 about fifty thousand plants were grown from a bulked population seeds visually selected based on presence of awn. Out of that about 1500 plants were selected based on presence of awn, plant type, grain, and panicle size. Selected plant population were grown in T. Aman 2019 and selected about 2,400 better performing plants in respect of plant stature, panicle size and awn. The selected plant population were grown in Boro 2019-20 and 1350 plant selection and 770 lines were bulked based on performance, uniformity and segregation present in each plant population.

YIELD TRIAL 2019-20

Observational yield trial (OYT), Boro 2019-20

A total of 101 entries along with four checks BRRI dhan28, BRRI dhan29, BRRI dhan58 and BRRI dhan74 were grown in BRRI RS, Charbadna farm, Barishal during Boro 2019-20. Each entry was grown in a 5.4 m x 1.0 m plot with a spacing of 20 cm x 20 cm using single seedling per hill. Standard fertilizer management and other cultural practices were done as and when necessary. Based on plant height, growth duration, phenotypic acceptability and grain yield performance, results of top ten genotypes were selected from 101 entries for further evaluation (Table 3).

PRELIMINARY YIELD TRIAL (PYT), 2019-20

PYT, T. Aus 2019

The PYT consisting of six genotypes along with the two checks BRRI dhan27 and BRRI dhan48 were evaluated at South Ghatkhali and Tiakhali block of Amtoli, Barguna in Aus 2019. The plant height was ranged from 97.7 cm to 131.0 cm. Growth duration was ranged from 105-112 days where as grain yield was ranged from 3.32-4.51 t/ha. The three genotypes BR9829-78-1-3-2 (4.51 t/ha), BR9829-78-1-2-1 (4.49 t/ha) and BR9830-5-2-2-3 (4.47 t/ha) yielded better than both the checks having more or less similar growth duration. The three advanced lines BR9829-78-1-3-2, BR9829-78-1-2-1 and BR9830-5-2-2-3 performed better in tidal non-saline ecosystem in terms of phenotypic acceptability, plant height, growth duration and grain yield and recommended f for further generation advanced as RYT in Barishal region.

PYT, Boro 2019-20

Eleven advanced breeding lines along with BRRI dhan28, BRRI dhan58 and BRRI dhan74 as standard checks were evaluated at Charbadna farm, BRRI RS, Barishal. The plant height (cm) and panicles per hill (no) were ranged from 97.0 -119.1 and 7.2-11.0 respectively. Thousand grain weight (g) and growth duration (days) ranged from 19.0 to 28.4 and 139 to 146 respectively. The highest grain yield was produced by check variety BRRI dhan74, and yield of test entries ranged from 5.41-6.78 t ha^{-1}.

Table 2. List of confirmed F_1 s during T. Aman 2019, BRRI RS, Barishal.

Parentage	BRBa no.
SumonSwarna/Katarivog	BRBa73
BRRI dhan28/Katarivog	BRBa74
BRRI dhan29/Katarivog	BRBa75
BRRI dhan58/BRRI dhan89	BRBa76
Parija/BRRI dhan58	BRBa77

Table 3. List of entries selected from OYT during Boro 2019-20, BRRI RS, Barishal.

Designation	Plant height (cm)	Growth duration (day)	Tiller/hill (no.)	Panicle/hill (no.)	Grain Yield (t ha^{-1})
BRBa16-28-2-1-6-B	113.9	153	13.2	12.0	8.34
BRBa12-38-1-2-3-B	122.8	155	12.4	10.0	8.33
BRBa12-43-3-1-3-B	114.3	158	12.4	11.2	7.92
BRBa13-44-1-4-1-B	112.8	154	12.6	11.4	7.71
BRBa12-27-2-2-3-B	119.7	152	12.6	12.0	7.68
BRBa13-43-1-2-3-B	105.6	159	11.2	10.6	7.47
BRBa13-44-2-5-3-B	89.3	151	16.0	15.2	7.20
BRBa11-81-2-2-3-B	120.3	150	9.6	9.0	6.96
BRBa12-24-8-3-4-B	104.2	150	14.8	13.2	6.70
BRBa15-45-2-2-4-B	106.7	157	11.0	10.0	6.67
BRRI dhan28 (Ck)	101.9	143	13.5	12.1	6.09
BRRI dhan29 (Ck)	101.7	156	14.3	13.2	6.93
BRRI dhan58 (Ck)	105.3	150	15.3	13.1	6.51
BRRI dhan74 (Ck)	99.6	149	13.8	12.3	6.77

DS: 28 Dec 2019 DT: 11 Feb 2020 Spacing: 20 cm × 20 cm

Special yield trial (SYT) for RLR and ZER, T. Aman 2019

A total of three entries along with the four checks BRRI dhan39, BRRI dhan49, BRRI dhan72 and BRRI dhan87 were grown at Charbadna farm, BRRI RS, Barishal during T. Aman 2019. Growth duration ranged from 116-143 days and grain yield ranged from 5.05-6.01 t ha^{-1}. The highest grain yield was found in the genotype BR8442-12-1-3-1-B5 (6.0 t ha^{-1}) followed by BRRI dhan87 (5.81 t ha^{-1}). The lowest grain yield (5.05 t ha^{-1}) was recorded in the genotype BRRI dhan39.

REGIONAL YIELD TRIAL (RYT), 2019-2020

RYT, T. Aus 2019

RYT consisting of three advanced breeding lines along with the two checks BRRI dhan27 and BRRI dhan48 was conducted at four locations of Barishal region. The two advanced lines BR8784-4-1-2-P2 and BR8781-16-1-3-P2 performed better in tidal non-saline ecosystem in terms of phenotypic acceptability, plant height, growth duration and grain yield and recommended f for further generation advanced as ALART in Barishal region (Table 4).

RYT for zinc enriched rice (ZER), T. Aman 2019

A total of six entries along with the two checks BRRI dhan49 and BRRI dhan72 were grown at Charbadna farm, BRRI RS, Barishal during T. Aman 2019. The highest grain yield was found in the genotype BR9871-29-1-3-B (5.93 t ha^{-1}) followed by BR10001-94-2-B (5.77 t ha^{-1}) and BR9868-19-40-3-B (5.69 t ha^{-1}). The lowest grain yield (5.46 t ha^{-1}) was recorded in the genotype BRRI dhan49.

RYT for disease resistant rice (DRR), T. Aman 2019

Six disease resistant (one blast, two BB and three RTV) entries along with the two checks BRRI dhan49 and BRRI dhan87 were grown at BRRI Charbadna farm, Barishal during T. Aman 2019.

Rats totally damaged he plots of BR10395-22-3-5 (blast). The genotype BR10393-2-2-2 (RTV) (6.31 t ha^{-1}) produced the highest grain yield among the check varieties BRRI dhan49 (5.30 t ha^{-1}) and BRRI dhan87 (5.64 t ha^{-1}). The genotype BR10397-4-1-2 (BB) (5.93 t ha^{-1}) produced the similar grain yield but with six days longer growth duration than the check BRRI dhan87 (5.64 t ha^{-1}). The genotypes BR10393-2-2-2-3 (RTV) (5.69 t ha^{-1} and 137 days) and BR10393-4-1-3-4 (RTV) (5.73 t ha^{-1} and 135 days) produced similar grain yield and growth duration with the check BRRI dhan49 (5.30 t ha^{-1} and 136 days). There was no disease symptom appeared in field condition of this trial.

Regional yield trial for favourable Boro rice (FBR), Boro 2019-20

Two regional yield trials of FBR were conducted. The details of the trials are as follows:

RYT # FBR-1. Ten entries along with the three checks BRRI dhan58, BRRI dhan81 and BRRI dhan89 were grown at Charbadna farm, BRRI RS, Barishal during Boro 2019-20. None of the genotypes performed better than the check varieties. The check variety BRRI dhan89 produced the highest grain yield (7.19 t ha^{-1}) followed by BRRI dhan58 (6.9 t ha^{-1}), BR8905-17-2-3-3-1-1 (6.82 t ha^{-1}), BR8902-38-7-1-1-1-1 (6.3 t ha^{-1}) and IR100740-89-B-2 (6.25 t ha^{-1}).

Table 4. Yield and ancillary characters of RYT genotypes T. Aus 2019, Barishal.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})				
			L1	L2	L3	L4	Mean
BR8784-4-1-2-P2	125.7	116	4.66	4.64	4.28	4.38	4.49
BR8781-16-1-3-P2	123.0	115	4.63	4.83	4.68	4.43	4.64
BR9006-62-2-2-2	117.0	108	4.24	4.16	3.88	4.05	4.08
BRRI dhan27 (Ck)	143.6	110	3.91	3.64	3.58	3.09	3.56
BRRI dhan48 (Ck)	109.2	107	4.31	4.38	4.24	3.99	4.23
LSD (0.05)	1.99	0.55					0.17
CV (%)	1.95	0.60			4.87		

L1=North Ghatkhali; L2=South Ghatkhali; L3=Tiakhali; L4=BRRI Charbadna farm.

RYT # FBR-2. A total of six genotypes along with the two checks BRRI dhan58 and BRRI dhan63 were grown at Sagardi farm, Barishal during Boro 2019-20. The genotype BRH11-9-11-4-5B-HR3 provided higher grain yield (8.37 t ha^{-1}) than the check BRRI dhan63 (6.45 t ha^{-1}) but produced similar grain yield to the check BRRI dhan58 (8.07 t ha^{-1}). The three genotypes BRH13-2-4-6-4B (7.85 t ha^{-1}), BRH11-2-1-3-8B (7.53 t ha^{-1}) and BRH9-7-4-1B (7.49 t ha^{-1}) produced higher grain yield than the check BRRI dhan63 (6.45 t ha^{-1}). The genotype IR12A177 produced the similar grain yield and growth duration to the check variety BRRI dhan63 (6.45 t ha^{-1}). The lowest grain yield was found in the genotype BRH11-2-4-9B (5.64 t ha^{-1}) that completely Submergence for five-days due to Amphan storm during reproductive phase (Table 5).

Regional yield trial for zinc enriched rice (ZER), Boro 2019-20

Three entries along with four checks BRRI dhan28, BRRI dhan29, BRRI dhan74 and BRRI dhan84 were grown at Sagardi farm, Barishal during Boro 2019-20.

The genotype IR105837-8-45-1-1 produced the highest grain yield (7.89 t ha^{-1} and 153 days) among all the check varieties (6.89-7.61 t ha^{-1} with 143-158 days) having five days earlier growth duration than the check variety BRRI dhan29 (153 days). The genotype BR8912-12-6-1-1-1-1 (7.82 t ha^{-1} with 154 days) produced the higher grain yield than the checks BRRI dhan28 (6.89 t ha^{-1} with 143 days), BRRI dhan84 (6.90 t ha^{-1} with 143 days) and BRRI dhan74 (7.17 t ha^{-1} with 147 days) but 11 days longer than BRRI dhan28 and BRRI dhan84 with seven days longer than BRRI dhan74.The genotype IR105837-8-95-2-1 (7.22 t ha^{-1} with 147 days) produced the higher yield but with four days longer growth duration than the checks BRRI dhan28 (6.89 t ha^{-1} with 143 days) and BRRI dhan84 (6.90 t ha^{-1} with 143 days).

Regional yield trial for premium quality rice (PQR), Boro 2019-20

Four entries along with three checks BRRI dhan50, BRRI dhan63, and BRRI dhan81 were grown at Sagardi farm, BRRI RS, Barishal during Boro 2019-20.

The genotype BR8526-38-2-1-HR1 (7.70 t ha^{-1} with 162 days) produced the highest grain yield but it took 10-17 days longer growth duration than all the check varieties (5.78-7.13 t ha^{-1} with 145-152 days). The genotype Habu Balam (7.17 t ha^{-1}) produced the similar yield with the check variety BRRI dhan81 (7.13 t ha^{-1}) whereas it produced the higher grain yield than the checks BRRI dhan50 (5.78 t ha^{-1}) and BRRI dhan63 (6.28 t ha^{-1}). The genotype Lata Balam (6.91 t ha^{-1}) produced higher grain yield than the checks BRRI dhan50 (5.78 t ha^{-1}) and BRRI dhan63 (6.28 t ha^{-1}).

Table 5. Yield and ancillary characters of RYT (FBR-2) genotypes, Boro 2019-20, BRRI RS, Barishal.

Designation	PH (cm)	GD (day)	Panicle/hill	PL (cm)	Fertility (%)	TGW (gm)	GY (t ha^{-1})
BRH11-9-11-4-5B-HR3	104.1	139	11.9	24.2	75.4	16.1	8.37
BRH11-2-1-3-8B	114.0	147	11.1	25.1	75.7	21.8	7.53
BRH11-2-4-9B	113.8	164	12.2	24.4	69.8	22.4	5.64*
BRH9-7-4-1B	113.9	147	9.2	25.9	81.4	22.4	7.49
BRH13-2-4-6-4B	102.3	140	11.8	24.2	71.0	16.6	7.85
IR12A177	105.4	143	13.7	26.9	90.7	23.8	7.01
BRRI dhan63 (ck)	93.5	139	11.5	23.9	81.6	20.6	6.45
BRRI dhan58 (ck)	107.6	142	11.4	25.0	83.0	22.6	8.07
LSD at 0.05	3.31	1.4	1.6	1.9	7.0	2.4	0.69
CV (%)	1.8	0.6	7.9	4.4	5.1	6.6	5.40

DS: 20 Dec 2019 DT: 30 Jan 2020 Spacing: 20 cm × 20 cm
PH=Plant height, GD=Growth duration, PL=Panicle length, TGW= 1000-grain weight, GY= Grain yield
* Completely submerged for five-day due to Amphan cyclone during reproductive phase.

RYT Bhanga, Boro 2019-20

Eleven entries along with two checks BRRI dhan50 and BRRI dhan89 were grown at Sagardi farm, BRRI RS, Barishal during Boro 2019-20. The genotype Bh Boro-18-SVIN063 (9.29 t ha^{-1}) provided the highest grain yield than the check varieties followed BRRI dhan50 (6.28 t ha^{-1}) and BRRI dhan89 (8.23 t ha^{-1}). The genotypes Bh Boro-18-SVIN076 (8.61 t ha^{-1} and 159 days) and Bh Boro-18-SVIN109 (8.53 t ha^{-1} and 160 days) produced similar grain yield and growth duration with the check variety BRRI dhan89 (8.23 t ha^{-1} with 161 days) but gave higher grain yield than the check BRRI dhan50 (6.28 t ha^{-1}). Six genotypes namely Bh Boro-18-SVIN064, Bh Boro-18-SVIN069, Bh Boro-18-SVIN077, Bh Boro-18-SVIN177, Bh Boro-18-SVIN074 and Bh Boro-18-SVIN066 produced higher grain yield than thee check variety BRRI dhan50 (6.28 t ha^{-1}). The genotype Bh Boro-18-SVIN055 produced the lowest grain yield among the check varieties and also showed neck blast susceptible (30-40% panicle infected by neck blast) at field condition.

RYT Cumilla, Boro 2019-20

A total of five entries along with the three checks BRRI dhan28, BRRI dhan58 and BRRI dhan81 were grown at BRRI RS, Sagardi farm, BRRI RS, Barishal during Boro 2019-20.

The genotype BRC269-15-1-1-3 provided the highest grain yield (7.17 t ha^{-1}) followed by BRC297-15-1-1-1 (7.14 t ha^{-1}) that are similar to the check variety BRRI dhan58 (7.14 t ha^{-1}). The genotype BRC302-2-1-2-1 (7.06 t ha^{-1} and 146 days) produced the highest grain yield but five days longer growth duration than the checks BRRI dhan28 (6.33 t ha^{-1} with 141 days) and BRRI dhan81 (6.20 t ha^{-1} with 142 days). The genotypes BRC297-15-1-1-1, and BRC302-2-1-2-1 showed heterogeneity.

ADVANCED YIELD TRIAL (AYT), 2019-2020

Advanced yield trial (AYT), T. Aman 2019

Thirty-six entries along with four checks BR23, BRRI dhan49, BRRI dhan52 and BRRI dhan87 were grown at Charbadna farm, BRRI RS, Barishal during T. Aman 2019. The plant height ranged from 78.3 cm to 134.2 cm where tallest genotype was IR103411-B-B-3-3 and shortest genotype was PR44522-15-5-2-B. Growth duration ranged from 121 to 139 days where as grain yield ranged from 4.23 to 6.06 t ha^{-1}. The genotype IR11A306 (6.06 t ha^{-1}) produced the highest grain yield than all the check varieties (4.48-5.26 t ha^{-1}). The genotype IR100842-B-B RGA-B RGA-B RGA-9 (5.49 t ha^{-1}) produced similar yield with the check variety BRRI dhan52 but produced higher grain yield than the checks BR23, BRRI dhan49 and BRRI dhan87. Five genotypes namely IR10N230 (5.29 t ha^{-1}), IR100638-12-AJY 3-CMU 2 (5.32 t ha^{-1}), IR14L395 (5.33 t ha^{-1}), IR12A329 (5.38 t ha^{-1}) and IR15L1203 (5.42 t ha^{-1}) provided the similar grain yield with the checks BRRI dhan52 and BRRI dhan87. The six genotypes viz IR 103411-B-B-3-3 (5.02 t ha^{-1}), IR04A428 (5.06 t ha^{-1}), IR14F690 (5.07 t ha^{-1}), IR 100692-AJY 5-1-AJY 1 (5.07 t ha^{-1}), IR13A515 (5.09 t ha^{-1}), and IR 108034-B-B-B-5-B-B (5.13 t ha^{-1}) produced higher grain yield than the check BRRI dhan49 (4.48 t ha^{-1}) but produced similar grain yield with the check BR23 (4.73 t ha^{-1}). The lowest grain yield (4.23 t ha^{-1}) was recorded in the genotype IR04A429.

AYT 1. Boro 2019-20

Six advance breeding lines along with three check varieties were evaluated at Charbadna farm, BRRI RS, Barishal during Boro 2019-20.The genotype BRBa 3-2-4 (6.79 t ha^{-1} and 144 days) produced the similar grain yield and growth duration with the check variety BRRI dhan74 (6.59 t ha^{-1} and 145 days) but showed lower thousand grain weight (TGW) that means the genotype BRBa 3-2-4 (21.7 gm) is slender grain type than the check BRRI dhan74 (28.8 gm). The genotypes BRBa 3-3-1 (6.48 t ha^{-1}) and BRBa 2-5-3 (6.57 t ha^{-1}) produced higher grain yield than the check BRRI dhan58 (6.14 t ha^{-1}). The genotypes BRBa 2-9-4 (6.36 t ha^{-1}) and BRBa3-4-7 (6.37 t ha^{-1}) provided similar grain yield with the check BRRI dhan58 (6.14 t ha^{-1}).

AYT 2. Boro 2019-20

Three advance breeding lines along with two check varieties were evaluated at Charbadna farm, BRRI RS, Barishal during Boro 2019-20 (Table 6). TGW ranged from 18.1 gm for BRBa 2-5-1 to 22.3 gm for BRRI dhan28. The genotype BRBa 2-2-1 (6.01 t ha^{-1}) provided the highest grain yield while the checks BRRI dhan28 produced 5.71 t ha^{-1} and BRRI dhan81 produced 5.18 t ha^{-1}. The genotypes BRBa 2-5-1 5.90 t ha^{-1} and BRBa 4-8-1 5.84 t ha^{-1} produced the similar grain yield with the check BRRI dhan28 (5.71 t ha^{-1}) but provided the higher grain yield than the check BRRI dhan81 (5.18 t ha^{-1}).

Table 6. Yield and ancillary characters of AYT#2 genotypes, Boro 2019-20, BRRI RS, Barishal.

Designation	PH (cm)	GD (day)	Panicle/ hill	PL (cm)	Fertility (%)	TGW (gm)	GY (t ha^{-1})
BRBa 2-2-1	94.5	134	11.5	25.2	75.9	18.4	6.01
BRBa 2-5-1	92.3	134	11.5	24.3	75.3	18.1	5.90
BRBa 4-8-1	94.6	134	13.1	24.7	76.9	19.6	5.84
BRRI dhan28 (ck)	101.1	132	8.4	26.5	76.4	22.3	5.71
BRRI dhan81 (ck)	91.3	131	9.5	25.0	79.5	21.8	5.18
LSD at 0.05	4.56	1.6	2.7	1.1	4.4	1.2	0.25
CV (%)	2.6	0.6	13.4	2.3	3.1	3.1	2.16

DS: 20 Dec 2019 DT: 02 Feb 2020 Spacing: 20 cm × 20 cm
PH=Plant height, GD=Growth duration, PL=Panicle length, TGW= 1000-grain weight, GY= Grain yield

AYT 3. Boro 2019-20

Ten advanced breeding lines along with two check varieties were evaluated at Charbadna farm, BRRI RS, Barishal during Boro 2019-20.

Three genotypes BRBa 1-4-9 (6.82 t ha^{-1}), BRBa 3-1-7 (6.79 t ha^{-1}) and BRBa 2-1-3 (6.76 t ha^{-1}) produced the similar grain yield with the check BRRI dhan74 (6.62 t ha^{-1}) but provided higher grain yield than the check BRRI dhan58 (6.18 t ha^{-1}). The genotype BRBa 3-2-2 (6.30 t ha^{-1} with 146 days) gave the similar grain yield to the check BRRI dhan58 (6.18 t ha^{-1} and 145 days). The lowest grain yield was found in the genotype BRBa 5-4-1 (5.53 t ha^{-1}).

AYT 4. Boro, 2019-20

Six advanced breeding lines along with two check varieties were evaluated at Sagardi farm, BRRI RS, Barishal during Boro 2019-20.

The genotypes IR12A329 (7.94 t ha^{-1} and 147 days) and IR13A515 (7.69 t ha^{-1} and 145 days) provided higher grain yield with similar growth duration than the checks BRRI dhan58 (7.06 t ha^{-1} with 147 days) and BRRI dhan74 (7.38 t ha^{-1} with 147 days). The genotype IR04A429 (7.42 t ha^{-1} and 144 days) produced the similar grain yield but with three days earlier growth duration them the check BRRI dhan74 (7.38 t ha^{-1} with 147 days) where as produced higher grain yield than the check variety BRRI dhan58 (7.06 t ha^{-1}).

AYT 5. Boro 2019-20

Eleven advanced breeding lines along with three check varieties were evaluated at Sagardi farm, BRRI RS, Barishal during Boro 2019-20. The genotype IR108000-B-B RGA-B RGA-14-1 (7.95 t ha^{-1}) provided the highest grain yield than the checks BRRI dhan28 (6.91 t ha^{-1}) and BRRI dhan58 (7.43 t ha^{-1}). The six genotypes namely IR15A2663 (7.46 t ha^{-1}), IR15A2820 (7.52 t ha^{-1}), IR15A3466 (7.52 t ha^{-1}), IR16A2022 (7.72 t ha^{-1}), IR15A2854 (7.78 t ha^{-1}) and IR107995-B-B RGA-B RGA-54-1 (7.47 t ha^{-1}) produced similar grain yield to the check BRRI dhan58 (7.43 t ha^{-1}) but provided higher grain yield than the check BRRI dhan28 (6.91 t ha^{-1}). The genotypes IR106236-B-B-B-PRN B-PRN 106 (7.39 t ha^{-1} with 139 days) and IR106236-B-B-B-PRN B-PRN 11 (7.28 t ha^{-1} with 139 days) produced similar grain yield but with four days longer growth duration them the check BRRI dhan28 (6.91 t ha^{-1} with 135 days).

INTERNATIONAL NETWORK FOR GENETIC EVALUATION OF RICE (INGER)

International Irrigated Rice Observational Nursery (IIRON), Boro 2019-20

Evaluation of elite breeding lines and varieties under irrigated condition. Seventy-nine advance breeding lines along with five check varieties (BRRI dhan28, BRRI dhan29 BRRI dhan58 BRRI dhan67, and BRRI dhan74) were evaluated at the Charbadna farm, The plant height ranged from 80.1 cm of SVIN339 to 112.3 cm of SVIN332. Growth duration ranged from 131 to 158 days whereas grain yield ranged from 4.68 to 7.67 t ha^{-1}. The genotype SVIN333 (7.67 t ha^{-1}) produced higher grain yield than all the check varieties (6.39 to 7.11 t ha^{-1}). Three genotypes SVIN366 (7.49 t ha^{-1} with 141 days), SVIN028 (7.47 t ha^{-1} with 141 days) and SVIN312 (7.35 t ha^{-1} with 141 days) gave the similar yield but with six days earlier growth duration them the check variety BRRI dhan29 (7.11 t ha^{-1}) and produced higher grain yield than the checks BRRI dhan28, BRRI dhan58, BRRI dhan67 and BRRI dhan74. Eight genotypes namely SVIN375 (6.81 t ha^{-1}), SVIN323 (6.82 t ha^{-1}), SVIN313 (6.89 t ha^{-1}), SVIN318 (6.96 t ha^{-1}) SVIN311 (7.00 t ha^{-1}), SVIN304 (7.02 t ha^{-1}), SVIN316 (7.07 t ha^{-1}) and SVIN302 (7.10 t ha^{-1}) provided similar grain yield with the checks BRRI dhan58 (6.80 t ha^{-1}) and BRRI dhan74 (6.85). Fourteen genotypes (6.39-6.77 t ha^{-1}) produced similar grain yield to the checks BRRI dhan28 (6.39 t ha^{-1}) and BRRI dhan67 (6.46 t ha^{-1}). The lowest grain yield (4.69 t ha^{-1}) was recorded in the genotype SVIN373.

Collection, characterization and utilization of local Aman germplasm

About 369 local germplasm, those are still cultivating in the farmers' field, were collected from different upazillas of Barishal region viz Barishal, Patuakhali, Barguna, Bhola, Pirojpur and Jhalakathi. Department of Agriculture Extension helped in collecting those germplasm. Germplasm were grown in BRRI RS, Barishal field in six line plots and characterized during T. Aman 2019. Purification was done through panicle selection from each plot. Ten germplasm were utilized in 20 crosses. Seedling height, plant and grain characters along with yield performances were recorded.

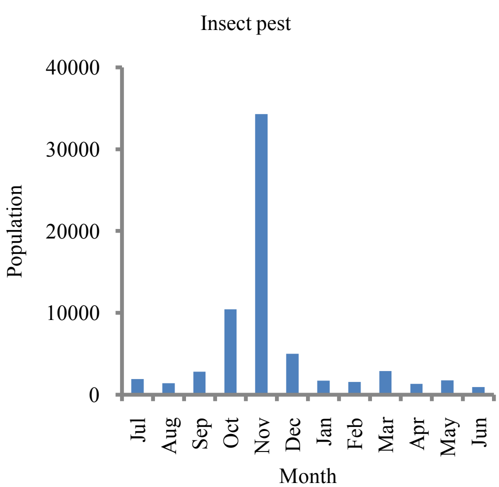
PEST MANAGEMENT

INSECT MANAGEMENT

Incidence of insect pest and natural enemies in light trap

Data were collected from July 2019 to June 2020 at Sagordi farm, BRRI RS, Barishal. Appearance of insect pests was higher than the previous reporting year. In the reporting year, the highest green leafhopper (20,348 nos.) followed by brown plant hopper (13,088 nos.) and yellow stem borer (9,103 nos.). In case of natural enemy the highest population was staphylinid beetle (6,920 nos.) followed by carabid beetle (3383), green mirid bug (2041) and lady birdbeetle (899). In this reporting year insect pest populations were found higher than natural enemy population may be because of zero insecticide (GI) was used in this period (Fig. 1).

Figure shows the abundance of two major insects yellow stemborer and brown planthopper in the reporting period. YSB found comparatively higher in T. Aman season than Boro season. September, October, November 2019 and March 2020 found higher yellow stemborer. Southern region is brown planthopper prone area in T. Aman season. This year we found higher number. of BPH in September, October and November 2019 (Fig. 2).



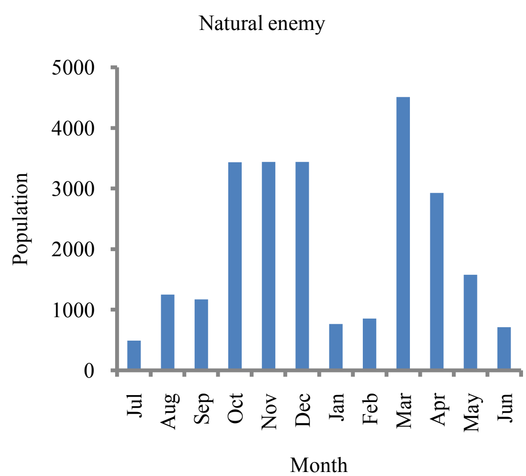
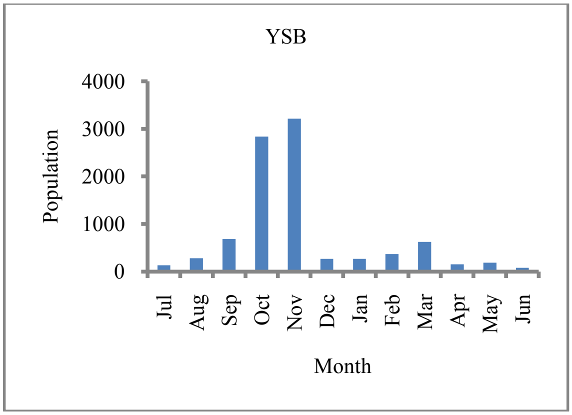


Fig. 1. Monthly insect pests and natural enemies abundance of BRRI RS, Barishal light trap.



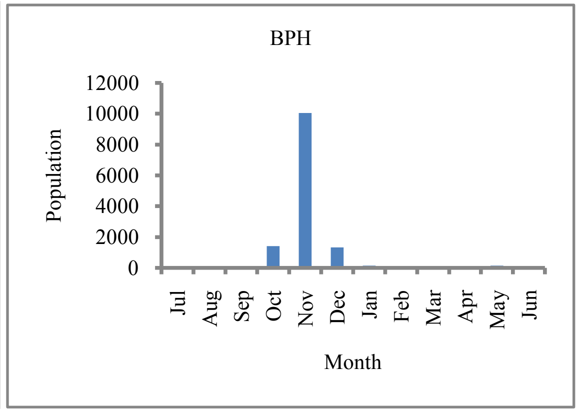


Fig. 2. Per month abundance yellow stemborer and brown planthopper in BRRI RS, Barishal.

Impact of lighting period on insect trapping

To find out effective light period for insect trapping and also find out insect and natural enemy comparatively caught overnight in light trap. Experiment conducted in 17 to 20 November 2019 at Sagordi farm, BRRI RS, Barishal. For catching in light trap, six treatments were observed; T1= 5.20 - 6.20pm, T2= 6.20-7.20pm, T3= 7.20-8.20pm, T4 =8.20-9.20 pm, T5=9.20- 10.20 pm,andT6= 10.20 to rest of the night and the treatments were replicated four times. T1 treatment that covers twilight (Godhuli) traps the highest number of insect pest and natural enemies (Table 7). Dusk to first four hours caught 69.28% insect pests.

First three hours (5.20 pm to 8.20 pm) insect caught decreasing and first 4 hours (5.20 to 9.20 pm) natural enemy caught also decreasing trend. Total insect pest and natural enemies caught in light trap was 16,825 and 1,942 that was in percentage of total population, 89.65% and 10.35% respectively.

Rat caught preference to different lure in traditional bamboo trap

To find out effective lure for rat trapping, an experiment was designed with four Treatments- T1=Coconut, T2=Dried fish, T3=Paddy, T4= Without feed/lure and the treatments were replicated thrice. The experiment was conducted with 20 Bamboo trap at Charbadhna farm, BRRI RS, Barishal during T. Aman 2019. Higher no. of rats caught found with coconut lure than followed by dried fish and paddy. Coconut lure more was found preferable to rat than dried fish and paddy.

Survey of rice insect pest in seedbed using yellow sticky trap

To find out the incidence patterns of the major rice insect and their natural enemies in rice seedbed during Boro 2019-20 at T. Aman seedbed in Sagordi and Charbadna farms, BRRI RS, Barishal. Population intensities of rice insect and their natural enemies counted through yellow sticky trap caught after seven days of setup. Ten and 11 no. of yellow sticky trap set up at Charbadna and Sagordi farm. BR26, BRRI dhan67 seedbed of Sagordi farm and BRRI dhan67, BRRI dhan88, BRRI dhan89, BRRI dhan28, BRRI dhan29, BRRI dhan58 of Charbadna farm.

Brown planthopper (BPH), white backed planthopper (WBPH), yellow stemborer (YSB), leaf folder (LF), green leafhopper (GLH), white leafhopper (WLH), zigzag leafhopper (ZLH) insect found in yellow sticky trap. Carabid beetle (CDB), lady bird beetle (LBB), green mirid bug (GMB) and spider (SPD) natural enemies were found.

Table 7. Percentage of insect pest and natural enemis population of different treatment in light trap.

Population	T1	T2	T3	T4	T5	T6
Insect pest	26.14562	16.46954	12.99851	13.66419	14.12184	16.6003
Natural Enemy	32.02884	19.61895	11.01957	9.732235	12.04943	15.55098

Higher insect and natural enemy found in Charbadna than Sagordi farm, BRRI RS, Barishal. Brown planthopper, green leafhopper, leaf folder, yellow stemborer were found higher population. On other hand, natural enemies green miridbug, lady bird beetle, carabid beetle were found on higher population.

Conservation of natural enemies through ecological engineering approaches

To conserve natural enemies through ecological engineering approaches, nectar-rich flowering plants and or weeds planted on bunds to provide food and shelter for different natural enemies, e.g. parasitoids. Twenty complete sweeps will be taken at every seven days interval up to flowering. T_1 = Flowering plants (marigold, sunflower) grown in rice bunds, T_2 = Control

Higher number of insect pest abundance was found in control plot than the ecological management plot. On the other hand, higher no. of natural enemies incidence was found in ecological engineering plot than control plot. The similar yield found in both ecological engineering plot (6.71 t ha^{-1}) and control plot (6.70 t ha^{-1}).

Insecticide free rice production in BRRI RS, Barishal farm

To reduce insecticide use in Sagordi and Charbodna farm of BRRI RS, Barishal, we installed 100 perch at one hectare of land to facilitate birds to sit on and took randomized 20 complete sweep for counting insect pests and natural enemy and identifying plots that occur potential infestation by certain insect pest. And it was practiced in the morning at every seven days interval before flowering. Once the infested plot was identified, complete sweeping operation was conducted in that plot and after every 40-50 sweeping harmful insects were damaged mechanically and beneficial insects were released with field. In Boro 2019-20 we found higher no. of insect in BRRI dhan67 followed by BRRI dhan89 and BRRI dhan88. Green leafhopper (GLH), white leafhopper (WLH), yellow stemborer (YSB) and brown planthopper (BPH) were found in all the three variety plot. On the other hand, higher no. of natural enemies were found in BRRI dhan89 than BRRI dhan88 and BRRI dhan67. On the higher yield performance in BRRI dhan89 than BRRI dhan88 and BRRI dhan67. Finally, we successfully cultivated breeder, TLS and experiment plot crop without any insecticide spray at Charbadna and Sagordi farms. Perching was done in all plots was found following BRRI recommended practice. Every full plot sweeping was done after 15 days of transplanting upto flowering. After every 20 complete sweeping over natural enemies harmful insects were damaged. In the morning yellow stem borers harbor upper portion of leaf. So, we did sweeping early in the morning 6.00 am to 10.00 am.

Fall armyworm monitoring in BRRI RS, Barishal farm

To find out fall armyworm (FAW) population and damage symptom of rice field five lure traps were setup at Charbadna farm and two lure traps were setup at Sagordi farm. In seven days interval fall armyworm population was counted. After every seven days interval FAW population was counted. Figure 3 shows the results after 15 weeks population counting. Trap no. 2 and 3 found higher no. of FAW population during Boro 2019-20 season (Fig 3).

DISEASE MANAGEMENT

Screening of available pesticides for controlling blast disease of rice, Boro 2019-20

Nine pesticidess *viz* Zeal, Difa, Kasumin, Amister Top, Karishma, Blastin, Sindazim, Sandomil and Nativo were used as test pesticides keeping one negative control (plain

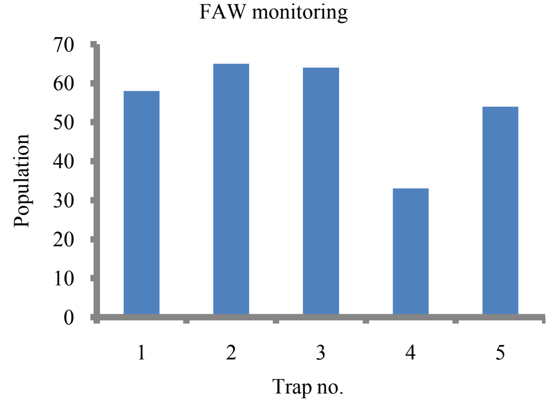


Fig. 3. Total fall armyworm population scenario of 5 lure trap in BRRI RS, Barishal.

water). Pesticides were tested on BRRI dhan28, a susceptible Boro HYV of rice to blast disease. Among the nine chemicals Nativo (91.10%), Difaa (76.52%), Blastin (72.27%), and Zeal (71.38%) significantly reduced neck blast (NB) disease. Rest of the chemicals were not effective (<60 % reduction) in reducing the blast disease. Further test of those effective chemicals was suggested for the next season.

Survey and monitoring of rice diseases in selected areas

In Aman and Boro seasons, survey on rice disease was conducted in 46 farmers' fields of Barishal district (Sadar, Ujirpur, Babuganj). Cropping pattern, rice growing ecosystem and cultivar adoption of the surveyed area were observed during 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 survey was followed in this study (Savary*et al.*, 1996). From each plot, randomly 20 hills were selected for recording the disease incidence and severity (Fig 4).

Demonstration on the management options of blast disease at farmers' field of Barishal region

To demonstrate the efficacy of fungicides against blast disease and to introduce management practices to the farmers the experiment was conducted during Aman 2019 farmers' field of Babuganj, Barishal under natural field condition using blast susceptible rice variety BRRI dhan34. BRRI recommended practices (RP) were tested over farmers' practices (FP). BRRI recommended practices were - application of half dose of MOP at basal and half at the last top dress of urea (PI stage); providing supplement irrigation immediately after disease initiation and judicial application of fungicides (Trooper/Zeal/Nativo two times at 10-15 days interval). Farmers didn't use

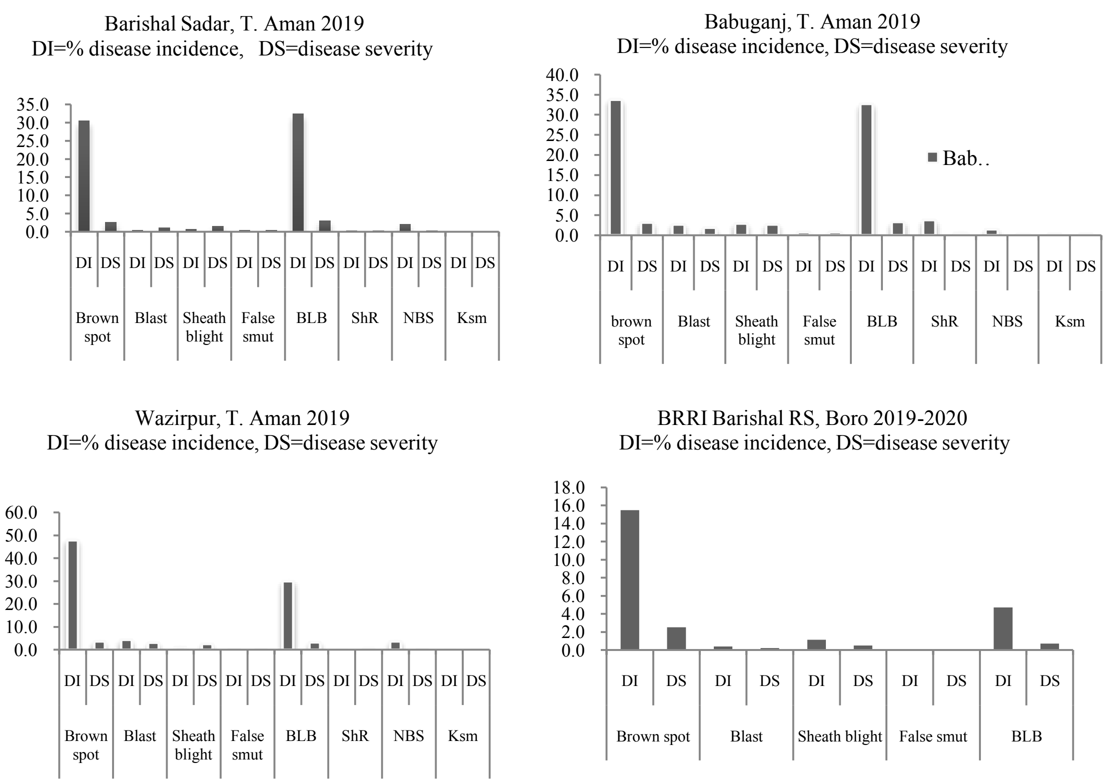


Fig. 4. Incidence and severity of different diseases in Barishal region.

MOP and/or chemical under Farmers' practice option.

For neck blast, fungicides were sprayed two times; first at heading stage (around 5% flowering) and 2nd at 10 days after the 1st spray. Chemical trooper was sprayed at afternoon. Disease severity and yield data were collected during ripening stages.

Yield of BRRI dhan34 was significantly higher in recommended practices (4.30 tha^{-1}) over farmers' practices (3.57 tha^{-1}). Disease incidence was 11.9% in RP treatment while it was 63% in control treatment.

TECHNOLOGY TRANSFER

Varietal replacement through head to head trial during T. Aman 2019 under TRB

Two groups of BRRI released modern rice varieties were tested at 10 locations of Barishal region, during T. Aman 2019. BRRI dhan52 group comprising of BRRI dhan 52, BRRI dhan72, BRRI dhan73, BRRI dhan76 and BRRI dhan79 was tested in five locations and BRRI dhan49 group, comprising of BRRI dhan49, BRRI dhan71, BRRI dhan75, BRRI dhan80 and BRRI dhan87 were tested in other five locations. Data showed that among the BRRI dhan52 group varieties at five locations in Barishal region, BRRI dhan72 (5.45 t ha^{-1}) provided the highest yield followed by BRRI dhan52 (5.29 t ha^{-1}), BRRI dhan76 (5.12 t ha^{-1}), BRRI dhan79 (4.84 t ha^{-1}) and BRRI dhan73 (4.58 t ha^{-1}). Similarly in BRRI dhan49 group, BRRI dhan87 (5.46 t ha^{-1}) produced the highest yield followed by BRRI dhan49 (5.3 t ha^{-1}), BRRI dhan80 (5.08 t ha^{-1}), BRRI dhan71 (4.83 t ha^{-1}) and BRRI dhan75 (4.68 t ha^{-1}). From the above discussion it can be said that among five varieties BRRI dhan52, BRRI dhan72, BRRI dhan76, BRRI dhan87 and BRRI dhan49 were found suitable for dissemination to the farmers in Barishal region. Farmers retained 10-50 kg seeds of those varieties for future use.

Varietal replacement through head to head trial during Boro 2019-20 under TRB

Two groups of BRRI released modern rice varieties were tested at six locations of Barishal region Dduring Boro 2019-20. BRRI dhan28 group comprising of BRRI dhan28, BRRI dhan67, BRRI dhan81, BRRI dhan84 and BRRI dhan88, was tested in four locations and BRRI dhan29 group, comprising of BRRI dhan29, BRRI dhan58, BRRI dhan89 and BRRI dhan92 was tested in other two locations. In the BRRI dhan28 group , BRRI dhan67 (6.41 t ha^{-1}) provided the highest yield followed by BRRI dhan88 (6.16 t ha^{-1}), BRRI dhan28 (5.98 t ha^{-1}), BRRI dhan81 (5.92 t ha^{-1}) and BRRI dhan84 (5.76 t ha^{-1}). In BRRI dhan29 group varieties at two locations in Barishal region, BRRI dhan29 (6.55 t ha^{-1}) provided the highest yield followed by BRRI dhan89 (6.43 t ha^{-1}), BRRI dhan92 (6.43 t ha^{-1}) and BRRI dhan58 (6.40 t ha^{-1}). Farmers retained 10-40 kg seeds of each variety for further use.

Stability analysis of BRRI released varieties

This study was conducted for finding out the suitable rice cultivars in Barishal region. Forty-two BRRI released varieties were tested with three groups namely short duration variety (14), medium duration variety (11) and long duration variety (17) during Aman 2019 season. Forty-three varieties with two groups namely short duration variety (20) and long duration variety (23). were evaluated during Boro 2019-20 seasons. Both the studies were accomplished at Charbadna farm, BRRI RS, Barishal.

The Aman 2019 experiment was affected by cyclone Bulbul on 10 November 2019. Among the tested 14 short duration varieties, the highest yield was observed in BRRI dhan87 (6.12 tha^{-1}) followed by BRRI dhan73 (5.38 t ha^{-1}). In medium duration varieties, the highest yield was found in BRRI dhan70 (6.18 t ha^{-1}) followed by BRRI dhan49 (5.39 t ha^{-1}). Finally, among the long duration varieties, the highest yield was found in BRRI dhan77 (5.55 t ha^{-1}) followed by BR 23 (5.49 t ha^{-1}) and BRRI dhan76 (5.39 t ha^{-1}).

Among the tested short duration varieties, the highest yield was observed in BRRI hybrid dhan3 (8.20 tha^{-1}) followed by BR1 (6.62 t ha^{-1}) and BRRI dhan68 (6.35 t ha^{-1}). In the long duration varieties, the highest yield was in BRRI dhan89 (8.20 t ha^{-1}) followed by BRRI dhan58 (7.56 t ha^{-1}) and BRRI dhan92 (7.00 t ha^{-1}).

SOCIO-ECONOMICS AND POLICY

TECHNOLOGY TRANSFER

Advanced line adaptive research trial (ALART) in T. Aman 2019. There were seven ALARTs, one in Aus 2019 three in T. Aman 2019 and and four in Boro 2019-20 conducted in farmers' field of Barishal.

ALART, T. Aus 2019

The ALART consisting of three B. Aus varieties, BRRI dhan42, BRRI dhan43 and BRRI dhan83 along with one T. Aus variety BRRI dhan48 as check was conducted to validate the performance of those B. Aus varieties in T. Aus condition. BRRI dhan83 (5.21 t ha^{-1}) is the only B. Aus variety that yielded better than the check BRRI dhan48 (4.83 t ha^{-1}) with similar growth duration (Table 8).

Rainfed lowland rice (RLR), T. Aman 2019. Four RLR advanced line BR8521-30-3-1, BR8441-38-1-2-2, BR8526-38-3-2-1-HR2 and BR8526-38-3-2-1-HR8 along with two standard check variety BRRI dhan49 and BRRI dhan87 were tested in Rakudia, Babuganj upazila of Barishal district during T. Aman 2019. Among the advanced line and check varieties, the check variety BRRI dhan87 provided the highest yield (5.80 t/ha) followed by the 2nd highest averaged yield (5.72 t/ha) by BR8441-38-1-2-2. On average, all the entries matured within 126-131 days. Therefore, none was recommended for proposed variety trial (PVT).

ALART, zinc enriched rice (ZER), T. Aman 2019. Three ZER advanced lines along with three standard check varieties were tested in Rakudia, Babuganj upazila of Barishal district during T. Aman 2019. Among the advanced line and check varieties, the check variety BRRI dhan87 produced the highest yield (6.13 t/ha) followed by the 2nd highest averaged yield (5.63 t/ha) by an advanced line BR8442-12-1-3-1-B7. All the entries matured within 104-133 days. Based on performance none was recommended for PVT.

ALART (Bio), T. Aman 2019. Two advanced lines BR (Bio) 9786-BC2-161-1-2 and BR (Bio) 9786-BC2-80-1-1 along with two standard checks BRRI dhan71 and BRRI dhan87 were tested in Rakudia, Babuganj upazila of Barishal district during T. Aman 2019.

Among the advanced lines and check varieties, the check variety BRRI dhan87 provided the highest mean yield (6.01 t/ha). Based on yield and growth duration and farmers' opinion, no advanced line may be considered for further advance.

ALART in Boro 2019-20

Premium quality rice (PQR), Boro 2019-20. Two advanced lines BR8862-29-1-5-1-3 and BR8995-2-5-5-2-1 along with a standard check variety BRRI dhan50 were tested in Srirampur, Nalsity, Jhalokathi during Boro 2019-20. Among the test entries, BR8862-29-1-5-1-3 produced the highest yield (7.14 t ha^{-1}) followed by by BR8995-2-5-5-2-1(6.24 t ha^{-1}). On average, all the entries matured within 147-150 days. The BR8995-2-5-5-2-1 line got the highest growth duration (GD) of 150 days where as BR8862-29-1-5-1-3 line got the lowest GD of 147 days. BRRI dhan50 produced 5.95 t ha^{-1} yield with growth duration 148 days. Based on higher yield and growth duration and farmers' opinion, BR8862-29-1-5-1-3 and BR8995-2-5-5-2-1 may be considered for further research program.

Table 8. Yield and ancillary characters of ALART genotypes, T. Aus 2019 BRRI RS, Barishal.

Designation	PH (cm)	GD (day)	Panicle/hill	PL (cm)	Fertility (%)	TGW (gm)	GY (t ha^{-1})
BRRI dhan42	117.8	106	9.7	24.6	81.2	21.4	3.82
BRRI dhan43	114.1	106	8.3	24.5	82.8	22.9	3.70
BRRI dhan83	116.6	110	7.7	25.1	84.8	21.4	5.21
BRRI dhan48 (ck)	103.8	108	7.7	24.3	86.3	22.3	4.83
LSD at 0.05	2.2	1.6	2.0	1.2	4.0	1.1	0.32
CV (%)	0.95	0.6	12.2	2.40	2.40	2.45	5.94

DS: 21 Apr 2019 DT: 16 May 2019 Spacing: 20 cm × 15 cm

Zinc enriched rice (ZER), Boro 2019-20. Four advanced breeding lines along with a standard check variety were evaluated in Srirampur, Nalsity, Jhalokathi during Boro 2019-20. It was a three tines replicated trial.

Among the test entries, IR99285-1-1-1-P2 produced similar yield (7.42 t ha^{-1}) to the check variety BRRI dhan29 (7.52 t ha^{-1}) having same growth duration of 154 but it have more than one ton yield advantage over BRRI dhan84, a zinc enriched rice. Based on higher yield, higher zinc content and farmers' opinion, IR99285-1-1-1-P2 may be considered for PVT trial.

ALART, blast resistant rice (BRR), Boro 2019-20. Three advanced breeding lines along with two standard check varieties were evaluated in Srirampur, Nalsity, Jhalokathi during Boro 2019-20.

Among the advanced line and check varieties, BRRI dhan29 got the highest yield and growth duration (7.50 t ha^{-1}, 156 days) followed by Path 2441 (7.36 t ha^{-1}, 155 days) and HR (Path)-11 (7.34 t ha^{-1}, 151 days). There was a clear advantage of blast incidence in Path 2441 (5-7%) and HR (Path)-11(5%) over BRRI dhan29 (10%) in field condition. Based on yield, growth duration, DI, and farmers' opinion, HR (Path)-11 and Path 2441 may be considered for further evaluation in PVT.

ALART (BBRR), Boro 2019-20. Four advanced breeding lines along with two standard check varieties were evaluated in Srirampur, Nalsity, Jhalokathi during Boro 2019-20. Among the test entriesBR8938-19-4-3-1-1-P2-HR3 produced the highest yield (7.65 t ha^{-1}) followed by BRRI dhan58 (7.21 t ha^{-1}) and BR9651-15-2-1-4 (7.20 t ha^{-1}). On average, all the entries matured within 139-150 days. Based on yield and growth duration and farmers' opinion, BR8938-19-4-3-1-1-P2-HR3, may be considered for PVT.

DEMONSTRATION, SEED PRODUCTION AND SCALING UP OF BRRI RICE VARIETIES

Demonstration under SPIRA projects. To introduce the appropriate BRRI rice varieties and to demonstrate their production technologies to the farmer with a view to utilize fallow land and ultimately maximize the farmers' income seven varietal demonstrations, three in T. Aman and four in Boro, were conducted during T. Aman 2019, four BRRI varieties viz BR23, BRRI dhan52, BRRI dhan76 and BRRI dhan77 were demonstrated in blocks of two bigha each variety in Babuganj, Barishal and Ghotkhali, Amtali, Barguna under SPIRA. The selected groups of farmers received seed, fertilizer, insecticides, pesticides, irrigation and labour support. The highest yield was obtained by BRRI dhan23 (5.1 t ha^{-1}) followed by BRRI dhan52 (5.07 t ha^{-1}) and BRRI dhan76 (4.9 t ha^{-1}). The growth duration varied from 143-156 days. Farmers retained theseed of those varieties especially BRRI dhan76 and BRRI dhan77 for selling or sharing with surrounding farmers and to cultivate in the next season.

During Boro 2019-20, five vatieries viz, BRRI dhan47, BRRI dhan58, BRRI dhan67, BRRI dhan74 and BRRI dhan89 were demonstrated and the highest yield was found in BRRI dhan89 (7.53 t ha^{-1}) followed by BRRI dhan74 (7.17 t ha^{-1}), BRRI dhan58 (6.82 t ha^{-1}), BRRI dhan67 (6.34 t ha^{-1}), BRRI dhan47 (5.99 t ha^{-1}). Farmers were motivated to cultivate BRRI dhan89, BRRI dhan74 and BRRI dhan58 and they retained the seeds of those varieties.

Seed support demonstration

Fifty-three seed support demonstrations were conducted. Twenty-five block demonstrations of ten bigha each with BRRI dhan76 and BRRI dhan77 during T. Aman 2019 in different upozilas of Bhola District were conducted with active collaboration of DAE. Similarly 28 seed support demonstrations were conducted in Babuganj Barishal during Boro 2019-20.

Farmers' training under different projects/GoB

Fifteen day-long farmers' training were conducted with 30-35 farmers participate in different locations of Barishal region during the reporting period out of that ten were conducted under GoB programme, three were under SPIRA project and two from Ecofriendly pest management programme. A total of 480 farmers and NGO personnel were trained (Table 9). These programmes certainly helped the farmers to create awareness for adopting the BRRI rice production technologies, ecofriendly pest management and to accelerate the dissemination rate of BRRI varieties in those areas.

Table 9. Daylong farmers' trainings at Barishal region during 2019-20.

Training programme	Duration	Total training	Participant				Total
			Male	Female	Imam	NGO Personnel	
Modern Rice Production Training	1 day	10	208	72	10	10	300
Training on rice production technology	1 day	3	90	24	3	3	120
Ecofriendly pest management	1 day	2	47	9	2	2	60
Total		15	345	105	15	15	480

FARMERS' FIELD DAY UNDER DIFFERENT PROJECTS/GOB

Nine field days were conducted of which one under Ecofriendly pest management programme (at Brishal, Barishal), one under Irrigation division (at Nalcity, Jhalokathi) and seven under SPIRA projects (three during T. Aman and four during Boro season). About 1,350 (643 male and 707 female) farmers, extension personnel, administrative peoples, public leaders were targeted to participate on these programmes.

Seed production

A total of 47,030 kg of breeders seed (BS) and 34,461 kg of truthfully labelled seed (TLS) were produced, processed and distributed 2019-20. Table 10 presents the season and variety-wise detailed.

Table 10. Details of seed production during 2019-20.

T. Aman 2019			Boro 2019-20		
Variety	BS (kg)	TLS (kg)	Variety	BS (kg)	TLS (kg)
BR22	-	1146	BR3	-	860
BR23	3169	1150	BRRI dhan26	7520	280
BRRI dhan34	3388	780	BRRI dhan28	8520	1320
BRRI dhan49	2113	100	BRRI dhan29	6000	1600
BRRI dhan52	3266	194	BRRI dhan47	3000	2200
BRRI dhan72	-	900	BRRI dhan48	-	1147
BRRI dhan75	-	303	BRRI dhan58	-	2280
BRRI dhan76	2025	2390	BRRI dhan67	3000	5070
BRRI dhan77	2039	1470	BRRI dhan74	3000	4431
BRRI dhan78	-	500	BRRI dhan82	-	750
BRRI dhan87	-	800	BRRI dhan84	-	800
Total	16,000	9,733	BRRI dhan88		1110
			BRRI dhan89	-	2780
			BRRI dhan92		100
			Total	31040	24728

BRRI RS, Bhanga

SUMMARY

In total 33 crosses were made using 17 parents and 2,692 F_1 seeds were produced for deepwater rice breeding and 26 crosses made for Aman Rice. In Boro 2019-2020, a total of 10,395 progenies from F_4 generation were grown following field RGA and 2,930 progenies of F_5 generation were harvested. In proposed variety trial (PVT) during Boro 2019-20, three sets (Set-1 for ZER, Set-2 and Set-3 for low glycemic index) of inbred trials were evaluated at BRRI RS, Bhanga, Faridpur. In ALART (PQR) Boro, two advanced lines BR8862-29-1-5-1-3 and BR8995-2-5-5-2-1 produced higher grain yield than the check varieties BRRI dhan50 with similar growth duration. In ALART (ZER) Boro, one advanced line IR99285-1-1-1-P2 produced higher yield than both the checks (BRRI dhan29 and BRRI dhan84) but the average growth duration was almost similar to BRRI dhan29 and longer than BRRI dhan84. Eight regional yield trials (RYT) were conducted in farmers' field and BRRI RS, Bhanga during Aman and Boro 2019-20 season. In RYT (DWR), Boroidigha and Fulkori yielded 2.06 t ha^{-1} and 1.47 t ha^{-1} higher than the check BR10230-15-27-7B with similar growth duration in Majhikanda, Bhanga and Talma, Nagorkanda. The highest yield was obtained from IR105837-8-45-1-1 (9.4 t ha^{-1}) followed by BR8912-12-6-1-1-1-1 (9.12 t ha^{-1}) and IR105837-8-95-2-1 (8.92 t ha^{-1}) which was the higher than other two checks (BRRI dhan28 and BRRI dhan84) in zinc enriched rice (ZER) programme. Five advanced lines such as BR9669-21-2-1-19, BR9669-23-3-2-23, BR9891-17-2-2-23, BR9891-8-2-1-41 and BR9891-18-1-2-7were found promising in insect resistant rice (IRR) programme and two lines, BRH9-7-4-1B and BRH13-2-4-6-4B performed better in favourable Boro rice (RYT#2-FBR) based on yield and agronomic traits.One hundred pigmented rice germplasm accessions were characterized, 10 tons of breeder seeds (BRRI dhan28 and BRRI dhan29) and 15 tons TLS of recently developed BRRI varieties produced in BRRI RS, Bhangaand also arranged 10 farmers training and sixfarmers' field days.

VARIETAL DEVELOPMENT

Hybridization. In Aman 2019 season, 10 crosses were made and 1986 F_1 seeds were produced for developing high yielding transplanting Aman rice varieties having desirable traits with emphasis on water stagnation tolerance, anaerobic tillering, earliness and acceptable grain quality.

For the development of deepwater rice variety, 23 crosses were made and 1,706 F_1 seeds were produced with desirable characters with emphasis on kneeing ability, nodal tillering, elongation ability and awnless grain with acceptable quality.

FRGA. In case of 'breeding for developing high yielding rice varieties for single Boro ecosystem' 10,395 plants of F_4 generation were grown during Boro 2019-20 using Field RGA and 2,930 progenies of F_5 generation were maintained by collecting single panicle from each plant as modified single seed descent (SSD) method.

PVT (Boro). Three sets (Set-1, Set-2 and Set-3) of inbred trials (Boro2019-20) were evaluated following randomized complete block design with three replications at BRRI RS, Bhanga, Faridpur (Table 1).

Table 1. Performance of proposed variety trial in Boro 2019-20 at BRRI RS, Bhanga.

PVT set	Location	Code no.	Growth duration (day)	Yield (t ha^{-1})
Set-1	BRRI RS, Bhanga	I-010 (ck)	150	7.40
		I-011(ck)	145	6.57
		I-012	150	8.63
Set-2		I-013(ck)	162	8.3
		I-014	159	8.75
		I-015(ck)	155	7.73
Set-3		I-016(ck)	147	7.63
		I-017	152	8.71

Set-1. In a proposed variety trial, one advanced breeding line I-012 along with two checks (I-010 and I-011) was tested. Line no.I-012 produced 8.63 t ha^{-1} which was 16.62% and 31.35% higher yield than both the check varieties coded I-010 and I-011 respectively. The growth duration of line no. I-012 was around five days longerthan I-011 or similarto the I-010 line respectively.

Set-2. One advanced breeding line I-014 was evaluated along with a check. This line produced 8.75 t ha^{-1} yield which was 5.42% higher than the check (I-013) with three days shorter growth duration.

Set-3. In this trial, one advanced breeding line (I-017) along with two checks (I-015 and I-016) were tested. Line no. I-017 produced8.71 t ha^{-1} yield which was 1.0 t ha^{-1} higher (12.67% and 14.15%) than both the checks. The growth duration of the lines ranged from 147-155 days andgrowth duration of theline no. I-017 was 152 days.

ALART (PQR) Boro. Two advanced lines BR8862-29-1-5-1-3 and BR8995-2-5-5-2-1 along with BRRI dhan50 (check) were tested at farmers' field at Nagarkanda, Faridpur. Two tested lines out yielded (6.91-7.47 t ha^{-1}) average yield of the check variety BRRI dhan50 (6.79 t ha^{-1}). The mean growth duration of BR8862-29-1-5-1-3 was 162 days which was similar to the check variety BRRI dhan50. Flowering and maturity of the line BR8995-2-5-5-2-1 was irregular (Table 2)

ALART (ZER) Boro. One advanced line IR99285-1-1-1-P2 along with BRRI dhan29 and BRRI dhan84 as checks were evaluated at farmer's field at Nagarkanda, Faridpur. The advanced line IR99285-1-1-1-P2 produced 9.12 t ha^{-1} yield which was a little higher (012 t ha^{-1}) than BRRI dhan29 and 4.0 t ha^{-1} higher than BRRI dhan84. The mean growth duration of advanced line IR99285-1-1-1-P2 was similar to the check variety BRRI dhan29 and 18 days longer duration than the other check BRRI dhan84 (Table 3).

RYT (DWR). Boroi digha and Fulkori yielded 2.06 t ha^{-1} and 1.47 t ha^{-1} significantly higher than the check BR10230-15-27-7B with similar growth duration in Majhikanda and Talma (Table 4).

RYT (FBR) Bhanga. Eleven advanced lines along with two checks (BRRI dhan50 and BRRI dhan89) were evaluated at on-station condition in six different locations. One advanced line SVIN076 Boro-18-Bhanga produced 7.90 t ha^{-1} yield which was relatively higher than the check varieties. The mean growth duration of SVIN076-Boro-18-Bhanga (162 days) was similar to the check variety BRRI dhan89 (162 days) and about four days longer than the other check variety BRRI dhan50 (158 days). Among the tested genotypes, SVIN076-Boro-18-Bhanga produced the highest mean yield (7.90 t ha^{-1}) ranged from 4.42 to 10.62 t ha^{-1} followed by SVIN063-Boro-18-Bhanga (7.67 t ha^{-1}), SVIN077-Boro-18-Bhanga (7.13 tha^{-1}), SVIN109-Boro-18-Bhanga (7.12 t ha^{-1}) and SVIN066- Boro-18-Bhanga (6.90 t ha^{-1}) (Table 5). On the other hand, nine advanced lines gave higher yield (6.18-7.90 t ha^{-1}) than the standard check BRRI dhan50 (6.15 t ha^{-1}) with a few days longer growth duration except SVIN069-Boro-18-Bhanga. SVIN076-Boro-18-Bhanga and SVIN063-Boro-18-Bhanga may be selected for conducting ALART that are suitable for single Boro ecosystem.

RYT (FBC). Five advanced lines were evaluated against three standard checks in RYT (FBC). The average grain yield of all advanced lines (5.57-7.77 t ha^{-1}) was lower than the check variety BRRI dhan58 (8.79 t ha^{-1}). Conversely, two advanced lines BRC302-2-1-2-1-DIH and BRC269-15-1-1-3 produced a higher yield than the check varieties BRRI dhan28 and BRRI dhan81 respectively (Table 6).

Table 2. Grain yield and ancillary characters of ALART PQR, Boro 2019-20 at BRRI RS, Bhanga.

Designation	Plant height (cm)	Growth duration (day)	Panicle/hill	Yield (t ha^{-1})
BR8862-29-1-5-1-3	94	162	14	7.47
BR8995-2-5-5-2-1	117	167	11	6.91
BRRI dhan50 (ck)	89	162	12	6.79
LSD (0.05)	5.15	0.76	1.51	1.04
CV (%)	2.27	0.20	5.45	6.52

Table 3. Grain yield and ancillary characters of ALART ZER, Boro 2019-20 at BRRI RS, Bhanga.

Designation	Plant height (cm)	Growth duration (day)	Panicle/hill	Yield (t ha^{-1})
IR99285-1-1-1-P2	103	164	11	9.12
BRRI dhan29 (ck)	102	165	10	9.03
BRRI dhan84 (ck)	112	147	11	5.07
LSD (0.05)	5.57	3.16	3.46	0.56
CV (%)	14.32	0.87	3.22	3.22

Table 4. Grain yield and ancillary characters of RYT- DWR2019 at BRRI RS, Bhanga.

Entries	Majhikanda, Bhanga			Talm, Nagorkanda		
	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
Baila-digha	211	155	1.39	149	151	1.12
Bashiraj	178	164	1.38	152	158	1.09
Boroi-digha	208	165	2.06	217	162	1.18
Dudlaki	211	155	1.49	224	150	1.28
Fulkori	185	160	1.43	225	155	1.47
Hizal-digha	205	160	1.51	244	151	1.35
Lal-mohon	210	155	1.39	220	152	1.09
Laxmi-digha	211	155	1.41	199	150	1.17
Sorsoria	213	158	1.52	228	151	1.34
BR10230-15-27-7B (ck)	183	165	1.75	153	156	1.28
LSD (0.05)	5.16	1.51	0.16	149	1.75	0.18
CV (%)	0.87	0.32	3.57	152	0.39	4.97

Table 5. Grain yield and ancillary characters of RYT-FBBhanga2019-20 at six locations.

Genotypes	Plant height (cm)	Growth duration (day)						Mean GD (day)	Yield (t/ha)						Mean yield (t ha^{-1})
		BAR	BHA	CUM	GAZ	HAB	RAJ		BAR	BHA	CUM	GAZ	HAB	RAJ	
SVIN055- Boro-18-Bhanga	103	152	169	139	165	163	162	158	5.94	8.64	5.91	4.02	6.97	6.9	6.40
SVIN063- Boro-18-Bhanga	106	161	172	146	168	166	158	162	9.29	10.46	7.58	6.08	5.93	6.67	7.67
SVIN064- Boro-18-Bhanga	95	152	163	142	162	164	160	157	7.72	8.25	5.87	3.65	5.4	5.83	6.12
SVIN066-- Boro-18-Bhanga	94	162	165	146	168	166	163	162	8.03	8.15	7.4	5.41	5.63	7.24	6.98
SVIN069- Boro-18-Bhanga	101	152	166	141	107	158	152	146	7.34	9.48	6.06	3.02	6.33	4.87	6.18
SVIN074- Boro-18-Bhanga	100	164	170	141	171	165	162	162	7.37	9.47	6.1	5.04	6.53	6.76	6.88
SVIN076- Boro-18-Bhanga	101	159	167	146	169	164	166	162	8.61	10.67	8.28	4.44	7.3	8.08	7.90
SVIN077- Boro-18-Bhanga	105	161	170	147	170	168	161	163	7.98	8.83	6.7	5.91	5.63	7.71	7.13
SVIN109- Boro-18-Bhanga	94	160	163	141	165	165	161	159	8.53	6.79	7.06	5.85	6.43	8.03	7.12
SVIN117- Boro-18-Bhanga	99	152	163	138	160	157	156	154	7.37	9.53	6.62	4.3	7.13	6.45	6.90
Bh Boro9945-12-1-3	100	146	160	138	106	162	152	144	6.04	7.41	6.05	2.84	5.1	5.09	5.42
BRRI dhan50 (ck)	85	152	168	146	165	162	154	158	6.28	8.54	5.83	3.98	6.27	6.02	6.15
BRRI dhan89 (ck)	110	161	169	149	166	166	164	162	8.23	10.12	7.67	5.76	7.47	7.55	7.80
LSD (0.05)	11.90	2.001	4.89	2.67	NS	2.05	2.42		0.72	1.83	1.97	3.42	0.91	1.44	
CV (%)	10.6	0.43	2.9	2.6	13.54	1.42	1.5		3.17	6.85	9.83	24.67	4.83	7.17	

BAR

Table 6. Grain yield and ancillary characters of RYT- FB Cumilla 2019-2020 at BRRI RS, Bhanga.

Designation	Plant height (cm)	Growth duration (Day)	Tiller no.	Panicle no.	Yield (t ha^{-1})
BRH11-9-11-4-5B-HR3	91	169	12	12	6.65
BRC302-2-1-2-1-DIH	99	166	12	12	7.77
BRC269-15-1-1-3	83	166	12	11	7.67
BRC298-18-2-3	93	175	13	12	6.89
BRC302-18-1-2-1	92	168	11	11	5.57
BRRI dhan28 (ck)	91	166	13	13	6.14
BRRI dhan58 (ck)	96	171	12	12	8.79
BRRI dhan81 (ck)	83	163	12	12	6.27
LSD (0.05)	NS	4.60	NS	NS	3.05
CV (%)	7.41	0.95	11.20	13.68	15.19
Heritability	0.60	0.94	-	-	0.68

RYT (ZER). Three advanced lines along with BRRI dhan28,BRRI dhan29, BRRI dhan74, BRRI dhan84 as checks were grown. All advanced lines produced lower yield (8.92-9.12 t ha^{-1}) than the check variety BRRI dhan29 (10.8 t ha^{-1}) and BRRI dhan74 (9.48 t ha^{-1}). On the other hand, the highest yield was found in advanced line IR105837-8-45-1-1 (9.4 t ha^{-1}) followed by BR8912-12-6-1-1-1-1 (9.12 t ha^{-1}) and IR105837-8-95-2-1 (8.92 t ha^{-1}) which was higher than the other two checks BRRI dhan28 and BRRI dhan84 (Table 7).

RYT (PQR). None of the tested entries produced higher yield (6.82-8.17 t ha^{-1}) than the check variety BRRI dhan50. But two advanced line BR8526-38-2-1-HR1 and Latabalam produced higher yield (8.17 t ha^{-1}) than both the checks (BRRI dhan63 and BRRI dhan81) with longer growth duration (Table 8).

RYT (IRR). Eleven advancedlines were evaluated against one check variety BRRI dhan58. Five advanced lines produced a higher yield (9.45-10.89 t ha^{-1}) than the standard check BRRI dhan58 (9.35 t ha^{-1}) with a few days longer growth duration (Table 9).

RYT (FBR). Eight advanced lines along with BRRI dhan58, BRRI dhan81 and BRRI dhan89 as checks were grown. None of the advanced lines produced higher yield (5.30-9.47 t ha^{-1}) than the check variety BRRI dhan89 (9.51 t ha^{-1}). But one line BR8905-17-2-3-3-1-4 gave higher than two checks (BRRI dhan58 and BRRI dhan81) (Table 10).

RYT FBR (2). Six advanced lines along with BRRI dhan58 and BRRI dhan63 as checks were tested. All the tested entries did not perform better than the check BRRI dhan58. Two advanced lines BRH9-7-4-1B and BRH13-2-4-6-4B produced a higher yield (7.23-7.73 t ha^{-1}) than the check variety BRRI dhan63 (7.07 t ha^{-1}) with similar or three days' higher growth duration (Table 11).

Morphological characterization of pigmented Boro rice germplasm. One experiment was conducted to characterize 100 pigmented rice germplasm through 51 agro-morphological traits (20 quantitative and 31 qualitative characters) using the Rice Germplasm Descriptors and Evaluation Form, GRSD, BRRI. The experiments were conducted in BRRI RS, Bhanga, Faridpur. The present study exhibits high variability in most of the observed traits of pigmented Boro rice germplasm.

FARMING SYSTEMS RESEARCH

For validation of improved fertilizer management option in Aman rice relayed with jute at farmers' field in a shallow flooded area, the highest yield (4.68 t ha^{-1}) was obtained from researcher fertilizer management practice (Fertilizer rate (Urea-TSP-MP-gypsum-zinc): 225-105-90-135-7.5 kg/ha through top dressing at weeding time than farmers practice (Table 12). Ten locations were selected for this trial and treated as dispersed replication. BRRI dhan39 performed better due to the researcher's management in all locations than that of farmers' practice (Fig. 1).

Table 7. Grain yield and ancillary characters of RYT- ZER 2019-2020 at BRRI RS, Bhanga.

Designation	Plant height (cm)	Growth duration (day)	Tiller no.	Panicle no.	Yield (t ha^{-1})
BR8912-12-6-1-1-1-1	95	173	12	11	9.12
IR105837-8-45-1-1	101	172	13	12	9.40
IR105837-8-95-2-1	104	166	12	12	8.92
BRRI dhan28 (ck)	84	158	12	11	6.38
BRRI dhan29 (ck)	96	173	13	12	10.8
BRRI dhan74 (ck)	85	160	14	13	9.48
BRRI dhan84 (ck)	95	156	12	11	6.93
LSD (0.05)	13.75	2.99	NS	2.62	2.34
CV (%)	5.1	0.63	8.71	7.77	9.39
Heritability	0.86	0.99	0.62	0.75	0.91

Table 8. Grain yield and ancillary characters of RYT- PQR 2019-2020 at BRRI RS, Bhanga.

Designation	Plant height (cm)	Growth duration (day)	Tiller no.	Panicle no.	Yield (t ha^{-1})
BR9713-3-4-4-6	104	171	11	11	6.82
BR8526-38-2-1-HR1	98	171	12	12	8.17
LataBalam	93	163	14	12	8
HabuBalam (RLR)	87	165	13	12	7.33
BRRI dhan50 (ck)	83	161	14	13	8.42
BRRI dhan63 (ck)	80	158	14	13	7.79
BRRI dhan81 (ck)	92	156	11	10	5.87
LSD (0.05)	7.88	2.19	3.32	2.37	2.42
CV (%)	3.03	0.47	9.03	6.9	11.31
Heritability	0.97	0.99	0.78	0.87	0.7

Table 9. Grain yield and ancillary characters of RYT- IRR 2019-2020 at BRRI RS, Bhanga.

Designation	Plant height (cm)	Growth duration (day)	Tiller no.	Panicle no.	Yield (t ha^{-1})
BR9667-54-2-2-97	111	175	13	13	9.02
BR9669-21-2-1-19	99	169	13	12	9.45
BR9669-23-3-2-23	109	172	13	12	10.06
BR969-15-3-2-31	102	172	12	11	9.24
BR9880-27-4-1-18	108	171	14	13	9.30
BR9891-19-2-2-8	100	169	12	11	9.16
BR9891-11-2-2-20	100	171	13	12	8.94
BR9891-17-2-2-23	102	172	12	11	10.13
BR9891-8-2-1-41	100	173	13	12	9.96
BR9891-18-1-2-7	106	171	13	12	10.89
T27A	118	172	19	7	0.71
BRRI dhan58 (Std. ck)	91	168	11	10	9.35
LSD (0.05)	12	NS	3.32	3.09	1.98
CV (%)	3.87	1.24	8.53	9.12	7.52
Heritability	0.88	0.54	0.88	0.87	0.98

Table 10. Grain yield and ancillary characters of RYT-FBR 2019-2020 at BRRI RS, Bhanga.

Designation	Plant height (cm)	Growth duration (day)	Tiller no.	Panicle no.	Yield (t ha^{-1})
IR100740-89-B-2	87	158	13	13	7.41
TP30433	86	161	12	12	7.60
IR100722-B-B-B-B-16	94	158	13	13	6.97
BR8905-17-2-3-3-1-1	85	158	13	12	6.02
TP26717	95	162	13	12	7.52
BR8905-17-2-3-3-1-4	100	166	14	14	9.47
BR8902-38-7-1-1-1-1	103	168	12	11	6.83
TP29654	56	157	12	11	5.30
BRRI dhan58 (Ck)	97	163	13	12	8.41
BRRI dhan81 (Ck)	91	156	12	12	5.55
BRRI dhan89 (Ck)	106	168	13	12	9.51
LSD(0.05)	9.14	2.57	NS	2.46	1.38
CV(%)	3.34	0.54	7.16	6.91	6.38
Heritability	0.96	0.99	0.47	0.61	0.96

Table 11. Grain yield and ancillary characters of RYT(2) FBR 2019-2020 at BRRI RS, Bhanga.

Designation	Plant height (cm)	Growth duration (day)	Tiller no.	Panicle no.	Yield (t ha^{-1})
BRH11-9-11-4-5B-HR3	87	165	12	12	6.85
BRH11-2-1-3-8B	105	170	12	12	6.87
BRH11-2-4-9B	98	171	13	13	6.71
BRH9-7-4-1B	104	169	11	10	7.73
BRH13-2-4-6-4B	89	165	11	10	7.23
IR12A177	100	164	19	13	5.74
BRRI dhan63 (ck)	82	165	19	14	7.07
BRRI dhan58 (ck)	97	168	15	14	8.18
LSD (0.05)	9.88	2.66	NS	NS	1.12
CV (%)	3.60	0.55	36.17	12.72	5.85
Heritability	0.95	0.96	0.26	0.53	0.90

Table 12. Yield performance forBRRI dhan39relayed with jute in validation of improved fertilizer management option at farmer's field in shallow flooded area.

Fertilizer management	GD (day)	Yield (t ha^{-1})
Recommended dose (T_1)	118	4.68
Farmers practice (T_2)	116	4.35
LSD (0.05)	0.633	0.0684
CV (%)	0.6023	1.69

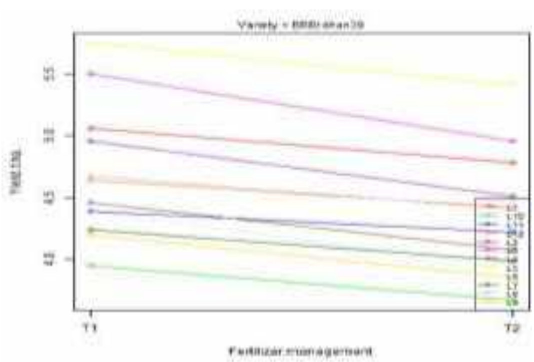


Fig. 1. Yield performance comparison between two management of BRRI dhan39 as relay crop with jute in ten locations.

Introduction of the intercropping system in different cropping pattern for the medium high land area is ongoing. For Rabi season the data was collected and then jute was in the main field. After jute harvesting the succession crop would be Aman rice in all fields. For Rabi season data, the REY was higher in cropping pattern (CP_1) and lowest in CP_3 (Table 13, Fig. 2).

CROP-SOIL-WATER MANAGEMENT

In the experiment on effect of nitrogen and potassium management on growth and yield of short duration T. Aman rice, yield of BRRI dhan71 was significantly higher in T_4 (4.2 t ha^{-1}) followed by T_2 (3.73 t ha^{-1}). There was no significant difference in yield among treatments when BRRI dhan75 was used. In context of plant height and sterility, there was no significant difference in two varieties among four treatments (Table 14).

SOCIO-ECONOMICS AND POLICY

Stability analysis. In long duration Aman varieties, BR22, BRRI dhan41 and BRRI dhan46 produced the highest grain yield (4.1 t ha^{-1}) followed by BRRI dhan44 (3.9 t ha^{-1}) and BR23 (3.6 t ha^{-1}). Among short duration Aman varieties, BRRI hybrid dhan4 produced the highest yield (4.2 t ha^{-1}) followed by BRRI dhan71 (3.7 t ha^{-1}) and BRRI dhan56 (3.6 t ha^{-1}). BRRI hybrid dhan6 obtained the highest grain yield (4.4 t ha^{-1}) among medium duration Aman varieties followed by BRRI dhan70 (4.3 t ha^{-1}) and BRRI dhan73 (4.1 t ha^{-1}), BRRI dhan53 (4.1 t ha^{-1}), BRRI dhan49 (4.1 t ha^{-1}). In Boro season, among the long duration varieties, yield of BR16 was the highest (7.4 t ha^{-1}) followed by BRRI dhan92 (7.32 t ha^{-1}) and BRRI dhan29 (7.10 t ha^{-1}). In short duration, Boro varieties BRRI Hybrid dhan2 produced the highest (7.8 t ha^{-1}) yield followed by BRRI Hybrid dhan5 (7.69 t ha^{-1}) and BRRI Hybrid dhan3 (7.16 t ha^{-1}).

TECHNOLOGY DISSEMINATION

Demonstrations of modern rice varieties during T. Aman 2019 and Boro 2019-20 were carried outat Bhanga, Faridpur, Muksudpur upazila, Gopalganj and Madaripur districts with the financial assistance of BRRI-SPIRA project. Mean grain yields with growth duration of Aman varieties were: 5.5 t ha^{-1} with 128 days for BRRI dhan71, 5.8 t ha^{-1} with 121 days for BRRI hybrid dhan4 and 5.7 t ha^{-1} with 120 days for BRRI hybrid dhan6. In Boro 2019-20, mean grain yield of BRRI dhan58 was 6.9 t ha^{-1} with growth duration of 155 days, 5.8 t ha^{-1} with 148 days for BRRI dhan74, 6.3 t ha^{-1}

Table 13. Yield performance and farmers' income of different improved cropping pattern for medium high land area in Faridpur district.

Cropping pattern (CP)		Rabi				
		Component yield (t ha^{-1})	Component REY (t ha^{-1})	Total REY (t ha^{-1})	Income (Taka)	Total income (Tk)
CP_1= Potato+Maize-Jute-T.Aman	Potato	12	11.5	15.4	300000	4,02,000
	Maize	5.1	3.9		102000	
CP_2= Onion+Pumpkin-Jute-T.Aman	Onion	11.2	10.8	13.1	280000	3,40,000
	Pumpkin	5	2.3		60000	
CP_3= Lentil+Maskmelon-Jute-T.Aman	Lentil	2.56	4.9	5.5	128000	1,44,000
	Maskmelon	2	0.6		16000	
CP_4= Mustard+watermelon-Mungbean-Jute-T.Aman	Mustard	1.12	2.4	7.9	61600	2,05,600
	watermelon	2.4	2.3		60000	
	Mungbean	1.2	3.2		84000	
CP_5= Onion-Jute-T.Aman (ck)	Onion	13	12.5	12.5	325000	3,25,000

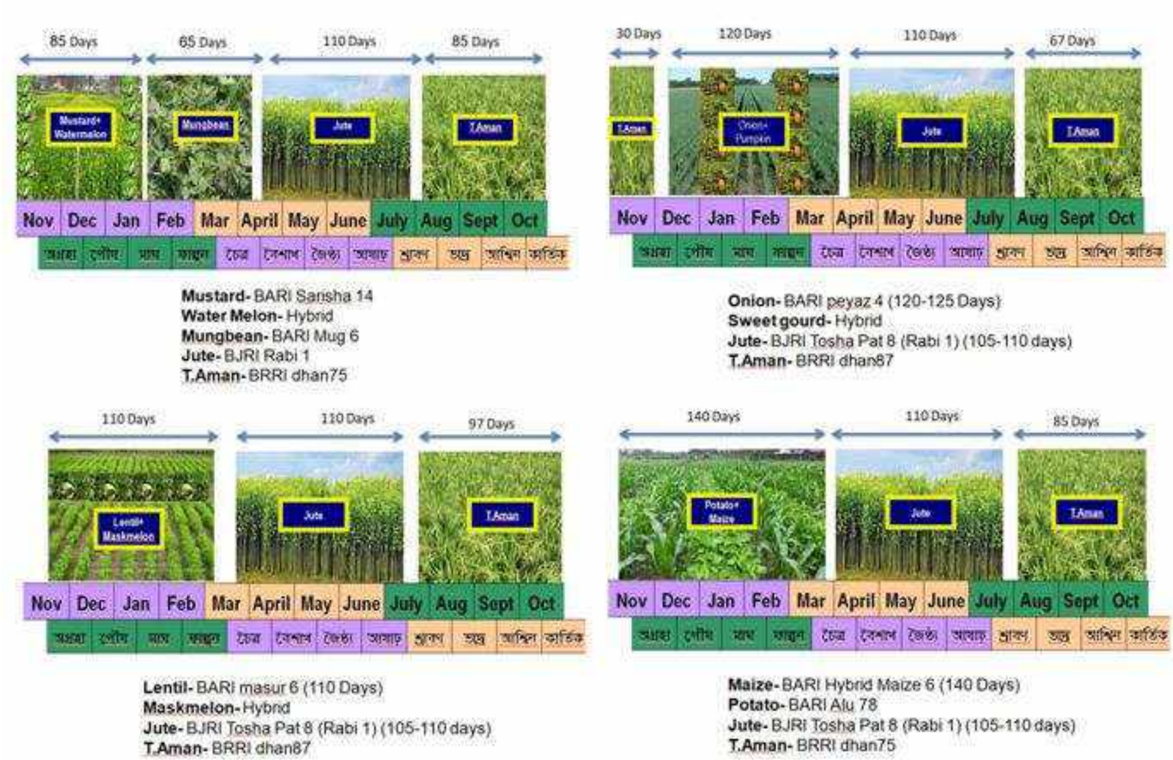


Fig. 2. Time frame and duration of different improved cropping patterns.

Table 14. Grain yield and yield component characters of N and K management of BRRI dhan71 and BRRI dhan75 in T. Aman 2019.

Treatment	Variety					
	BRRI dhan71			BRRI dhan75		
	Plant height (cm)	Sterility (%)	Yield (t ha^{-1})	Plant height (cm)	Sterility (%)	Yield (t ha^{-1})
T_1	110	15.3	3.07	98.	30.5	3.45
T_2	109	18.3	3.73	97	27.3	3.32
T_3	110	15.9	3.43	98	28.5	3.38
T_4	109	15.2	4.2	98	25.4	3.84
LSD (P<0.05)	NS	NS	0.5995	NS	NS	NS
CV(%)	2.68	11.74	8.31	1.42	6.81	7.77

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with 148 days for BRRI dhan81, 8.2 t ha^{-1} with 162 days for BRRI dhan89. One field day was organized with the help of DAE at the maturity stage of the crop. During field day, the trial farmers shared their experience to neighbouring farmers, which made them interested to these varieties to cultivate those varieties in their own plots and thereby a demand for quality seeds was generated.

In Aman 2019, five head to head trials were conducted as a part of varietal replacement strategyin five upazilas of two districts namely Faridpur and Gopalganj under BRRI RS, Bhanga with the financial assistance of BRRI-TRB project. Six BRRI varieties likę BRRI dhan39, BRRI dhan49, BRRI dhan71, BRRI dhan75, BRRI dhan80 and BRRI dhan87 and one BINA variety

BINA dhan 7 were included in one bigha trial. The highest grain yield in different locations were as follows: 5.56 t ha^{-1} in BRRI dhan39 at Shibrampur, Faridpur sader; 6.15 t ha^{-1} in BRRI dhan49 at Nagarkanda, Faridpur; 6.17 t ha^{-1} in BRRI dhan71 at Nagarkanda; 5.43 t ha^{-1} in BRRI dhan75 at Kashiani, Gopalganj; 6.72 t ha^{-1} in BRRI dhan80 at Nagarkanda, Faridpur; 6.80 t ha^{-1} in BRRI dhan87 at Nagarkanda and 5.78 t ha^{-1} in BINA dhan 7 at Nagarkanda, Faridpur.

Similarly, in Boro 2019-20 a total of nine varieties such as BRRI dhan28, BRRI dhan67, BRRI dhan81, BRRI dhan84, BRRI dhan88 are included in BRRI dhan28 group while BRRI dhan29, BRRI dhan58, BRRI dhan89, BRRI dhan92 are included in BRRI dhan29 group. Seven (four BRRI dhan28 group and three BRRI dhan29 group) head to head trials were conducted as varietal replacement strategy in six upazilas of four districts namely Faridpur, Shariatpur, Gopalganj and Rajbari under BRRI RS, Bhanga with the financial assistance of BRRI-TRB project. The highest grain yield with growth duration in different locations were: 6.68 t ha^{-1} with BRRI dhan28 in Bhanga; 8.13 t ha^{-1} with BRRI dhan67 in Muksudpur, Gopalganj; 6.31 t ha^{-1} with BRRI dhan81 in Bhanga, Faridpur; 6.62 t ha^{-1} with BRRI dhan84 in Bhanga, Faridpur; 6.07 t ha^{-1} BRRI dhan88 in Bhanga, Faridpur; 9.63 t ha^{-1} with BRRI dhan29 in Nagarkanda, Faridpur; 8.98 t ha^{-1} the BRRI dhan58 in Nagarkanda, Faridpur; 9.79 tha^{-1} BRRI dhan89 in sadar, Faridpur and 9.85 t ha^{-1} BRRI dhan92 in sadar, Faridpur. The trial farmers stored their seeds according to their choice for growing in the next Boro season.

In total 25.0 tons of seeds were produced in BRRI RS, Bhanga farm. Out of them, 10 tons of breeder seeds of BRRI dhan28 and BRRI dhan29 and the rest about 15.0 tons were TLS of short duration Aman varieties such as BRRI dhan39, 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 2019 -2020 season.

Three hundred farmers of greater Faridpur region were trained on modern rice production technologies through 10 training programmes in BRRI RS, Bhanga with the cooperation of DAE and the financial assistance of GOB and BRRI-SPIRA project.

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BRRI RS, Cumilla

SUMMARY

Altogether 45 crosses were made and 43 crosses were confirmed during T. Aman and Boro seasons at BRRI RS, Cumilla. A total of 761, 589, 299, 95 and 29 plant progenies with desirable plant type and high yield potential were selected from F_2, F_3, F_4, F_5 and F_6 generations respectively. Forty-six homozygous lines were bulked under the varietal development programme. Eighty-four genotypes were selected from observational yield trial (OYT) having desirable characters and high yield potential. Seventy-two materials were selected from AGGRi Network Trial. Forty-nine, 21, 20 and 36 genotypes were selected from different PYT, SYT, RYT and AYT respectively. A total of 282 advanced lines were selected from different yield trials during T. Aus 2019, T. Aman 2019 and Boro 2019-20 seasons.

Disease incidence of bacterial blight, sheath blight, neck blast, false smut and brown spot were 5-30, 5-90, 1-80, 0.01-5 and 20-100 % respectively during T. Aman 2019 season in Cumilla region. During Boro 2019-20 season, major rice diseases viz bacterial blight, sheath blight and neck blast were recorded ranging from 1-50, 1-60 and 1-40 % in BRRI released and local varieties respectively. About 219 rice lines and checks were evaluated against blast, bacterial blight and tungro disease and 11 blast, 25 BB and 11 tungro resistant lines were obtained in natural condition. From the blast resistant LST lines in the field condition, neck and leaf blast free 36 genotypes (out of 3,988) were selected. Yield loss in aromatic rice was saved upto 42% following BRRI developed blast disease management technology. Temperature, low rainfall, susceptible rice variety and huge number of GLH in the seedbed are the most critical factors for tungro disease devastation. Two times spray of systemic insecticide in the seedbed was sufficient for preventing GLH population in the seedbed and rice field as well as rice tungro disease in the most tungro prone areas in Cumilla region. From the ALART field trial, four BB and two blast resistant rice genotypes showed highly susceptible to neck blast disease, whereas one line HR (Path)-11 showed highly resistant to both leaf and neck blast resistant but high tendency of lodging.

Among the major nutrient elements, omission of N seemed most yield limiting factor for rice for T. Aman and Boro season. In T. Aman 2019 and Boro 2019-20 seasons, the highest grain yield was recorded in BRRI dhan87 (6.31 t ha^{-1}) and BRRI dhan89 (7.39 t ha^{-1}) respectively when 100 kg K/ha and 100 kg N/ha were used. Application of 2 ton/ha bio fertilizer with N (70%) + KS (100%) appeared as the best for grain yield and straw yield during T. aman 2019 and Boro 2019-20respectively during BRRI dhan75 and BRRI dhan58. DAP+ $N_{100\%}$ (3 times) produced higher grain and straw yield.

Among the rice varieties used in HTH trial and block demonstration, the yield of BRRI dhan87 showed the highest and ranged from 5.74 to 6.54 t/ha in Aman season andBRRI dhan92 showed the highest yield (7.88-8.14 t ha^{-1}) during Boro season. A total of 344 farmers and 16 SAAOs were trained up in modern rice cultivation.

In T. Aman 2019 and Boro 2019-20 seasons, a total of 32.48 (8.23 t and 24.25 t, respectively) ton breeder seeds of different BRRI varieties were produced and sent to GRS Division, BRRI Gazipur. However, 41.422 tons of TLS of BRRI rice varieties were produced during the reporting year.

VARIETAL DEVELOPMENT

Different yield trials such as preliminary yield trial (PYT), secondary yield trials (SYT), regional yield trial (RYT), advanced yield trials (AYT) were conducted in RCB and row-column designed. Spacing was maintained 20 × 20 cm in Boro and 20 × 15 in T.Aus season.

T. Aus 2019

BRRI RS, Cumilla programme

Four entries viz BR9829-30-3-2-1, BR9829-79-2-3-2, BR9829-79-3-1-1 and BR9029-51-3-5 were selected from Advanced yield trial based on yield and growth duration (Table 1). Yield range of selected lines was 4.01 to 4.16 t ha^{-1}. One line viz BR9011-62-2-1-2 and BR8781-16-10-3B was selected from each of RYT#1 and RYT#2 respectively. Four entries named BR9829-80-2-2-1, BR9829-80-2-2-2, BR9830-53-3-5-1 and BR9830-74-4-3-1 were selected from PYT.

Table 1. Yield and agronomic performances of breeding materials from advanced yield trial (AYT), T. Aus 2019-20, BRRI RS, Cumilla.

Designation	PH (cm)	GD (day)	Yield (t ha^{-1})
BR9829-30-3-2-1*	134.87	119	4.16
BR9829-78-1-2-1	142.27	120	3.75
BR9829-78-1-3-2	128.53	113	3.91
BR9829-79-2-3-2*	121.73	88	4.02
BR9829-79-3-1-1*	130.67	114	4.08
BR9829-79-3-1-3	113.20	110	3.18
BR9830-5-2-2-3	127.53	87	3.44
BR9830-44-1-8-1	124.53	113	3.48
BR9830-53-3-5-1	125.73	121	3.53
BR9830-74-4-1-1	123.27	120	3.50
BR9011-62-2-1-2	114.40	104	3.66
BR9011-25-4-1-3	115.27	106	3.42
SP21-1-4	104.87	104	3.64
BR8773-9-1-3	114.40	106	3.63
BR9029-51-3-5*	107.33	105	4.01
BR9029-51-3-12	107.33	105	3.54
BR8781-16-1-3-2-P1	117.73	122	3.92
BR8774-18-3-2-2-4	120.67	120	3.22
BR9006-54-1-3-2	108.60	106	2.46
BR8781-16-1-3-2-P2	118.30	117	3.53
BR8774-4-1-2-2-3	123.33	118	3.68
BR26(Ck)	112.40	103	3.42
BRRI dhan28(Ck)	108.73	113	3.66
BRRI dhan48(Ck)	124.40	111	3.85
BRRI dhan85(Ck)	116.67	105	4.12
LSD (5%)	4.56	1.31	0.32

PH= Plant height, GD= Growth duration, *Selected entries

Investigator: T Chakrabarty,P Nandi, M AMuttaleb, M M Rashid and K M Iftekharuddaula.

T. Aman 2019

AGGRi network trial. Seventy-two entries were selected from 387, based on yield (4.41-5.62 t ha^{-1}) in T. Aman season.

BRRI HQ programme. From HQ RYT trials**,** four entries (BR9880-40-1-3-34, BR9887-17-2-2-22, BR9881-24-2-2-25 and BR9880-2-2-2-1), two entries (BR10397-4-1-2, BR10395-22-3-5 (Blast)), three entries (BR9571-28-2-1-2-1, BR9571-4-1-2-2-1 and BR9571-4-2-6-1-1), 1 entry (BR9571-13-1-9-1-1), one entry (BR10001-94-2-B) and two entries (BR8492-9-5-3-2 (RLR) and BR7528-2R-HR16-2-24-1) lines were selected from RYT Insect, RYT (BB), RYT#1 (RLR), RYT#2 (RLR), RYT (ZER) and RYT ZER (RLR) respectively. No entries were selected from RYT Kataribhog (PQR), RYT (DTR), RYT #1 (DWR), RYT#2 (DWR) and RYT (Bio).

BRRI RS, Cumilla breeding programme. From the observational trial (OYT-Com), three lines viz BRC436-17-3-1-1, BRC437-44-1-4-1 and BRC417-16-2-2-1 were selected on the basis of yield and growth duration from 23 genotypes where standard checks were BRRI dhan49, BRRI dhan75 and BRRI dhan87. From different PYT and SYT trials 27 and five entries were selected, respectively. Among the two AYT trials four entries (BR9043-11-3-2-2, BRC315-14-2-3-1-1-H1, IR70213-10-CPA-4-2-2-2 and BR7849-35-2-2-1-1-P2)were selected based on their yield performance, growth duration and desirable phenotypic characters (Table 2).

Table 2. Yield and agronomic performance of breeding materials of AYT#1 (COM) and AYT#2 (WS) T. Aman 2019-20, BRRI R/S, Cumilla.

	AYT#1 (COM)		
Designation	PH (cm)	Yield (t ha^{-1})	GD (day)
BR9043-11-3-2-2	116	4.95	122
BRC315-14-2-3-1-1-H1	124	4.99	120
IR09L305	134	4.58	123
IR70213-10-CPA-4-2-2-2	108	5.46	123
BR8226-8-5-2-2	110	3.93	129
BRRI dhan49 (Ck)	104	4.89	124
BRRI dhan75 (Ck)	103	4.75	115
BRRI dhan71 (Ck)	125	5.63	111
BRRI dhan87 (Ck)	117	6.30	123
LSD (5%)	6.61	0.44	3.23
	DSk: 9 Jul 19 DT:7 Aug 19		
	AYT#2 (W/S)		
PH (cm)	Yield (t ha^{-1})	GD (days)	
BR7846-14-1-2-1-4-P1	142	4.85	156
BR7849-35-2-2-1-1-P2	120	5.23	166
BR7849-48-1-2-1-2-P3	158	4.78	154
BR7846-14-1-2-1-4-P2	148	4.82	156
BRRI dhan76 (Ck)	146	5.14	167
BRRI dhan77 (Ck)	131	4.91	157
LSD (5%)	10.05	0.15	4.22
	DSk: 9 Jul 19 DT: 21 Aug 19		

PH- Plant height, GD- Growth duration

Investigator. T Chakrabarty, P Nandi, M A Muttaleb, M M Rashid, B Saha and K M Iftekharuddaula.

Boro 2019-20

TRB project. Two genotypes, BR9943-4-2-3-1 (9.06 t ha^{-1} and 162 days) and BR9943-26-2-3-6 (8.74 t ha^{-1} and 161 days) were selected from PYT (BB) for their high yield potential and shorter growth duration. Twenty-seven genotypes produced the higher yield (above 7 t ha^{-1}) compared to the checks in AYT (FB). Forty-one and 17 entries were selected form OYT (FBR) and OYT (BB) respectively based on their higher yield. In the breeding value estimation (BVE) trial, out of 220 entries 22 produced higher yield (>8 t ha^{-1}) and those entries might be selected for breeding materials.

BRRI HQ programme. Three entries viz Habu Balam (RLR), BR9713-3-4-4-6 and BR8526-38-2-1-HR1 in RYT (PQR) performed better than the standard checks (Table 3). BR8912-12-6-1-1-1-1 in RYT (ZER) and BRH11-9-11-4-5B-HR3 in RYT#2 performed better than the standard check varieties. No entry performed better than the check variety in RYT (Bhanga) and RYT (FBR).

Table 3. Performance of entries in RYT-PQR, Boro 2019-20.

Designation	GD	PH	ET	Y
BR9713-3-4-4-6**	141	107	13	6.29
BR8526-38-2-1-HR1**	149	106	13	7.37
LataBalam	144	103	11	6.25
HabuBalam (RLR)**	147	98	12	6.57
BRRI dhan50 (ck)	146	86	14	5.57
BRRI dhan63 (ck)	144	86	12	5.95
BRRI dhan81 (ck)	139	91	12	6.26
LSD (0.05)	3.27	5.00	2.00	0.88
H	0.89	0.96	0.56	0.68

DSk: 30 Nov 2019 DT: 7 Jan 2020
**performed better

BRRI Cumilla breeding programme. Twenty-three genotypes were selected out of 37 genotypes based on yield and other parameters from the observational yield trial. Sixteen genotypes viz BRC491-5-2-1, BRC491-5-2-2, BRC454-36-3-3, BRC454-59-4-4, BRC425-4-2-2-1, BRC430-1-1-3-3, BRC430-2-1-3-1, BRC430-2-1-3-3, BRC430-12-1-8-6, BRC430-12-1-8-7, BRC430-14-1-4-1, BRC430-14-1-4-2, BRC430-14-1-4-3 BRC430-14-1-4-4 and BRC430-14-2-3-2; 9 entries viz. BRC426-4-2-1, BRC427-9-1-3, BRC428-3-1-1, BRC428-3-1-2, BRC389-4-2-4-2, BRC394-1-1-1-2, BRC394-1-1-1-5A, BRC398-4-1-1-1B and BRC401-1-1-1-1B; 4entries viz. BRC428-2-2-1, BRC366-2-2-4-2-1, BRC366-2-2-4-2-2 and BRC366-2-2-4-2-3 were selected from PYT (COM), SYT#1 (COM) and SYT#2 (COM) respectively. No entries can be selected from RYT based on the yield as the genotypes did not perform better than the check varieties. In AYT (COM), BRC335-1-3-2-2-1 was selected based on its higher yield and shorter growth duration.
Investigator: A K M Shalahuddin, P Nandi, M A Muttaleb, M M Rashid, M Hossain and K M Iftekharuddaula.

PEST MANAGEMENT

Survey and monitoring of rice diseases in selected areas in 2019-20. Twenty-five spots of each area of four upazillas of Cumilla in T. Aman 2019 and different seed production plots of BRRI RS, Cumilla during Boro 2019-20 were selected for survey. Disease incidence of bacterial blight, sheath blight, neck blast, false smut and brown spot were ranged 5-30, 5-90, 1-80, 0.01-5 and 20-100 % respectively during T. Aman 2019 season. In Boro 2019-20 season, major rice diseases were bacterial blight, sheath blight and neck blast where percent disease incidence was ranged 1-50, 1-60 and 1-40 % respectively. Neck blast disease was mostly observed in local aromatic rice.
Investigators: M M Rashid, F H Khan, M S Mian, M Hossain, M A I Khan and M A Latif

Screening of Blast, BB and Tungro resistant monogenic lines in disease hot spot areas. Two field trials were conducted during T. Aman 2019 with 108 lines (99 lines and nine checks) in Debidwar and during Boro 2019-20 with 111 lines (103 lines and eight checks) in Barura, Cumilla. In T. Aman 2019, all the blast resistant lines (# 1-46) and # 95-98 showed resistantce to blast whereas two check varieties BRRI dhan34 (#101) and BRRI dhan90 (#100) were susceptible to neck blast disease. In Boro 2019-20, entry # 16, 42, 44, 45, 46, 95 along with check BRRI dhan74 showed both leaf and neck blast resistantce and entry # 5, 26, 96, 97, 98 showed neck blast resistantce in the natural field condition. In both the seasons, BB resistant lines # 47-73, all lines including the checks didn’t show BB disease except two lines # 47 and 48 (DS 5-7) in Aman season. Among the tungro resistant lines # 74-91, entry # 74-76, 81-83, 87-91 showed resistant reaction to rice tungro disease whereas, check varieties showed susceptible to tungro during Aman but these lines including check didn’t show Tungro disease in Boro season.
Investigators: M M Rashid, F H Khan, M S Mian, M Hossain, M A I Khan and M A Latif.

Screening of blast resistant LST population in blast hot spot area. Out of 3988 genotypes neck and leaf blast free 36 were selected (Table 5).
Investigators: M M Rashid, F H Khan, M S Mian, M Hossain, T H Ansari, M A I Khan and M A Latif

Validation of rice neck blast disease management technology under farmer’s field condition. According to BRRI recommendation 5 kg MOP/bigha (applied) additionally during last top dress of urea and sprayed fungicide Trooper or Tricyclazole group fungicides @ 1 g/L water for two times as preventive: 1st at late booting stage and 2nd at flowering stage in the evening. Neck blast disease was found severe at 66% disease incidence (DI) in BRRI dhan34 at farmers practice compared to BRRI practice (5% DI) at BRRI farm, Cumilla during T. Aman 2019 season. Rice yield loss was saved by 42% by managing neck blast disease following BRRI developed blast disease management technology.
Investigators: M M Rashid, F H Khan, M S Mian, M Hossain, M A I Khan and M A Latif

Factors affecting rice tungro disease and its management in Cumilla region. Field experiments were conducted during T. Aus 2019, T. Aman 2019 and Boro 2019-20 seasons in order to find out the factors and a sustainable management practice of rice tungro disease for tungro disease prone areas of Cumilla region. GLH population was very low in

Table 5. List and selected blast resistant rice genotypes during Boro 2019-20 in Cumilla.

Cross combination	Target gene	Generation	No. of population	Selected blast resistant genotypes
NILpi21/BD28//BD28	*pi21*	BC1F6	260	C-137, C-231
NILPb-1/BD28/2*BD28	*Pb-1*	BC2F6	270	
BD28/NILPiz-t-T/2*BD28	*Piz-t*	BC2F6	287	
BD28/NILPi9-M/2*BD28	*Pi9*	BC2F6	297	
BD29/ NILpi21/2*BD29	*pi21*	BC2F6	260	H-237
BD29/ NILPb1/2*BD29	*Pb-1*	BC2F6	245	
BD29/ NILPish-S/2*BD29	*Pish*	BC2F6	208	
BD63/ NILpi21/2*BD63	*pi21*	BC2F6	248	K-116, K-152, L-24, L-25, L-35, L-112, L-116, L-182, L-215, L-218, L-227, M-207, N-86, N-195, N-218
BD63/ NILPb1/2*BD63	*Pb-1*	BC2F6	279	
IRBLzt-T/ BD63/2*BD63	*Piz-t*	BC2F6	261	
IRBL9-M/ BD63/2*BD63	*Pi9*	BC2F6	242	
NILpi21/BD64//BD64	*pi21*	BC1F6	295	P-29, P-60, P-61, P-85, P-87, P-92, P-117, P-131, P-133, P-245, P-260, P-265, P-274, P-282, P-284, P-285, P-292, Q-180
NILPb-1/BD64/2*BD64	*Pb-1*	BC2F6	300	
BD64/NILPiz-t-T/2*BD6428	*Piz-t*	BC2F6	210	
BD64/NILPi9-M/2*BD64	*Pi9*	BC2F6	326	
		Total	3988	36

insecticide sprayed seedbed and main plot compared to control plots. The weather parameters greatly influenced the population of GLH in rice field. Increased yearly temperature, low rainfall, susceptible rice variety and huge number of GLH in the seedbed were the most critical factors for tungro disease devastation. High temperature and low rainfall encouraged the GLH population. In BRRI RS, Cumilla, due to high temperature and low rainfall, GLH population was higher in 2018compared to 2019. Recommendation for rice tungro disease management from three seasons eexperiments includes:

- Seedbed along with surroundings should be kept free from GLH by light trapping/hand sweeping/insecticide spraying.
- Spray systemic insecticide (MIPC is the most effective) in the seedbed two times for controlling GLH. The season-wise spray times are as follows:

a) In Aus season, 10 days after seeding (DAS) and 20 DAS (about 3-5 days before transplanting)

b) In T. Aman season, 10-15 DAS and about five days before transplanting

c) In Boro season, 15-20 DAS and about five days before transplanting

- Uprooting the visible tungro infected plants followed by insecticide spray

Investigators: M M Rashid, M S Mian, F H Khan M Hossain, S A I Nihad, M A I Khan, M A Latif

Tracking the infection sources of rice false smut disease. A net house experiment was conducted in T. Aman 2019 to identify whether the seed/soil and/or the air was the carrier of the pathogen or not. The treatments were: T1 = Seedlings were transplanted from infected seeds with sterilized soil, T2 = Seedlings were transplanted from treated healthy seeds with sterilized soil, T3 = Seedlings were transplanted from treated healthy seeds with infected soil, T4 = Seedlings were transplanted from infected seeds with infected soil. False smut disease was not observed at all. Therefore, the experiment is needed to repeat in the next T. Aman 2020 season.

Investigators: M M Rashid, B Nessa, M Hossain, M A Latif

ALART for bacterial blight resistant rice (BBRR) during Boro 2019-20. Four resistant genotypes viz V1 = BR8938-19-4-3-1-1-P2-HR3, V2 = BR9651-15-2-1-4, V3 = BR (Bio) 11447-1-28-14-3, V4 = BR (Bio) 11447-3-10-7-1 along with two susceptible checks,V5 = BRRI dhan28 (Sus ck) and V6 = BRRI dhan58 (Std ck) were used in this experiment. The disease incidence and disease severity were recorded in natural field condition. The BB resistant genotypes BR8938-19-4-3-1-1-P2-HR3, BR9651-15-2-1-4 and BR (Bio) 11447-1-28-14-3 and check BRRI dhan58 didn't show BB disease. One genotype BR (Bio) 11447-3-10-7-1 showed very low BB disease (% DI 10 and DS 3) along with check BRRI dhan28 (% DI 20 and DS 3), which indicated that BB disease pressure is naturally very low in the reporting season. However, all the four genotypes showed remarkably susceptible to neck blast disease (% DI 23-73 and DS 7-9). For this reason, none of the genotypes were recommended from BRRI RS, Cumilla for further progress in varietal development programme.

Investigators: M M Rashid, Shamsunnahar, F H Khan, M Hossain, M A Islam

ALART for blast resistant rice (BRR) during Boro 2019-20. Three blast resistant genotypes HR (Path)-11, Path2441, BR (Path) 12452-BC3-16-19, along with two susceptible checks BRRI dhan58 (Std ck) and BRRI dhan29 (Std ck) were used in this experiment. The disease incidence and disease severity of tested genotypes were recorded in natural field condition. The genotype HR (Path)-11 showed fully resistant (%DI 0 and DS 0) to both leaf (LB) and neck blast (NB) compared to susceptible checks BRRI dhan58 (NB % DI 48, DS 7) and BRRI dhan29 (NB %DI 85, DS 9). Other two genotypes (Path2441 and BR (Path) 12452-BC3-16-19) showed highly the susceptible to neck blast as susceptible checks. During grain filling stage, HR (Path)-11 showed 100 % lodging. For those reasons, none of the genotypes were recommended for further progress, but HR (Path)-11 can be used as blast resistant donar parent.

Investigators: M M Rashid, Shamsunnahar, F H Khan, M Hossain, M A Islam

CROP-SOIL-WATER MANAGEMENT

Long-term missing element trial. The experiment was conducted on a permanent layout at the BRRI RS, Cumilla (N 23.66653° and E 91.15887°) since Boro 2014. 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), 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 2019 and 145-31-77-13-1.5 kg/ha for Boro 2019-20. Nutrient element, nitrogen was recorded as the most yoeld limiting factor for both the seasons.

Investigators: F H Khan, B Saha, T Ferdous, M M Rashid and M Hossain

Effect of NK interaction on the yield of BRRI dhan87 and BRRI dhan89. The experiment was conducted under four N doses (0, 50, 75 and 100 kg/ha), four K doses (0, 50, 100 and 150kg/ha) during T. Aman 2019, four N doses (0, 100, 120 and 140 kg/ha) as well as four K doses (0, 50, 100 and 150 kg/ha) during Boro 2019-20. The highest grain yield was recorded with BRRI dhan87 (6.31 t ha^{-1}) in T. Aman, and BRRI dhan89 (7.39 t/ha) in Boro seasonwhen 100 kg K/ha and 100 kg N/ha were used.

Investigators: F H Khan, B Saha, T Ferdous, M M Rashid and M Hossain

Efficiency of DAP fertilizer for the supplementation of nitrogen fertilizerduring Boro 2019-20. BRRI dhan81 was used as a test variety. Treatments were T_1 = DAP, T_2 = DAP (Urea appli $_{100\%}$; 30 +45 DAT), T_3 = DAP (Urea appli $_{100\%}$; 15+30 +45 DAT), T_4 = DAP (Urea appli (-) $_{25\%}$; 15+30 + 45 DAT),T_5 = DAP (Urea appli (-) $_{50\%}$; 15 + 30 +45 DAT),T_6 = DAP (Urea appli (-) $_{75\%}$; 15 + 30 +45 DAT). Treatment, DAP+ $N_{100\%}$ (3 times), produced the highest grain and straw yield whereas, T_6 = DAP + (-) $N_{75\%}$ (3 times) produced the lowest grain and straw yield. As there was 10-25% blast infestation in different plots, the experiment was suggested to repeat in the next season.

Investigators: B Saha, F H Khan, T Ferdous, M M Rashid and M Hossain

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI developed rice varieties. Eleven, 42 and 43 BRRI released rice varieties were evaluated to determine the stability index at BRRI RS, Cumilla during T. Aus 2019, T. Aman 2019 and Boro 2019-20 seasons respectively. In T. Aus 2019, BRRI dhan48 (4.42 t ha^{-1}) obtained the highest yield followed by BRRI dhan43 (3.72 t ha^{-1}) BRRI dhan65 (3.60 t ha^{-1}), BRRI dhan85 (3.60 t ha^{-1}), BRRI dhan82 (3.56 t ha^{-1}) andBRRI dhan42 (3.50 t ha^{-1}). In T. Aman 2019, BRRI hybrid dhan4 produced the highest yield (6.08 t ha^{-1}) followed by BRRI dhan87 (5.47 t ha^{-1}), BRRI dhan52 (5.2 t ha^{-1}), BRRI dhan51 (5.18 t ha^{-1}), BRRI dhan57 (5.16 t ha^{-1}) and BR23 (5.10 t ha^{-1}). In Boro 2019-20, BRRI hybrid dhan3 produced the highest yield (9.38 t ha^{-1}) followed by BRRI dhan89 (8.81 t ha^{-1}), BRRI hybrid dhan2 (8.65 t ha^{-1}), BRRI dhan29 (8.37 t ha^{-1}), BRRI hybrid dhan5 (8.26 t ha^{-1}), BR14 (8.23 t ha^{-1}), BRRI dhan92 (7.87 t ha^{-1}), BRRI dhan47 (7.55 t ha^{-1}).

Investigators: F H Khan, M M Rashid, A K M Shalahuddin, B Saha, T. Ferdous and M Hossain

TECHNOLOGY TRANSFER

Field demonstration of BRRI rice variety. A total of 37 field demonstrations (at least one bigha each) was conducted during T. Aman 2019. The yield of BRRI dhan75 and BRRI dhan87 ranged from 4.15 to 5.90 and 5.15 to 6.60 t ha^{-1}, respectively. Farmer's acceptance of BRRI dhan87 was found very high in those respective areas for its grain size panicle length and high yield. Of the 33 field demonstrations in Boro 2019-20, the highest grain yield was recorded from BRRI dhan92 (8.14 t ha^{-1}) followed by BRRI dhan89 (7.75 t ha^{-1}), BRRI dhan84 (6.18 t ha^{-1}) and BRRI dhan81 (5.25 t ha^{-1}). In all the locations (five demo) yield of BRRI hybrid dhan5 varied from 8.75 to 9.72 t ha^{-1}.

Investigators: F H Khan, M M Rashid, B Saha, T Ferdous, A K M Salahuddin, and M Hossain

Varietal replacement through head to head (HTH) trial. Among the rice varieties used in this study during T. Aman 2019, BRRI dhan87 produced the highest yield (6.54 t ha^{-1}) compared to the other rice varieties. Farmers' acceptance of BRRI dhan87 and BRRI dhan71 were higher than the other varieties. In Boro 2019-20, BRRI dhan88 (7.31 t ha^{-1}) showed the highest yield followed by BRRI dhan67 (6.99 t ha^{-1}), BRRI dhan81 (6.92 t ha^{-1}) and BRRI dhan84 (6.41 t ha^{-1}).

Investigators: F H Khan, M M Rashid, B Saha, T Ferdous, A K M Salahuddin, and M Hossain

Block demonstration, dissemination and quality seed production of rice varieties (SPIRA project). Four block demonstrations using new rice varieties BRRI dhan75and BRRI dhan87 in T. Aman 2019 and two block demonstrations using BRRI dhan84, BRRI dhan89 and BRRI dhan92 in Boro 2019-20 were conducted. In T. Aman 2019, the average yield of BRRI dhan75 was 4.78 t ha^{-1} ranging from 5.15 to 6.60 t ha^{-1} and with BRRI dhan87 it was 5.95 t ha^{-1} ranging from 5.15 to 6.60 t ha^{-1}. In Boro 2019-20, the average yield of BRRI dhan84, BRRI dhan89 and BRRI dhan92 were 6.39, 7.56, and 8.01 t ha^{-1} respectively. Demo farmers as well as neighbour farmers were also interested to cultivate BRRI dhan87 in T. Aman and BRRI dhan89 and BRRI dhan92 in Boro season.

Investigators: F H Khan, M M Rashid, B Saha, T Ferdous, A K M Salahuddin, and M Hossain

Training/Field day/Agricultural fair

Training on modern rice cultivation. Eight farmers' trainings (240 farmers) from GOB and 3 from SPIRA project (104 farmers and 16 SAAO) were conducted in different locations of Cumilla and Chandpur districts to disseminate rice varieties and build up their knowledge on modern rice cultivation technologies.

Investigators: F H Khan, M M Rashid, B Saha, T Ferdous, A K M Salahuddin, and M Hossain

Field day and fair. Six field days were conducted in the block demonstration areas in Cumilla and Chandpur districts due to demonstrate the newly released BRRI varieties during Aman 2019 and Boro 2019-20 seasons funded by SPIRA project. About 1200 farmers as well as extension personnel attended the field days. Most of the farmers got interested to cultivate new rice varieties in their areas specially BRRI dhan87, BRRI dhan89 and BRRI dhan92. BRRI RS, Cumilla also participated in Krishimela, agriculture fair and development fair.

Investigators: F H Khan, M M Rashid, B Saha, T Ferdous, A K M Salahuddin, and M Hossain

Breeder and TLS seed production. In T. Aman 2019 and Boro 2019-20 seasons, a total of 32.48 (8.23 t and 24.25 t, respectively) ton breeder seeds of different BRRI varieties were produced and sent to GRS Division, BRRI Gazipur. However, 41.422 tons of TLS of BRRI rice varieties were produced during the reporting year.

BRRI RS, Habiganj

SUMMARY

Deep water rice genotypes BR7733-2-1-2B, BR7735-1-1-2B and BR7920-1-2-3B produced 0.3 t ha^{-1} more yield over the check Hbj. Aman-I in SYT-1 and genotypes BR7730-1-1-2B, BR7918-1-2-3B and BR7919-1-1-3B produced 0.9 t ha^{-1} yield advantage over the check Hbj. Aman-IV in SYT-2 during Broadcast Aman.

Premium quality rice genotypes BR9126-15-3-4-1 (4.2 t ha^{-1}) and BR9126-15-3-4-2 (4.0 t ha^{-1}) produced higher grain yield than all the checks (Kataribhog, Dinajpur Kataribhog and BRRI dhan37) with 135 days growth duration in RYT during T. Aman.

Zinc enriched rice genotype BR8912-12-6-1-1-1-1 produced higher grain yield (7.7 t ha^{-1}) than all the check varieties (BRRI dhan28, BRRI dhan29, BRRI dhan74 and BRRI dhan84) in RYT during Boro.

Premium quality rice genotype BR8862-29-1-5-1-3 produced higher grain yield than all the tested varieties with 6-15 days later than the checks in RYT during Boro.

Insect resistance rice genotype BR9891-11-2-2-20 (7.2 t ha^{-1}, 162 days) showed almost the same yield and growth duration of the check BRRI dhan58 (7.4 t ha^{-1}, 158 days) in the RYT during Boro.

The genotype TP29654 produced the highest yield among the tested entries and about 1.5 t ha^{-1} more yield than the check BRRI dhan81 with same growth duration in the RYT#FB-1 during Boro.

The genotype BRC269-15-1-1-3 produced the highest grain yield (7.7 t ha^{-1}) than all the tested genotypes with similar duration (162 days) of the check BRRI dhan58 in the RYT#FB-2.

With four different sowing times, all the tested advanced short duration genotypes produced higher yield in the sowing time of 5 December but BRRI dhan28 (ck) showed higher yield in the showing time of 25 November.

From a long-term missing element trial of Boro-Fallow-Fallow cropping pattern, it was found that besides NK, K is the most yield limiting nutrient element in BRRI RS, Habiganj farm.

Application of N @ 140 kg ha^{-1} with 50 kg K ha^{-1} BRRI dhan89 produced significantly higher grain yield of 7.48 t ha^{-1} than the other combination of N and K fertilization during Boro in Habiganj farm.

Vermicompost organic manure during Aus, T. Aman and Boro rice cultivation could be very useful atmospheric and soil management strategy to reduce about 14-97% of global warming potential and increase rice yield about 5-17%.

The alternate wetting and drying irrigation system significantly reduced about 23-46% of total global warming potential than continuous flooding because of reducing methane emission rates.

BRRI dhan92 also reduced about 7% CH_4 emission than BRRI dhan29.

About 17 tons truthfully labeled seeds were distributed to the stakeholders from previous year's produce and more than 20 tons produced during the reporting year. About 26 tons breeder seeds were also produced and sent to the Genetic Resource and Seed Division of BRRI.

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 (B. Aman)

Preliminary yield trial (PYT). Promising local deep-water rice genotypes for yield potential and adaptability under deep water eco-system were evaluated. Nine deep water rice genotypes were evaluated. 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 the vegetative and maturity stages and yield calculated.

Three genotypes; Lal-mohan, Sor-soria and Charali were selected for SYT according to their yield performance (Table 1).

Table 1. Yield performance of local deep-water rice genotypes in PYT, B. Aman 2019.

Designation	Yield (t ha^{-1})
Lal-mohan	1.9
Dud-laki	1.5
Kipho-digha	0.9
Laxmi-digha	1.4
Bashiraj	1.5
Sor-soria	1.8
Bila-digha	1.5
Hizal-digha	1.2
Charali	2.1
LSD (5%)	0.23

Secondary yield trials (SYT). 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.

Secondary yield trials (SYT-1). Five genotypes along with local check Hbj. Aman-I were evaluated.

Genotypes BR7733-2-1-2B, BR7735-1-1-2B and BR7920-1-2-3B produced about 0.3 t ha^{-1} yield over the check Hbj. Aman-I (Table 2).

Secondary yield trials (SYT-2). Five genotypes along with local check Hbj. Aman-IV were evaluated.

Genotypes BR7730-1-1-2B, BR7918-1-2-3B and BR7919-1-1-3 B provided about 0.9 t ha^{-1} yield advantage over the check Hbj. Aman-IV (Table 3).

TRANSPLANT AMAN (RAIN-FED)

Development of pigmented/Anti-oxidant rice. Experiments were done to select progenies with emphasis on earliness, plant type, grain type and high yield potential compared to the standard varieties. In total, 24 F_2 populations were grown. The plant populations were 3000-4000 in each cross. Thirty-day-old single seedlings were transplanted at 20 cm × 20 cm spacing. 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 3,175 progenies from 20 crosses were selected based on grain and plant types and other agronomic traits in field RGA.

Regional yield trial (RYT# PQR). Genotypes for specific and general adaptability were evaluated. Twenty-nine-day-old seedlings were transplanted in 5.4 m × 12 rows plot with 20 × 20 cm spacing using 2-3 seedlings $hill^{-1}$ in RCB design with three 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. Data were recorded on date of flowering and maturity dates, plant height, phenotypic acceptability at vegetative and maturity stage as well as yield.

Seven genotypes along with three checks Kataribhog, Dinajpur Kataribhog and BRRI dhan37 were evaluated. Genotypes BR9126-15-3-4-1 (4.2 t ha^{-1}) and BR9126-15-3-4-2 (4.0 t ha^{-1}) produced higher grain yield with all the check varieties within 135 days growth duration (Table 4).

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 flowering and maturity dates, plant height, phenotypic acceptability at vegetative and maturity stages and yield.

Table 2. Yield performance of selected genotypes in secondary yield trial (SYT-1), B. Aman 2019.

Designation	Yield (t ha^{-1}) at 14% M
BR7733-2-1-2B	1.9
BR7735-1-1-2B	2.0
BR7738-2-2-2B	1.3
BR7920-1-2-3B	2.1
BR7921-1-1-1-3B	1.6
Hbj. Aman-I (L. ck)	1.7
LSD (5%)	0.23

Table 3. Yield performance of selected genotypes in secondary yield trial (SYT-2), B. Aman 2019.

Designation	Yield (t ha^{-1}) at 14% M
BR7730-1-1-2B	2.8
BR7731-1-1-2-2B	2.1
BR7737-1-2-2B	2.3
BR7918-1-2-3B	2.7
BR7919-1-1-3B	2.6
Hbj. Aman-IV (L. ck)	1.8
LSD (5%)	0.30

Regional yield trial (RYT# ZER). Three genotypes along with four checks BRRI dhan28, BRRI dhan29, BRRI dhan74 and BRRI dhan84 were evaluated. The genotype BR8912-12-6-1-1-1-1 produced higher grain yield (7.7 t ha^{-1}) than all the check varieties (Table 5).

Regional yield trial (RYT) (PQR). Four genotypes along with three checks BRRI dhan50, BRRI dhan63 and BRRI dhan81 were evaluated. The genotype BR8526-38-2-1-HR1 produced higher grain yield (6.8 t ha^{-1}) than all the tested varieties but 6-15 days later than the checks (Table 6).

Regional yield trial (RYT# insect resistant). Ten genotypes along with two check varieties BRRI dhan28 and BRRI dhan58 were evaluated. None of the genotype produced higher yield than the check varieties but the genotype BR9891-11-2-2-20 (7.2 t ha^{-1}, 162 days) showed almost same yield and growth duration with the check BRRI dhan58 (7.4 t ha^{-1}, 158 days) (Table 7).

Regional yield trial (RYT# FB-01). Eight genotypes along with three checks BRRI dhan58, BRRI dhan81 and BRRI dhan89 were evaluated during Boro 2019-20. The genotype TP29654 produced the highest yield (7.1 t ha^{-1}) among the tested entries which is about 1.5 t ha^{-1} higher than the check BRRI dhan81 with same growth duration (Table 8).

Regional yield trial (RYT # FB-2). Five advanced lines along with three checks BRRI dhan28, BRRI dhan58 and BRRI dhan81 were evaluated during Boro 2019-20. The genotype BRC269-15-1-1-3 (7.7 t ha^{-1}) produced the highest grain yield than all the tested genotypes with similar duration of the check variety BRRI dhan58 (162 days) (Table 9).

Regional yield trial (RYT # FB-3). Six advanced lines along with two checks BRRI dhan63 and BRRI dhan58 were evaluated during Boro 2019-20. BRH11-2-4-9B and IR12A177 produced higher grain yield than BRRI dhan63. The genotype IR12A177 showed almost similar yield and growth duration with the check variety BRRI dhan58 (6.8 t ha^{-1}, 164 days) (Table 10).

Regional yield trial (RYT# FB-4). Six advanced lines along with two checks BRRI dhan50 and BRRI dhan89 were evaluated. No entries produced higher yield than the check BRRI dhan89 but three genotypes; Bh Boro-18-SVIN117, Bh Boro-18-SVIN076 and Bh Boro-18-SVIN055 produced higher yield over the check BRRI dhan50 with similar growth duration (Table 11).

IIRON2019 (set-2). International Irrigated Rice Observational Nursery (IIRON2019). 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 79, only 14 genotypes were selected according to their yield performance, phenotypic acceptance and growth duration. These materials will be re-tested in the next season (Table 12).

Table 4. Yield performance of advanced genotypes in RYT-PQR, T. Aman 2019.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR9126-15-3-4-1	119	135	4.2
BR9126-15-3-4-2	124	132	4.0
BR8887-26-8-2-3	130	121	3.2
BR9178-7-2-4-4	149	145	3.8
BR8528-2-2-3-HR1	139	130	2.7
BR8528-2-2-3-HR2	131	131	3.0
BR8882-30-2-5-2	141	132	3.2
Kataribhog(ck)	185	142	3.4
Dinajpur Kataribhog(ck)	183	143	2.4
BRRI dhan37(ck)	171	143	3.5
LSD (5%)	15.01	4.76	0.35

DS: 1 Jul 2019 DT: 30 Jul 2019

Table 5. Yield and ancillary character of ZER materials, Boro 2019-20.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR8912-12-6-1-1-1-1	100	165	7.7
IR105837-8-45-1-1	100	163	6.3
IR105837-8-95-2-1	103	158	6.8
BRRI dhan28 (ck)	101	152	6.2
BRRI dhan29 (ck)	101	166	7.5
BRRI dhan74 (ck)	100	145	6.9
BRRI dhan84 (ck)	106	150	6.6
LSD (5%)	1.58	6.05	0.42

DS: 24 Nov 2019 DT: 9 Jan 2020

Table 6. Yield and ancillary character of PQR lines, Boro 2019-20.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR9713-3-4-4-6	103	169	6.7
BR8526-38-2-1-HR1	96	173	6.8
Lata Balam	94	160	6.3
Habu balam (RLR)	89	171	5.6
BRRI dhan50 (ck)	83	167	6.2
BRRI dhan63 (ck)	81	158	6.5
BRRI dhan81(ck)	86	157	5.7
LSD (5%)	5.72	4.86	0.36

DS: 22 Nov 2019 DT: 6 Jan 2020

Table 7. Yield and ancillary character of IRR lines, Boro 2019-20.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BR9667-54-2-2-97	120	164	6.4
BR9669-21-2-19	105	158	5.9
BR9669-23-3-2-23	109	167	6.3
BR9669-15-3-2-31	102	160	5.9
BR9880-27-4-1-18	102	168	5.0
BR9891-19-2-2-8	103	162	6.6
BR9891-11-2-2-20	97	162	7.2
BR9891-17-2-2-23	101	164	6.1
BR9891-8-2-1-41	97	166	5.9
BR9891-18-1-2-7	98	167	6.2
BRRI dhan58 (ck)	92	158	7.4
BRRI dhan28 (ck)	97	157	6.5
LSD (5%)	4.11	2.19	0.36

DS: 23 Nov 2019 DT: 9 Jan 2020

Table 8. Yield and ancillary character of FBR lines, Boro 2018-19.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
IR100740-89-B-2	93	155	5.8
TP30433	95	165	7.0
IR100722-B-B-B-B-16	98	160	6.3
BR8905-17-2-3-3-1-1	89	159	6.7
TP26717	95	155	6.7
BR8905-17-2-3-3-1-4	97	167	6.5
BR8902-38-7-1-1-1-1	113	165	5.5
TP29654	86	154	7.1
BRRI dhan58 (ck)	95	162	6.7
BRRI dhan81(ck)	91	155	5.6
BRRI dhan89 (ck)	104	167	8.1
LSD (5%)	4.44	3.03	0.44

DS: 22 Nov 2019 DT: 5 Jan 2020

Table 9. Yield and ancillary character of FBR lines (Biotech.), Boro 2019-20.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRC297-15-1-1-1	101	166	6.9
BRC302-2-1-2-1	103	164	7.0
BRC269-15-1-1-3	91	163	7.7
BRC298-18-2-3	98	168	6.0
BRC302-18-1-2-1	102	164	7.4
BRRI dhan28 (ck)	97	151	6.4
BRRI dhan58 (ck)	89	162	7.3
BRRI dhan81(ck)	89	155	6.2
LSD (5%)	4.09	3.97	0.41

DS: 23 Nov 2019 DT: 9 Jan 2020

Table 10. Yield and ancillary character of FBR lines (Biotech.), Boro 2019-20.

Designation	Plant height (cm)	Growth duration (day)	Yield (t ha-1)
BRH11-9-11-4-5B-HR3	95	162	6.1
BRH11-2-1-3-8B	102	171	5.7
BRH11-2-4-9B	102	179	6.7
BRH9-7-4-1B	102	171	5.6
BRH13-2-4-6-4B	94	165	5.8
IR 12A 177	93	167	6.6
BRRI dhan63 (ck)	84	155	6.3
BRRI dhan58 (ck)	94	164	6.8
LSD (5%)	4.31	5	0.33

DS: 23 Nov 2019 DT: 9 Jan 2020

Table 11. Yield and ancillary character of FBR lines, Boro 2019-20, BRRI RS, Habiganj.

Designation	Plant height (cm)	Growth duration (day)	Yield ($t\ ha^{-1}$)
Bh Boro9945-12-1-3	106	162	5.1
Bh Boro-18-SVIN064	94	164	5.4
Bh Boro-18-SVIN069	105	158	6.3
Bh Boro-18-SVIN077	102	168	5.6
Bh Boro-18-SVIN117	98	158	7.1
Bh Boro-18-SVIN074	100	166	6.6
Bh Boro-18-SVIN076	98	165	7.3
Bh Boro-18-SVIN109	94	166	6.5
Bh Boro-18-SVIN055	100	163	7.0
Bh Boro-18-SVIN063	107	166	5.9
Bh Boro-18-SVIN066	95	167	5.6
BRRI dhan50 (ck)	87	162	6.2
BRRI dhan89 (ck)	104	167	7.5
LSD (5%)	3.16	1.78	0.41

DS: 23 Nov 2019 DT: 7 Jan 2020

Table 12. Yield and ancillary characters of selected entries from IIRON (2019), Boro 2019-20.

Designation	Plant height (cm)	Growth duration (day)	Yield ($t\ ha^{-1}$)
SVIN312	108	159	8.0
SVIN332	104	162	7.6
SVIN344	77	157	7.5
SVIN306	100	154	7.4
SVIN026	100	157	7.4
SVIN051	95	155	7.4
SVIN047	100	156	7.4
SVIN329	95	161	7.4
SVIN303	102	160	7.4
SVIN304	102	160	7.3
SVIN308	97	158	7.2
SVIN333	101	159	7.1
SVIN023	101	160	7.1
SVIN054	100	156	7.1
BRRI dhan28 (ck)	101	153	6.3
LSD (5%)	3.45	1.31	0.18

DS: 25 Nov 2019 DT: 11 Jon 2020

Effect of planting time on growth, yield and yield contributing factors of some short duration rice varieties. Research activities were done to identify the suitable planting time and variety for Haor areas. Three short duration advanced lines along with the check BRRI dhan28 were evaluated in a time series of sowing date (T_1 = 5 Nov, T_2 = 15 Nov, T_3 = 25 Nov and T_4 = 5 Dec) during Boro 2019-20. 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 $ZnSO_4$ 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 all the tested advanced lines produced higher yield in the sowing time of 5 December. But BRRI dhan28 (ck) showed higher yield in the 25 November. It was observed that the best sowing time for short duration varieties (<140 days) is 5 December but 25 November for BRRI dhan28 (Table 13).

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 nutrients. The experiment comprised of 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 2019-20 was the 12th year continuation of the experiment. NPKSZn @ 120-38-50-9-3 kg ha^{-1} respectively were used. Tested cropping pattern was Boro-Fallow-Fallow. BRRI dhan89 was used as a test crop.

Complete treatment (NPKSZn) significantly increased 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 (7.76 t ha^{-1}) followed by T_3 (6.62 t ha^{-1}). The K omission treatment (T_4) produced significantly lower yield (6.03 t ha^{-1}) than the other treatments. From the experiment it may be concluded that besides NK, K is the most yield limiting nutrient element in BRRI RS, Habiganj farm (Table 14).

Table 13. Yield and growth duration in different sowing time of short duration rice, Boro 2019-20.

Sowing time	BRRI dhan29-SC3-P8 (Hbj)		BRRI dhan29-SC3-P11 (Hbj)		BR8845-18-1-1-1 (SP21)		BRRI dhan28 (ck)	
	GD (days)	Y (t ha^{-1})	GD (day)	Y (t ha^{-1})	GD (day)	Y (t ha^{-1})	GD (day)	Y (t ha^{-1})
T_1 (5 Nov.)	156	3.0	156	3.1	156	4.1	161	4.8
T_2 (15 Nov.)	146	4.2	146	3.4	146	4.4	151	6.1
T_3 (25 Nov)	141	4.5	141	4.5	141	4.4	149	6.3
T_4 (5 Dec.)	139	5.0	139	5.5	139	5.3	145	5.6
LSD (5%)	7.44	0.83	7.44	1.06	7.44	0.52	6.67	0.65

Table 14. Effects of nutrient element omission from the complete treatment on grain yield of BRRI dhan89, Boro 2019-20, Habiganj.

Treatment	Panicle m^{-2}	Grain yield (t ha^{-1})
T_1 (NPKSZn)	375	7.76
T_2 (-N)	290	6.12
T_3 (-P)	352	6.62
T_4 (-K)	340	6.03
T_5 (-S)	356	6.59
T_6 (-NP)	351	6.60
T_7 (-NK)	316	6.20
T_8 (All missing)	207	4.83
LSD $_{(5\%)}$	6.73	0.35

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)

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. 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 dhan89. The experimental design was split-plot with three replications. Phosphorus and S was applied as blanket dose. Forty-five-day-old seedlings were transplanted maintaining 20 cm × 20 cm 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 (7.48 t ha^{-1}) than the other combination of N and K fertilization (Table 15).

Greenhouse gas emission and global warming potential under triple rice cropping systems in Bangladesh. Field experiment was conducted at BRRI experimental farm (23°85.9'N and 90°82.4' E, elevation 12 m), Gazipur, in 2019-20. 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 T. Aman, Boro and Aus rice season respectively. Results revealed that VC fertilization treatment decreases GHG and GWP than CD and PM treatments. The CD and PM significantly increased total CH_4, N_2O and GWP around 14-97%, 10-85% and 14-97% of VC fertilization with triple rice cropping system (Table 16). There was also significant difference of rice yield between organic amendment and chemical fertilization systems in Aus, T. Aman and Boro season (Table 17). It can be concluded that the VC organic manure could be very useful for atmospheric and soil management strategy to reduce about 14-97% of GWP and increase about 5-17% rice yield.

Table 15. Effect of N and K rates on grain yield (t ha^{-1}) of BRRI dhan89, Boro 2019-20, BRRI RS, Habiganj.

K dose (kg ha^{-1})	N dose (kg ha^{-1})			
	0	100	120	140
0	6.03ab B	6.36 c A	6.56 c A	6.76 c A
50	6.20 ab D	6.56 b C	6.77 b B	7.48a A
100	5.10 c C	6.90 a B	7.32 a A	7.14 a A
150	6.73 a B	6.82 a B	7.09 a A	6.93 b A
200	6.32 b B	6.94 a A	6.86 a A	7.07 b A
CV (%)	4.47			

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

Table 16. Total GHG and GWP with Aus-T. Aman-Boro rice season under organic amended rice soil.

Treatment	Total greenhouse gas emission (kg ha^{-1})		Global warming potential (kg CO_2 eq. ha^{-1})
	CH_4	N_2O	
	Aus season		
NPKSZn	139	0.161	3939
Cowdung with IPNS	280	0.271	7917
Poultry manure with IPNS	400	0.456	11334
Vermicompost with IPNS	203	0.247	5752
Control	120	0.080	3393
$LSD_{0.05}$	8.06	0.01	207
	T. Aman season		
NPKSZn	206	0.510	5895
Cowdung with IPNS	325	0.688	9281
Poultry manure with IPNS	468	0.603	13268
Vermicompost with IPNS	285	0.610	8153
Control	204	0.185	5753
$LSD_{0.05}$	7.44	0.02	102
	Boro season		
NPKSZn	203	0.309	5771
Cowdung with IPNS	577	0.518	16300
Poultry manure with IPNS	765	0.650	21587
Vermicompost with IPNS	503	0.457	14217
Control	124	0.226	3539
$LSD_{0.05}$	10.07	0.04	313

Table 17. Grain yield with Aus-T. Aman-Boro rice season under organic amended rice soil.

Treatment	Grain yield (t ha^{-1})		
	Aus season	T. Aman season	Boro season
NPKSZn	3.76	3.54	6.58
Cowdung	4.08	4.03	7.19
Poultry manure	4.00	4.02	7.03
Vermicompost	4.98	4.26	7.25
Control	2.69	2.63	2.51
$LSD_{0.05}$	0.17	0.20	0.39

Comparison of greenhouse gas emission under continuous flooding and AWD irrigation system. We hypothesize that organic amendments under varied water management options greatly influences greenhouse gas (GHG) emission patterns and global warming potential (GWP), which has been evaluated in the present study. The experiment was conducted at the BRRI experimental farm, Gazipur, Bangladesh during January to May 2020. Incorporation of cowdung, poultry manure and vermicompost into soil was as integrated plant nutrient system (IPNS) and was termed as cowdung with IPNS, poultry manure with IPNS and vermicompost with IPNS and compared with NPKSZn commercial fertilizer treatments. We have used RCB design with three replications for imposing treatments in four multiply five-meter plots. BRRI dhan29 was grown as irrigated rice culture. Two water management systems were applied; continuous flooding (CF) and alternate wetting and drying (AWD). In CF, plots were kept flooded until harvesting and in AWD, plots were irrigated when water level fell below 12-15 centimeter of soil surface. Two perforated PVC pipes were installed (15 cm depth) for monitoring water depth in the AWD plots. We have followed standard gas sampling techniques for recording N_2O, CO_2 and CH_4 emission patterns.

GHG and GWP during dry season. In dry season, total CH_4 flux was 217-567 kg ha^{-1}, CO_2 flux 671-1040 kg ha^{-1} and N_2O flux 0.40-0.72 kg ha^{-1} under continuous flooding condition during study period (Table 19). The AWD irrigation system significantly reduced total CH_4 fluxes by 28-56% over CF. The AWD irrigation system was mainly responsible for increased total CO_2 and N_2O fluxes by 5-6% and 39-46% over CF system respectively. Nonetheless of irrigation systems, CO_2 and CH_4 were more important GHG emissions for influencing of total GWP growth scale, however N_2O emission was insignificant of total GWP scale (Table 19). Seasonal CH_4 fluxes covered 88-93% of total GWP and CO_2 fluxes about 6-10% of total GWP under both the water management systems. Only 1-2% contribution of total GWP by the N_2O fluxes under continuous flooding and AWD irrigation systems. The AWD irrigation system significantly reduced about 23-46% of total GWP than continuous flooding because of reducing CH_4 emission rates (Table 18).

Design and development of fertilizer deep placement mechanism for existing rice transplanter. A research experiment was conducted to incorporate the fertilizer deep placement (FDP) mechanism 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 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 produced significantly higher yield than the other treatments (Table 19). There is significant difference of CH_4 and N_2O emission 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 but GWP was not significantly different among the methods. Nutrient use efficiency was also higher in mechanical transplanter with mixed fertilizer.

Performance of grain yield and emission 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 compared 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 new rice varieties such as BRRI dhan84, BRRI dhan88, BRRI dhan89 and BRR dhan92 and existing rice cultivars BRRI dhan28 and BRRI dhan29 were used. Short duration rice varieties; BRRI dhan84 and BRRI dhan88 produced significantly higher yield (6.6-7.0 t ha^{-1}) than BRRI dhan28 (6.0-6.5 t ha-1). However, GHG emission was not different during the Boro season. The long duration BRRI dhan92 showed higher grain yield (8.6-9.0 t ha-1) than BRRI dhan29. BRRI dhan92 also reduced about 7% CH_4 emission than BRRI dhan29 (Table 20).

Table 18. Seasonal fluxes of GHGs and GWP as influenced by water management and soil amendments.

Irrigation system (A)	GHG	Soil amendment (B)				Statistical analysis		
		NPKSZn	CD with IPNS	PM with IPNS	VC with IPNS	A	B	A x B
CF	CH_4 (kg ha^{-1})	226	439	567	345	***	***	***
	CO_2 (kg ha^{-1})	700	800	1040	671	***	***	***
	N_2O (kg ha^{-1})	0.45	0.58	0.64	0.52	***	***	***
	GWP (t CO_2 eq. ha^{-1})	7.16	13.25	17.10	10.48	***	***	***
AWD	CH_4 (kg ha^{-1})	164	282	412	268			
	CO_2 (kg ha^{-1})	734	857	1085	700			
	N_2O (kg ha^{-1})	0.58	0.86	0.95	0.75			
	GWP (t CO_2 eq. ha^{-1})	5.59	9.09	13.07	8.50			

AWD = Alternate wetting and drying, CF = Continuous flooding

Table 19. Grain and straw yield under different transplanting and mode of fertilizer application during 2019-20.

Treat	T. Aman		Boro	
	Kushtia	Gazipur	Kushtia	Gazipur
		Grain (t ha^{-1})		
T_1	4.91	3.66	6.81	6.65
T_2	4.44	3.81	6.68	6.55
T_3	5.77	4.83	7.79	7.29
CV (%)	4.23	1.46	5.55	6.12
$LSD_{0.05}$	0.39	0.17	0.36	0.39

Note: T1 = Mechanical transplanting and top dressing of fertilizer, T2 = Farmers' practice and T3 = Mechanical transplanting along with mixed fertilizer deep placement.

Table 20. Grain yield and CH_4 emission compared to existing rice varieties and newly released rice varieties.

Short duration variety			Long duration variety		
Variety	Yield (t ha^{-1})	CH_4 emission (kg ha^{-1})	Variety	Yield (t ha^{-1})	CH_4 emission (kg ha^{-1})
BRRI dhan28	6.0-6.5	62.9	BRRI dhan29	8.0-8.3	72.3
BRRI dhan84	6.3-6.6	60.8	BRRI dhan89	7.5-8.5	67.6
BRRI dhan88	6.8-7.0	60.8	BRRI dhan92	8.6-9.0	67.6
LSD (5%)	0.56	0.79	LSD (5%)	0.69	1.0

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 26 tons breeder seeds (BS) were produced and sent to the Genetic Resources 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 410 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.

BRRI RS, Rajshahi

SUMMARY

In Aus season, 10 breeding lines from two regional yield trial (RYT) were evaluated of which four entries appeared promising for further evaluation. In the proposed variety trial (PVT), the line coded by I-003 produced higher grain yield than I-004. Out of 257 advanced breeding lines, 2 genotypes produced more than 6 t ha^{-1} grain yield at two locations i.e. Lalpur and Tanore under the project of high night temperature (HNT). In hybridization program in T. Aman season, 855 F_1 seeds were produced from ten crosses. Eight RYTs were conducted in T. Aman in which a total of 56 breeding lines were evaluated and six entries were found promising for further advancement. In the proposed variety trial (PVT) in Aman season, the line coded by I-005 showed 0.96 t ha^{-1} higher grain yield with 13 days longer growth duration over I-007. In breeding zone trial (BZT), 384 advanced lines were evaluated in which 48 entries produced higher grain yield than the checks and the highest yield was found in IR17A2129. In AGGRi Alliance, 300 advanced lines were evaluated under control and stress conditions of which 18 genotypes were selected.

In EC-IFAD trial, BRRI dhan71 produced similar grain yield with 30 days shorter growth duration than Sumon Swarna. In IRLON trial, 95 genotypes were evaluated in which seven entries produced higher grain yield than all the check varieties.

In preliminary yield trial (PYT), 14 advanced breeding lines were evaluated for disease resistance (BB) rice under TRB project in which only one entry was found promising. A total of 228 genotypes/varieties were evaluated for breeding value estimation of rice elite breeding pool and among them two varieties produced more than 5 t ha^{-1} grain.

In Boro season, 1,145 F_1 seeds were produced from 25 crosses. Out of 10 crosses, five crosses were selected and confirmed as true F_1s and 57 individual progenies were harvested from F_2 generations through FRGA (Field rapid generation advance) method. During Boro, seven RYTs with 44 breeding lines were conducted of which seven lines were found promising for further advancement.

In Breeding zone trial (BZT), 20 entries showed more than 7 t ha^{-1} yield with 136 days to 157 days of growth duration. The highest grain yield was produced by the genotype IR17A2076 followed by IR17A1544. In heat tolerance rice experiment, seven entries produced more than 5.5 t ha^{-1} grain yield.

Under the TRB project, in OYT-BB, 172 advanced breeding lines were evaluated and one entry produced more than 6 t ha^{-1} yield and 10 advanced breeding lines were evaluated in PYT-BB of which one entry produced more than 8 t ha^{-1} grain yield.

Grain yields remained higher under puddled cultivation than un-puddled condition. Rice straw incorporation significantly increased the rice yield of BRRI dhan88 in Boro season. AEZ based fertilization found the best regarding rice grain yield.

In T. Aman and Boro season, N was found as the most yield-limiting nutrient followed by P and K at AEZ 11 and AEZ26 locations.

The calculated rate of N that maximizes the yield of BRRI dhan87 was around 96 kg ha-1 for AEZ26 and AEZ11 while it was 150 kg ha-1 for AEZ26 and 125 kg ha-1 for AEZ11 in case of BRRI dhan81. The calculated rate of P that maximizes the yield of BRRI dhan87 was around 21.8 kg ha-1 for AEZ26 and AEZ11 while it was 30 kg ha-1 for AEZ26 and 20 kg ha-1 for AEZ11 in case of BRRI dhan81. The calculated rate of K that maximizes the yield of BRRI dhan87 was 98.7 kg ha-1 for AEZ26 and 91.9 kg ha-1 for AEZ11. Potassium rates for BRRI dhan81 were found enough 125 kg ha-1 for AEZ26 and 75 kg ha-1 for AEZ11. The calculated rate of Zn that maximizes the yield of BRRI dhan87 was 1.3 kg ha-1 for both AEZ26 and AEZ11. Zinc rates for BRRI dhan81 were found enough 2.0 kg ha-1 for AEZ26 and 1.5 kg ha-1 for AEZ11. The calculated rate of B that maximizes the yield of BRRI dhan87 was 1.25 kg ha-1 for both the AEZ26 and AEZ11. Boron rates for BRRI dhan81 were found enough 1.5 kg ha-1 for both AEZ26 and AEZ11.The suitable combination of N and K for BRRI dhan49 was 50 kg N and 40 kg K ha-1. On the other hand, this combination for BRRI dhan29 was 150 kg N and 40 kg K/ha.

In four crops cropping pattern trial, the (rice equivalent yield) REY remained higher in Mustard-

Onion/Maize (relay)-T. Aman (BRRI dhan75) pattern followed by Mustard-Onion-T. Aus-T. Aman (BRRI dhan75) pattern. Considering cropping system yield, REY, as well as gross return and margin, were found higher in strip-tillage un-puddled rice through rice transplanter followed by strip tillage maize and mungbean. The similar grain yield was found in urea applicator and urea broadcast method although 20% less urea was applied in urea applicator method.

Fipronil 50SC was found as an effective pesticide against stem borer control. Among the species of stem borer, dark-headed borer remained higher followed by yellow stem borer and pink borer. Bamboo made trap was found more effective for capturing of rat against box type and snap type traps.

In Aman season, BRRI hybrid dhan4 ranked top in terms of yield followed by BRRI dhan87 while in Boro season BRRI hybrid dhan5, BRRI hybrid dhan2 and BRRI dhan29 were the top-ranking varieties. Besides these, 10 farmers training programmes were arranged at different Upazill as of Rajshahi region. Fifty-five field demonstrations were conducted in this period covering 50 acres of land with newly released BRRI varieties. Twenty-two tons of breeder seed and 14 tons of TLS seed were produced during this period at BRRI RS, Rajshahi.

VARIETY DEVELOPMENT

Regional yield trial RYT # 1, T. Aus 2019

Three genotypes along with the standard check BR26 were evaluated at BRRI RS, Rajshahi farm. BR9011-62-2-1-2produced significantly higher grain (5.48 t ha^{-1}) with two days longer growth duration than the check variety BR26 (5.09 t ha^{-1}).

Regional yield trial RYT # 2, T. Aus 2019

Seven genotypes were evaluated along with the standard checks and BR9006-40-2-3-1 produced the highest grain yield (5.73 t ha^{-1}) with oneday shorter growth duration than the check variety BRRI dhan48.

Proposed variety trial (PVT), T. Aus 2019

Two genotypes coded as I-003 and I-005 were evaluated at BRRI RS, Rajshahi research plot. The advanced breeding lines I-003 performed higher grain yield (5.68 t/ha) and one-day longer growth duration than I-004 (4.70 t/ha).

Observational yield trial (OYT), T. Aus 2019

In total, 257 advanced breeding lines along with the standard check BRRI dhan48 were evaluated at two locations i.e. Lalpur, Natore and Paba, Rajshahi. At Lalpur, the genotype IR 99853-B-B-B-302 produced the highest yield (6.24 t ha^{-1} and 119 days) but nine days longer growth duration than BRRI dhan48 followed by IR 99853-B-B-B-548 (6.16 t ha^{-1} and 120 days).

At Paba site, 18 genotypes produced higher grain yield (4.40-5.40 t/ha and 104-119 days) than the check variety BRRI dhan48 (3.83 t ha^{-1} and 110 days). The genotype IR 99853-B-B-B-603 produced the highest yield (5.40 t ha^{-1}) with two days longer growth duration than BRRI dhan48 followed by IR 99853-B-B-B-490 (5.36 t/ha and 112 days).

Hybridization, T. Aman 2019

For the development of drought-tolerant rice, 855 F_1 seeds were produced from ten crosses using nine parents in T. Aman 2019 season.

F_1 confirmation, T. Aman 2019

Out of seven crosses, six crosses were selected and confirmed as true F_1s and seeds of these selected F_1 plants were selfed to produce F_2 seeds. At maturity, F_2 seeds of all selected plants were harvested individually, dried, cleaned and preserved.

Regional yield trial (RYT), T. Aman 2019

A total of 56 breeding lines were evaluated in eight RYTs with two rainfed lowland rice (RLR), one drought-tolerant rice (DTR), one zinc enriched rice (ZER), one disease resistance rice (DRR), one insect resistance rice (IRR), one premium quality rice (PQR), and one high yielding rice (Biotechnology) at BRRI RS farm, Rajshahi against 18 different standard checks. Among them, the genotype BR10001-94-2-B produced significantly higher grain (6.05 t ha^{-1}) with two days longer growth duration than the check variety BRRI dhan49 (5.61 t ha^{-1}) and gave similar grain yield with the check BRRI dhan72 (5.92 t ha^{-1}) in RYT-ZER. In RYT-DRR, the tested entry BR10397-4-1-2 performed significantly higher grain yield (5.09 t ha^{-1}) than the check BRRI dhan49 (4.38 t ha^{-1}) and produced similar grain yield to the check variety BRRI dhan87 (5.07 t ha^{-1}). BR9881-1-4-2-10 and BR9881-17-2-2-22 produced similar grain yield (4.80-4.91 t ha^{-1} days) with 10-11 days shorter growth duration than the check variety Swarna (Lal) (4.73 t ha^{-1} and 134 days) but higher grain yield than BRRI dhan33 in RYT-IRR. In RYT-PQR, the highest grain yield (3.52 t/ha) was produced by the entry BR8887-26-8-2-3 with 29-39 days' shorter growth duration than the check varieties followed by BR8882-30-2-5-2 (3.44 t/ha and 129 days).

Proposed variety trial (PVT), T. Aman 2019

Two PVT sets one consists of I-005 and I-007, another set contains three codes viz I-006, I-008 and I-009 were evaluated at BRRI RS, Rajshahi. Among them I-005 showed 0.96 t/ha higher grain yield (5.52 t ha^{-1}) with 13 days longer growth duration over the genotypes I-007 (4.56 t/ha). In another set, I-008 produced higher grain yield (5.40 t ha^{-1} with 130 days) but having four days longer growth duration than I-006 (4.85 t/ha and 126 days) and I-009 (3.65 t/ha and 111 days).

Observational yield trial (OYT) of breeding zone trial, T. Aman 2019

A total of 384 advanced lines were evaluated against three standard check varieties BRRI dhan49, BRRI dhan75 and BRRI dhan87 at BRRI RS, Rajshahi. Out of 384, 48 tested entries produced higher grain yield (5.76-7.61 t ha^{-1} and 112-125 days) than all the check varieties (4.90-5.75 t ha^{-1} and 112-126 days). The highest grain yield was produced by the genotype IR17A2129 (7.61 t ha^{-1}) with a growth duration of 113 days followed by IR17A1305 (7.27 t ha^{-1} and 117 days).

OYT of AGGRi network trial, T. Aman 2019

A total of 300 advanced lines along with 12 local and global checks were evaluated under control and stress conditions at Alimganj, Paba. In a controlled condition, 15 entries produced more than 5,000 kg ha^{-1} grain (5,100-5,690 t ha^{-1}). On the other hand, six genotypes produced more than 5,000 kg ha^{-1} grain (5,060-5,300 kg ha^{-1}). The genotype IR12A173 performed the highest grain yield (5,090-5,690 kg ha^{-1}) both in controlled and stressed condition followed by the entry IR118172-B-2-3-1-4 (4,950-5,650 kg ha^{-1}). Eighteen genotypes (Bold colour) (4,586.51-5,304.94 kg ha^{-1}) were selected based on the performance in stressed condition for further trial in the next T. Aman 2020 season.

Validation of BRRI dhan71 and publication of package of practices (POPs) for the cultivation of drought-tolerant varieties in Rajshahi region, T. Aman 2019

Non-replicated trials were conducted in farmers fields at Paba, Godagari and Tanore upazila of Rajshahi region in T. Aman 2019 season. Four treatments e.g. Popular variety (Sumon Swarna) + common BRRI recommendation (T_1), Improved variety (BRRI dhan71) + common BRRI recommendation (T_2), Popular variety (SumonSwarna) + BRRI Rajshahi developed site-specific matching management practices (T_3), Improved variety (BRRI dhan71) + BRRI RS, Rajshahi developed site-specific management practices (T_4) were tested.

Growth duration of BRRI dhan71 (109-111 days) was more or less 30 days earlier than the local variety Sumon Swarna (137-138 days). Moreover, BRRI dhan71 produced similar grain (4.57-5.14 t ha^{-1}) with local SumonSwarna (4.86-5.19 t ha^{-1}). Higher grain yield and shorter growth duration of both the varieties were observed in site-specific (BRRI RS, Rajshahi) management practices than BRRI recommended management practices.

International rainfed lowland observational nursery (IRLON), Set-19, T. Aman 2019

A total of 95 genotypes against five standard checks; BRRI dhan49, BRRI dhan56, BRRI dhan66, BRRI dhan71 and BRRI dhan87 were evaluated at BRRI RS, Rajshahi farm. Out of 95 tested entries, seven entries produced higher grain yield (3.79-4.78 t ha^{-1} and 104-126 days) than all check varieties (2.87-4.78 t ha^{-1} and 108-124 days).

Preliminary yield trial (PYT), disease resistance (BB), T. Aman 2019, TRB-BRRI

A total of 14 advanced breeding lines along with IRBB60 as a resistant check and BRRI dhan33, BRRI dhan49 and BRRI dhan87 as susceptible checks were evaluated at Alimgans, Paba, Among all the tested entries, the genotype BR10401-5-3-2-

1 (5.16 t ha^{-1}) produced similar grain but three days shorter growth duration than the check variety BRRI dhan87 (5.28 t ha^{-1}).

Breeding value estimation (BVE) of rice elite breeding pool, T. Aman 2019, TRB-BRRI

A total of 228 genotypes/varieties were evaluated at Alimgans, Paba, followed by Augmented RCBD. In this trial, grain yield was ranged from 1.14- 5.35 t ha^{-1} and growth duration varied from 91-143 days. Among them,BRRI dhan73 produced the highest grain yield (5.35 t ha^{-1}) followed by BR 7879-17-2-4-HR3-P1 (5.09 t ha^{-1}). Due to heavy rainfall (Bulbul), most of the entries were lodged, as a result, grain yield was reduced.

Hybridization, Boro 2019-20

A total of 1,145 F_1 seeds were produced from 25 crosses using 11 parents in Boro 2019-20 season.

F_1 confirmation, Boro 2019-20

Out of 10 crosses, five crosses were selected and confirmed as true F_1s comparing with their parents respectively and registered in the BRR aj cross-register. Seeds of these selected F_1 plants were selfed to produce F_2 seeds. At maturity, F_2 seeds of all selected plants were harvested individually, dried, cleaned and preserved.

Rapid generation advance of segregating nurseries, Boro 2019-20

In total, 57 individual progenies were harvested from F_2 generations through FRGA method.

Regional yield trial (RYT), Boro 2019-20

Seven RYTs viz four favourable Boro rice (FBR- 2 from BRRI HQ, Gazipur, one from BRRI RS, Cumilla, one from BRRI RS, Bhanga), one zinc enriched rice (ZER), one premium quality rice (PQR) and one cold-tolerant rice (CTR) were conducted against 11 different standard checks (BRRI dhan28, BRRI dhan29, BRRI dhan50, BRRI dhan58, BRRI dhan63, BRRI dhan69, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan88 and BRRI dhan89) in Boro season Forty-four breeding lines were evaluated from these trials.

RYT#2 (FBR#2). Six advanced lines were evaluated in which the genotype BRH9-7-4-1B produced significantly higher grain yield (8.89 t ha^{-1}) and 1-10 days longer growth duration than all check varieties (6.77-8.39 t/ha).

RYT#3 (FBR-Cumilla). Five genotypes were evaluated against three check varieties BRRI dhan28, BRRI dhan58 and BRRI dhan81 at BRRI RS, Rajshahi farm. The genotype BRC302-2-1-2-1 produced similar grain yield (8.06 t ha^{-1}) and one day shorter growth duration with the check variety BRRI dhan58 (8.00 t ha^{-1}) followed by BRC269-15-1-1-3 (7.66 t ha^{-1} and 159 days).

RYT#4 (FBR-Bhanga). Out of 11, two genotypes BhBoro-18-SVIN109and BhBoro-18-SVIN076 produced significantly higher grain yield (8.07-8.22 t ha^{-1} with 161-166 days) than all the check varieties (6.02-7.55 t ha^{-1} and 154-164 days).

Observational yield trial (OYT) of breeding zone trial, Boro 2019-20

This trial was conducted with 354 RGA derived advanced breeding lines along with five international and three national check varieties. The breeding lines were planted in 436 plots following partially replicated design. The entries showed a wide yield range of 1.8-7.91 t/ha with growth duration of 131-163 days. Out of 354 entries tested, 20 entries showed more than 7.0 t/ha yield with 136 days to 157 days growth duration. Three genotypes IR17A2076, IR17A1544 and IR17A2241 produced higher grain (7.69-7.91 t/ha and 143-155 days) yield than all the check varieties (5.23-6.44 t/ha and 138-141 days).

OYT of heat tolerance rice under AGGRi network trial, Boro 2019-20

A total of 300 advanced lines along with 12 local and global checks were evaluated under heat stress conditions at Alimganj, Paba under the supervision of BRRI RS, Rajshahi. The entries showed a grain yield range of 0.26-6.60 t/ha with growth duration varies from 114 to 136 days. Out of 312 genotypes, seven entries produced more than 5.5 t ha^{-1} grain yield (5.51-6.60 t ha^{-1} with 119-130 days). The genotype IR82589-B-B-84-3 produced the highest grain yield (6.60 t ha^{-1} and 129 days) followed by IR66946-3R-149-1-1 (5.88 t ha^{-1} and 130 days).

OYT-FBR and cold tolerant rice (CTR), Boro 2019-20, TRB-BRRI

A total of 435 advanced breeding lines along with six standard check varieties BRRI dhan28, BRRI dhan29 BRRI dhan58, BRRI dhan69, BRRI dhan81 and BRRI dhan89 were evaluated at Sahapur, Tanore. Out of 435, 15 entries produced higher grain (8.41-9.98 t ha^{-1} and 146-159 days) than all the check varieties (6.33-8.26 t ha^{-1} and 145-160 days). The seven entries viz BR10595-5R-194, BR10604-5R-97, BR10623-5R-86, BR10623-5R-89, BR11303-5R-10, BR11303-5R-108 and BR9945-5R-119 produced more than 9 t ha^{-1} grain yield (9.98-9.12 t ha^{-1} and 145-153 days).

Advanced yield trial (AYT)-cold tolerant rice (CTR), Boro 2019-20, TRB-BRRI

Seventy-eight advanced breeding lines along with six standard checks BRRI dhan28,BRRI dhan45 BRRI dhan58, BRRI dhan69, BRRI dhan81 and BRRI dhan89 were evaluated at Sahapur, Tanore, Rajshahi. Due to stress condition (severe cold) out of 78 entries, 14 entries were not germinated and 36 entries were not possible to transplant with two replications due to seedling shortage. The genotype BR10717-5R-67 (7.74 t ha^{-1}) produced higher grain yield with seven days shorter growth duration against the check variety BRRI dhan69 (7.14 t ha^{-1}).

OYT, disease resistance rice (BB), Boro 2019-20, TRB-BRRI

A total of 172 advanced breeding lines along with IRBB60 as a resistant check, BRRI dhan28 and BRRI dhan58 as two standard checks were evaluated at Sahapur, Tanore, Rajshahi. Among all the tested entries, the entry 11604-4R-148 gave higher grain (6.75 t ha^{-1} with GD of 146 days) than the check BRRI dhan58 (6.61 t ha^{-1} with GD of 150 days). The experiments were suffered from cyclone Amphan as a result most of the entries were lodged which caused low grain yield.

Preliminary yield trial (PYT)-disease resistance rice (BB), Boro 2019-20, TRB-BRRI

A total of 10 advanced breeding lines along with the resistant check IRBB60 and the three susceptible checks BRRI dhan29, BRRI dhan58 and BRRI dhan89 were evaluated at Sahapur, Tanore. Among all the tested entries, the genotype BR9942-38-4 produced the highest grain yield (8.26 t ha^{-1} and 153 days) than all the check varieties (4.54-7.62 t ha^{-1} and 151-159 days).

CROP-SOIL-WATER MANAGEMENT

Nutrient management under conservation agriculture (CA) in a double rice cropping system

This experiment was conducted in farmer’s field at Paba Rajshahi during T. Aman 2019 and Boro 2019-20. The design was split-split-plot with three replications. Crop establishment methods were assigned in the main plot, residue management in the sub-plot and fertilizer rates in the sub-sub-plots. Test rice varieties were BRRI dhan75 for T. Aman season and BRRI dhan88 for Boro season. Grain yields were always significantly higher under puddled cultivation than un-puddled condition. Moreover, 75% of the recommended fertilizer was enough for BRRI dhan75 cultivation under puddled condition. Rice straw incorporation significantly increased the rice yield of BRRI dhan88 in Boro season. When 25% extra fertilizer application significantly increased the grain yield of the variety irrespective of residue management and crop establishment method.

Suitable and profitable nutrient management for rice in Barind Tract soils

BRRI dhan71 in Aman 2019 season was evaluated with three fertilizer recommendation tools e.g., Rice Crop Manager (RCM) based, FRG 2012 (AEZ based) and Nutrient Expert (NE) based. Among these tools, AEZ based fertilization found the best regarding rice grain yield. NE and RCM performed equally in T. Aman season (Table 1).

Table 1. Yield performance of BRRI dhan71 rice under different fertilizer management tools at Paba, Rajshahi, T. Aman 2019.

	Treatment	Tiller/m^2	Panicle/m^2	Grain yield
T. Aman 2019	RCM	152	139	4.45 b
	AEZ	174	164	5.50 a
	NE	161	154	4.84 b
	CV (%)	9.23	9.97	5.12

Means with the same letter are not significantly different

Determination of yield-limiting nutrients in soils by omission plot technique

The experiments were conducted at BRRI RS farm Rajshahi and farmer's field of Rajshahi in T. Aman 2019 and at BRRI RS farm Rajshahi in Boro 2019-20 seasons to identify the nutrient (s) that limit the rice yield in soils. Treatments for the experiment were Native nutrients, Recommended dose of NPKSZn, PKSZn (-N), NKSZn (-P), NPSZn (-K), NPKZn (-S) and NPKS (-Zn). Treatments were compared under Randomized complete block design with three replications.

The omission of different nutrients from the recommended NPKSZn dose significantly affected the rice yield over the locations and seasons (Table 2). Native nutrients always produced the lowest rice grain and recommended NPKSZn application resulted in the highest grain yield. In T. Aman 2019 season, N was found as the most yield-limiting nutrient followed by P and K at both the locations. In Boro 2019-20 season, N omission resulted in the lowest rice yield of BRRI dhan63 followed by K.

Response of T. Aman and Boro rice to applied nitrogen in Barind tract and calcareous soil

The experiment was conducted in T. Aman 2019 and Boro 2019-20 seasons to find out the N requirement of BRRI dhan87 and BRRI dhan81 respectively. Eight N rates- 0, 25, 50, 75, 100, 125, 150 and 175 kg/ha were applied following RCB design with three replications. The locations were BRRI RS farm Rajshahi (AEZ11) and Paba, Rajshahi (AEZ26). The calculated rate of N that maximize the yield of BRRI dhan87 was 96.6 kg/ha for AEZ26 and 94.9 kg N ha-1 for AEZ 11. Nitrogen rates for BRRI dhan81 were found enough 150 kg ha-1 for AEZ26 and 125 kg/ha for AEZ11.

Response of T. Aman and Boro rice to applied phosphorus in Barind Tract and calcareous soil

The experiment was conducted in T. Aman 2019 and Boro 2019-20 seasons to find out the P requirement of BRRI dhan87 and BRRI dhan81 respectively. Eight P rates- 0, 5, 10, 15, 20, 25, 30 and 35 kg/ha were applied following RCB design with three replications. The locations were BRRI RS farm Rajshahi (AEZ11) and Paba, Rajshahi (AEZ26). The calculated rate of P that maximizes the yield of BRRI dhan87 was 21.8 kg ha-1 for AEZ26 and 21.81 kg ha-1 for AEZ11. Phosphorus rates for BRRI dhan81 were found enough 30 kg ha-1 for AEZ26 and 20 kg ha-1 for AEZ11.

Response of T. Aman and Boro rice to applied potassium in Barind tract and calcareous soil

The experiment was conducted in T. Aman 2019 and Boro 2019-20 seasons to find out the K requirement of BRRI dhan87 and BRRI dhan81 respectively. Eight K rates- 0, 25, 50, 75, 100, 125, 150 and 175 kg ha-1 were applied following RCB design with three replications. The locations were BRRI RS farm, Rajshahi (AEZ11) and Paba, Rajshahi (AEZ26). The calculated rate of K that maximize the yield of BRRI dhan87 was 98.7 kg/ha for AEZ 26 and 91.9 kg ha-1 for AEZ11. Potassium rates for BRRI dhan81 were found enough 125 kg ha-1 for AEZ26 and 75 kg ha-1 for AEZ11.

Response of T. Aman and Boro rice to applied zinc in Barind Tract tand calcareous soil

The experiment was conducted in T. Aman 2019 and Boro 2019-20 seasons to find out the Zn requirement of BRRI dhan87 and BRRI dhan81 respectively. Six Zn rates- 0, 0.5, 1.0, 1.5, 2.0 and 2.5 kg ha-1 were applied following RCB design with three replications. The locations were BRRI RS farm, Rajshahi (AEZ11) and Paba, Rajshahi (AEZ26). The calculated rate of Zn that maximizes the yield of BRRI dhan87 was 1.3 kg ha-1 for both AEZ26 and AEZ11. Zinc rates for BRRI dhan81 were found enough 2.0 kg ha-1 for AEZ26 and 1.5 kg ha-1 for AEZ11.

Response of T. Aman and Boro rice to applied boron in Barind tract and calcareous soil

Table 2. Effect of nutrient omissions on grain yields of rice, Rajshahi 2019-20.

Treatment	Grain yield (t ha^{-1})		
	T. Aman 2019 (BRRI dhan71)		Boro 2019-20 (BRRI dhan63)
	BRRI RS, Rajshahi	Paba	BRRI RS, Rajshahi
T1 = Native nutrients	2.70 e	3.19 e	1.88 d
T2 = NPKSZn	5.14 a	5.18 a	5.82 a
T3 = PKSZn (-N)	3.19 d	3.71 d	3.42 c
T4 = NKSZn (-P)	3.34 cd	4.07 c	5.31 ab
T5 = NPSZn (-K)	3.43 cd	4.27 b	4.93 b
T6 = NPKZn (-S)	4.62 b	4.25 b	5.17 ab
T7 = NPKS (-Zn)	3.65 c	4.28 b	5.23 ab
CV (%)	4.05	2.30	5.93

Means with the same letter are not significantly different

The experiment was conducted in T. Aman 2019 and Boro 2019-20 seasons to find out the B requirement of BRRI dhan87 and BRRI dhan81 respectively. Six B rates- 0, 0.5, 1.0, 1.5, 2.0 and 2.5 kg ha-1 were applied following RCB design with three replications. The locations were BRRI RS farm, Rajshahi (AEZ11) and Paba, Rajshahi (AEZ26). The calculated rate of B that maximize the yield of BRRI dhan87 was 1.25 kg ha-1 for both AEZ26 and AEZ11. Boron rates for BRRI dhan81 were found enough 1.5 kg ha-1 for both AEZ26 and AEZ11.

Effect of nitrogen and potassium rates on rice cultivation

The experiment was conducted in T. Aman 2019 and Boro 2019-20 seasons to find a suitable combination of N and K for BRRI dhan49 and BRRI dhan29 respectively. The experimental design was split-plot with three replications. Five N rates- 0, 50, 100, 150 and 200 were assigned in the main plot and six K rates (kg/ha): 0, 40, 80, 120, 160, 200 kg/ha were applied in the sub-plot. The location was BRRI RS farm, Rajshahi (AEZ11). The suitable combination of N and K for BRRI dhan49 was 50 kg N and 40 kg K/ha. On the other hand, this combination for BRRI dhan29 was 150 kg N and 40 kg K/ha.

RICE FARMING SYSTEMS

Evaluation of crop productivity and soil health under four crops cropping patterns in Rajshahi region

The trial was conducted at BRRI RS, Rajshahi during 2019-20 in RCB design with three replications to identify the profitable cropping pattern in Rajshahi region. The cropping patterns were 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 dhan49). BRRI and BARI recommended crop and fertilizer management practices were followed for all the treatments.

The rice equivalent yield (REY) yield of 1st crop of the cropping patterns remained higher (10.8 t ha^{-1}) in CP_2 (Potato) followed by CP_6 (Potato) and CP_1 (Potato) and that was found lower in 5.64 t ha^{-1} in CP_3 (Field pea). In 2nd crop, the higher REY (11.49 t ha^{-1}) was found in CP_5(Onion) and the lower REY (3.66 t ha^{-1}) in 2nd crop was found in CP_2 (Mungbean). The REY in 3rd crop was found higher in CP_5 (Maize) followed by CP_4 (BRRI dhan82). T. Aman was the 4th crop in all the cropping patterns and the higher yieldin T. Aman season was found in T_6 (5.59 t ha^{-1}) followed by CP_3 (5.33 t ha^{-1}). The lower yield (4.94 t ha^{-1}) in Aman season was found CP_4. Among the six cropping patterns, the REY remained higher in CP_5 (29.43 t ha^{-1}) followed by CP_4 (26.5 t ha^{-1}) while the REY remained lower in CP_6 (22.41 t ha^{-1}).

Evaluation of crop productivity and soil health under a strip-tillage system in Maize-Mungbean-Rice cropping pattern

The trial was conducted at BRRI RS, Rajshahi during Kharif II, Rabi and Kharif I season under Rice-Maize-Mungbean cropping pattern 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 transplanter followed by strip tillage maize and mungbean, T_3: Conventional tillage transplanted rice followed by strip tillage maize and mungbean, T_4: Conventional transplanted rice followed by conventional maize and mungbean. In case of strip-tillage dry seeded rice, rice was sown directly in the strip of soil which was made through power tiller operated seeder (PTOS). In the case of strip-tillage un-puddled rice, rice was transplanted through rice transplanter in un-puddled condition. In case of maize and mungbean, strip tillage was done through power tiller operated seeder where sowing of seeds and opening of strips were made simultaneously.The crop varieties were BRRI dhan75 for rice, NK 40 for maize and BARI Moog-6 for mungbean. BRRI and BARI recommended crop and fertilizer management practices were followed for all treatments.

The grain yield of rice and maize affected significantly by the treatments and the higher grain yield of rice was found in T_4 (4.71 t ha^{-1}) treatment which was statistically similar with all other treatments except T_1 (4.30 t ha^{-1}). In contrast, the lower grain yield of maize was found in T_4 (9.47 t ha^{-1}) treatment. The grain yield of maize remained higher in T_1 (10.88 t ha^{-1}) treatment followed by T_2 (10.27 t ha^{-1}) treatment. In mungbean, the grain yield was not influenced by the treatments ranged from 1.06 t ha^{-1} in T_3 to 1.6 t ha^{-1} in T_2. Considering cropping system yield, the rice equivalent yield (REY) remained higher in T_1 and T_2 treatments (17.09 t ha^{-1}) and that was found lower in T_4 (16.35 t ha^{-1}). The gross return, as well as gross margin, was found higher in T_2 (Tk 1,44,670/ha and Tk. 30370/ha) followed by T_1 (Tk 1,44,220/ha and Tk 28870/ha). The data also revealed that the gross return, as well as gross marginremained lower in T_4 (Conventional) treatment (Tk 1,38,600/ha and Tk 13,150/ha).

Effects of urea application techniques on different Boro varieties in Barind region

The trial was conducted at BRRI RS, Rajshahi during Boro season in a split-plot design with three replications. The urea application methods were T_1: Urea control, T_2: Urea broadcast, T_3: Urea applied by using the applicator and the rice varieties were V_1: BRRI dhan29, V_2: BRRI dhan58, V_3: BRRI dhan81. BRRI recommended fertilizer was used in case of urea broadcast treatment (T_2) where urea was applied in three equal splits. In urea application by applicator treatment, 20% less urea was used than the recommended dose and urea was applied in one time after 15 days of transplanting.

The mean grain yields of rice varieties affected significantly by urea application methods and the higher yields were found in urea applicator (5.92 t/ha) closely followed by urea broadcast method. Irrespective of urea application method, the grain yield of rice varieties was not affected significantly ranging from 4.92 t/ha in BRRI dhan29 to 4.64 t/ha in BRRI dhan81. The results concluded that the similar grain yield was found in urea applicator and urea broadcast method although 20% less urea was applied in urea applicator method (Table 3).

PEST MANAGEMENT

Effect of selected insecticide for stem borer management

The investigation was conducted at the BRRI RS, Rajshahi farm to study the efficacy of certain chemical insecticide. Four single-molecule insecticides along with control were used in this experiment.

The performance of different insecticides against stem borer was significantly different at seven DAS. The lowest dead heart infestation was found from Fipronil 50SC treated plot (4.36%) and the highest dead heart damage of 26.42% was found in the control plot. At 15 DAS on the first spray, the similar trend insecticides efficacy against stem borer was found. The percent white head infestation due to stem borer revealed significant at seven DAS and Fipronil 50SC (3.44% white head) was found superior among all insecticides but at per with Cartap 50SC (4.45% whitehead). The highest white head infestation (13.96%) was found in the control plot and it was significantly different from the other treatments. At 15 DAS significantly the lowest infestation was found in Fipronil 50SC (2.20% whitehead) and significantly the highest infestation was found in control (8.17% whitehead). The yield performance was significantly different among the treatments. Significantly the highest yield (4.27 t ha^{-1}) was in Fipronil 50SC treated plot and the lowest yield was found in the control plot (3.14 t ha^{-1}).

Species composition of stem borer in Rajshahi region

The experiment was conducted at Paba, Tanore and Godagari upazila of Rajshahi district as well as BRRI RS, Rajshahi during Aus and Aman 2019. Five locations of each upazila were selected to collect the data.

Among the species, the highest number was of dark-headed borer followed by yellow stem borer and the lowest was pink borer (54.84%, 43.67% and 1.49% respectively). Among the different locations, the highest number of dark-headed borer larvae (75.09%) was found in TanoreUpazila and the lowest number was (64.12%) in BRRI RS, Rajshahi. In the case of yellow stem borer, the highest number was (34.55%) found in BRRI RS, Rajshahi and lowest was (22.99%) Tanore upazila. The highest number of pink borer species was (1.92%) found in Tanore upazila then Godagari upazila (1.79%) and the lowest were (0.62%) in Paba upazila.

Table 3. Effect of urea application methods on grain yield ($t\ ha^{-1}$) of Boro rice, BRRI RS farm, Rajshahi, Boro 2018-19.

Method	BRRI dhan29	BRRI dhan58	BRRI dhan81	Mean
Urea control	3.12	2.76	2.73	2.87
Urea broadcast	6.17	5.77	5.79	5.91
Urea applied by using applicator	6.26	5.74	5.75	5.92
Mean	4.92	4.55	4.64	
LSD (0.05)	0.52 for variety and 0.41 for applicator			
CV (%)	10.98 (a), 10.94 (b)			

Means with the same letter are not significantly different.

Effect of different trap design for rat management

The experiment was conducted in the rice field of BRRI RS, Rajshahi farm during Aus and Aman season 2019. Three different types of traps were used in this expeiment for capturing rats such as bamboo made trap, snap trap and box type live trap.

The highest number of rats (20.20 rats /trap) were captured by bamboo made-trap and it was significantly different from the other two types of traps. The lowest number of rats (0.27 rat/trap) captured by box type live trap and it was not significantly different with snap trap (0.60 rat/trap).The highest number of rat captured (27.64 rat/trap) by bamboo made-trap and it was significantly different from the other traps. The lowest number of rats was captured by box type live trap and it was not significantly different with snap trap (0.36 rat/trap) (Table 2).

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI developed T. Aman rice varieties

Forty-three Aman rice varieties were evaluated at BRRI RS, Rajshahi farm. Among them, BRRI hybrid dhan4 top ranked in terms of yield (6.36 $t\ ha^{-1}$) followed by BRRI dhan87 (6.13 $t\ ha^{-1}$), BRRI hybrid dhan6 (5.98 $t\ ha^{-1}$), BRRI dhan72 and BRRI dhan49 (5.97 $t\ ha^{-1}$). BRRI dhan37, BRRI dhan62, BRRI dhan5 and BRRI dhan38 were found low yielding varieties and the yield ranging from 3.26to 3.68 $t\ ha^{-1}$.

Stability analysis of BRRI developed Boro rice varieties

Forty-two Boro rice varieties were evaluated at BRRI RS, Rajshahi farm. Top three varieties were hybrid dhan5 (7.29 $t\ ha^{-1}$), BRRI hybrid dhan2 (7.24 $t\ ha^{-1}$) and BRRI dhan29 (7.22 $t\ ha^{-1}$). BR17 and BRRI dhan45 were the low yieldings (4.61 $t\ ha^{-1}$) 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 10 training programmes at different upazillas of Rajshahi region. Three hundred and thirty farmers participated in the training programme, Among them, 260 were male and 70 were female farmers. Most of the farmers were very much impressed by taking this rice production training.

Demonstration of BRRI released varieties

Field demonstrations were carried out at different locations of Rajshahi region during T. Aus, T. Aman and Boro seasons. A total of 55 demonstrations with the latest released BRRI varieties at Rajshahi region were conducted during the reported period. The farmers of Rajshahi areas were very much interested to these BRRI released varieties.

Truthfully labelled and breeders seed production

Nucleus seed stock was collected from GRS Division of BRRI. The 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, T. Aman and Boro seasons. Considering three seasons (Aus T. Aman and Boro), 22 and 14 tons of breeder and TLS seeds respectively.

Advisory services

Any serious problem related to rice production at farmers' field was addressed duly in co-operation with the Department of Agricultural Extension (DAE), Bangladesh Agricultural Development Corporation (BADC), Barind Multipurpose Development Authority (BMDA), Seed Certification Agency (SCA) and different NGOs. Field visits were there mainly to address different problems on insect and disease attack, seed sterility at the flowering time etc.

BRRI RS, Rangpur

SUMMARY

To develop suitable modern rice varieties for Rangpur region, 33 germplasms were collected from different sources for maintenance breeding. Thirty-five single crosses were made and four F_1s were confirmed. A total of 8,000 progenies from 20 F_4 generations were advanced through field RGA nurseries. One hundred plants were selected from observational yield trial. Under TRB projects, IR98777-GAZ-13-1-2-4 for drought tolerant, BR11185-5R-1020-2, IR14F468 and IR16F1083 for submergence and water stagnation tolerance were selected in T. Aman season. Two genotypes BR10317-5R-19 and BR10717-5R-82 were selected from cold tolerant breeding programme in boro season. In addition, 11 segregating advanced lines were selected and 31 bulk were made. Twenty parental varieties/lines were selected from breeding value estimation programme in both the seasons, which will be used for future breeding programme. In T. Aman season, BR8528-30-2-5-2 and BR8882-30-2-5-2 were selected from premium quality RYT trial. BR8882-30-2-5-2 produced 0.79 t/ha high yield over BRRI dhan37. BR9881-1-4-2-10 and BR10397-4-1-2 were selected from insect resistant rice and disease resistant RYT trials. Moreover, BR (Bio) 10376-AC11-3-1 was selected for its earliness and PAcp at maturity from high yielding rice programme. In Boro Season, BR8912-12-6-1-1-1-1 was selected based on the PAcp at maturity from zinc enriched rice trial. From premium quality rice programme, BR8526-38-2-1-HR1 was selected for further evaluation. In insect resistant programme, BR9669-23-3-2-23 was selected compared to BRRI dhan58. Under favourable environment, BRH9-11-4-5B-HR3, BRH13-2-4-6-4B and BRC297-15-1-1-1 performed better than the standard check varieties. Higher yield was observed at 15 August planting with all seedling age irrespective of spacing under yield maximization experiment of BRRI dhan71. By rice transplanter, BRRI dhan89 produced about 0.7 t ha^{-1} higher yield with Mg_2 and Mg_3 over Mg_1 due to produced more number of grain and panicle and Mg_3 is better than Mg_2 in light textured soil in Rangpur region. For quality seedling raising in Boro season, there was no significant difference in grain yield among polythene cover treatments but day-night polythene cover (T_3) reduces growth duration by 2-3 days compered to the other treatments. Treatment T_3 is farmers' friendly because it is hassle free, a few labour consuming (cost effective) and risk free. In Rangpur region, BRRI dhan88 and BRRI dhan89 produced similar grain yield with all seedling age (35-65 days) in Boro season. Although total growth duration was higher in A_{65} but field duration was lower than younger seedling but produced similar grain yield. In total 400 farmers and 50 SAAOs were trained on modern rice production technology from different Upazilas of Rangpur-Dinajpur region. A total of 79 varietal demonstrations were conducted at different locations of Rangpur region during T. Aus 2019, T. Aman 2019 and Boro 2019-20. BRRI dhan48 and BRRI dhan82 in T. Aus, BRRI dhan52, BRRI dhan70, BRRI dhan71, BRRI dhan75 and BRRI dhan87 in T. Aman, BRRI dhan74, BRRI dhan81, BRRI dhan89 and BRRI hybrid dhan3 and BRRI hybrid dhan5 in Boro season were used. Farmers showed keen interest about those newly released varieties. A total of 10,256 kg TLS and 7,580 kg breeder seeds were produced in T. Aus, T. Aman and Boro season, respectively. In this reporting period, 3,224kg TLS was distributed among the farmers for dissemination and popularization of the latest BRRI varieties in Rangpur-Dinajpur region.

VARIETY DEVELOPMENT PROGRAMME

Development of rice varieties suitable for T. Aman and Boro season in Rangpur region

In total 33 germplasm were collected from farmers' field and genebank of GRSD for maintenance breeding. Thirty-five single crosses were made using thirty two parents (Table 1). Four F_1s were confirmed (Table 2). Twenty F_4 generations were advanced through field RGA. Totally 8000 individual plants were selected from field RGA (Table 3). One hundred plants were selected from observational yield trial (OYT).

TRB project

Development of transplant Aus (T. Aus) rice

In PYT, the highest yield was found in BR9829-79-3-1-3 (4.17 t ha-1) and lowest in BR9830-5-2-2-2 (3.73 t ha-1) among the tested genotypes.

Table 1. List of crosses made, breeding for standard rice varieties for Rangpur region, 2019-2020.

Cross combinations	F_1 seeds	Characteristics
	T. Aman, 2019	
BR8470-3-4-Rang2-4-2-2/Black rice (GRSD)	35	Premium quality
BR8470-3-4-Rang2-4-2-2/BRrang13-RGA-1-1	27	Premium quality
BR8470-3-4-Rang2-4-2-2/BRRI dhan87	30	High yield potential
BRRI dhan87/Black rice (GRSD)	27	Premium quality
BRRI dhan87/Basmati (Acc. No. 4905)	25	Premium quality
BRRI dhan87/Shompa katari	18	Premium quality
BRRI dhan87/Swarna5	19	High yield potential
Swarna5/Basmati (Acc. No. 4905)	15	Premium quality
Swarna5/Black rice (GRSD)	14	Premium quality
Long Panicle (collection)/Lata Balam (M-6)	28	Premium quality
Lata Balam (112/12)/Gainza	50	Premium quality
Lata Balam (M-6)/Gainza	54	Premium quality
BRRI dhan87/Nizarsail	58	Premium quality
Gainza/Lata Balam (M6)	57	Premium quality
	Boro 2019-20	
BR8412-5-4-Rang5-8-1-1-1-P1/BRRI dhan28	15	High yield potential
BR8412-5-4-Rang5-8-1-1-1-P1/ BRrang13-RGA-1-1	27	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P1/BRRI dhan81	29	High yield potential
BR8412-5-4-Rang5-8-1-1-1-P2/CN6	24	High yield potential
BR8412-5-4-Rang5-8-1-1-1-P2/Basmati (Acc. No. 4905)	28	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P2/BRRI dhan92	24	High yield potential
BR8412-5-4-Rang5-8-1-1-1-P2/Habu dhan	21	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P3/ BRrang13-RGA-1-1-1	25	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P3/Katari (Gaibandha)	26	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P3/BRRI dhan50	24	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P4/BRRI dhan28	27	High yield potential
BR8412-5-4-Rang5-8-1-1-1-P4/ BRrang13-RGA-1-1	21	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P5/ BRRI dhan28	29	High yield potential
BR8412-5-4-Rang5-8-1-1-1-P5/ BRrang13-RGA-1-1	28	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P6/ BRrang13-RGA-1-1-1	24	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P6/ BRRI dhan50	20	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P6/ Katari (Gainbandha)	18	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P7/ Habu dhan	19	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P7/ Lata Balam	17	Premium quality
BR8412-5-4-Rang5-8-1-1-1-P7/ CN6	20	High yield potential
BR8412-5-4-Rang5-8-1-1-1-P7/ BRRI dhan92	28	High yield potential

Table 2. List of F_1 confirmed, breeding for standard rice varieties for Rangpur region, Boro, 2019-2020.

BR no.	Cross	Objective
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

Table 3. List of segregating generation, breeding for standard rice varieties for Rangpur region, Boro, 2019-2020.

BR no.	Cross	Objective
F_4 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

Breeding for submergence (SUB) and water stagnation tolerance (SFT) for T. Aman, 2019

Under this programme, two OYT (OYT-3 and OYT4), two PYT (PYT-2 and PYT-3), one AYT and one PVS trial for T. Aman 2019 in two locations (Dhamur, Gangachara and Tepa-modhupur, Kaunia) under Rangpur district were conducted. From OYT-3, only BR11185-5R-1020-2 (5.37 t ha-1) was selected compare to BRRI dhan79 (4.78 t ha-1). BR11186-5R-1 (5.37 t ha-1) was selected from OYT-4. IR14F468 (4.85 t ha-1) was selected from PYT#2. In AYT#1, the highest yield was found in IR16F1083 (6.35 t ha-1) among 16 genotypes. In PVS, both BR9158-3-2-2-14-3 (5.23 t ha-1) and BRRI dhan52 (5.10 t ha-1) ranked 1st position among the tested genotypes. From the pedigree nursery, 13 progenies from F_4, 13 genetically fixed lines from F_6, 48 genetically fixed lines from F_7 and 50 genetically fixed lines from F_8 were selected. Twenty advanced breeding lines were selected from OYT.

Development of drought tolerant rice for T. Aman, 2019

The highest yield was found in IR98777-GAZ-13-1-2-4 (5.89 t ha^{-1}) among the tested genotypes with shorter growth duration (119 days). Whereas BRRI dhan71 (ck.) produced 5.65 t ha^{-1} grain yield with similar growth duration.

Development of disease resistance (BLB, BB, Blast and RTV) rice for T. Aman, 2019

In PYT, BR10397-3-2-1-1 (4.98 t ha^{-1}) was selected among the tested 14 fixed lines for BB, blast and RTV. There was no disease and insect infestation was found in this selected lines.

Estimation of breeding value of rice elite breeding pool for T. Aman, 2019

The main objective of this trial is to determine breeding values of T. Aman parental lines and estimation of effective population size. A total of 213 genotypes/varieties were evaluated at BRRI RS, Rangpur. Ten parents were selected for future breeding programme.

Development of cold tolerant rice (CTR) for irrigated Boro season

One OYT, one AYT and one PYT were conducted under this programme. But none of the trial faced to cold stress at late vegetative and reproductive stage. Advanced lines BR10317-5R-19 was selected from 435 tested breeding genotypes from OYT. In AYT, 18 bulk and six segregating advanced lines were selected based on survivability at cold stress, PAcp score at maturity stage, growth duration, grain yield and disease and insect infestation. From PYT, 13 bulk and five segregating progenies were selected among 36 genotypes. The highest grain yield was found in BR10717-5R-82 (8.58 t ha-1) and while the lowest was yield in BR11002-5R-64 (PS) (4.87 t ha-1). Homogeneous line, BR11002-5R-64 (PS), showed the highest cold tolerant (SES 1) at early vegetative stage.

Estimation of breeding value of rice elite breeding pool for Boro season, 2019-2020

A total of 220 genotypes/varieties were evaluated at BRRI RS, Rangpur. Ten parental varieties/lines were selected for future breeding programme.

Development of disease resistance (BLB) rice for irrigated Boro season

In OYT, seven genetically fixed and three segregating lines were selected among 173 tested lines based on disease severity condition, agronomic and yield performance, PAcp at maturity and shorter growth duration.

From PYT, the highest grain yield was found in BR9943-7-1-2-4 (7.92 t ha-1) with 173 days growth duration and no disease infestation was found without any pesticide spray over the life cycle. While the lowest yield was found in BR9942-1-2-1-1-B1 (4.17 t ha-1) as like as susceptible check BRRI dhan89 (4.21 t ha-1) due to higher BLB and neck blast infestation.

Regional yield trial (RYT), T. Aus, 2019 (GOB)

A total of 2 RYTs were conducted under T. Aus seasons:

RYT 1. Seven genotypes along with two checks BRRI dhan48 and BRRI dhan82 were assessed. One genotype BR9013-28-2-3 having 0.7 t ha^{-1} yield advantage over check variety BRRI dhan48.

RYT 2. Three genotypes along with standard check BR26 were evaluated. BR9011-62-2-1-2 ving 0.18 t ha^{-1} yield advantage over the check variety BR26 with similar growth duration.

Regional yield trial (RYT), T. Aman, 2019

Seven RYTs were conducted in T. Aman season with two rainfed lowland (RLR), one zinc enriched rice (ZER), one premium quality (PQR), one insect resistant rice (IRR), one disease resistant rice (DRR), one high yielding rice (HYR) 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 than 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). Six genotypes along with two checks BRRI dhan49 and BRRI dhan72 were evaluated. None of the tested genotypes were found high yielder over the check variety.

RYT 4 (PQR). Seven genotypes and three checks viz Kataribhog, Dinajpur Kataribhog and

BRRI dhan37 were evaluated. BR8528-30-2-5-2 and BR8882-30-2-5-2 performed better over standard check varieties. BR8882-30-2-5-2 produced 0.79 t ha^{-1} higher yield than BRRI dhan37.

RYT 5 (IRR). Eleven genotypes were tested along with three checks Lal Swarna, BRRI dhan33 and T27A49. BR9881-1-4-2-10 and BR9887-17-2-2-22 performed better than the three checks.

RYT 6 (DRR). Six genotypes were tested along with two checks BRRI dhan49 and BRRI dhan87. BR10397-4-1-2 produced highest yield over the check varieties.

RYT 7 (HYR. Biotechnology Division). Three genotypes were tested along with one check BRRI dhan71. BR (Bio) 10376-AC11-3-1 was selected for its earliness and PAcp at maturity.

Regional yield trial (RYT), Boro, 2019-2020

Nine RYTs were conducted during Boro season: Three cold tolerant rice (CTR), one favorable boro rice (FBR), one zinc enriched rice (ZER), one premium quality rice (PQR), one insect resistant rice (IRR), one high yielding rice (HYR) and one favourable Boro rice (FBR-Cumilla) against standard check varieties.

RYT 1-3 (CTR 1, 2 and 3). Five genotypes along with three checks BRRI dhan28, BRRI dhan69 and BRRI dhan88 were evaluated. IR100722-B-B-B-B-11 and TP16199 performed better than BRRI dhan28 and BRRI dhan88.

RYT 4 (FBR). Eight genotypes were tested against BRRI dhan58, BRRI dhan81 and BRRI dhan89. None of the tested entries performed better than BRRI dhan58 and BRRI dhan89.

RYT 5 (ZER). Three genotypes were evaluated along with the four checks BRRI dhan28, BRRI dhan29, BRRI dhan74 and BRRI dhan84. BR8912-12-6-1-1-1-1 was selected based on the PAcp at maturity.

RYT 6 (PQR). Four genotypes were evaluated along with the checks BRRI dhan50, BRRI dhan63 and BRRI dhan81. BR8526-38-2-1-HR1 performed better than the standard check varieties.

RYT 7 (IRR). Ten genotypes were tested with check varieties BRRI dhan58 and T27A. BR9669-23-3-2-23 was selected compared to BRRI dhan58.

RYT 8 (HYR). Six genotypes along with BRRI dhan58 and BRRI dhan63 were evaluated. BRH9-11-4-5B-HR3 and BRH13-2-4-6-4B performed better than the standard check varieties.

RYT 9 (FBR-Cumilla regional station). Five genotypes were evaluated against BRRI dhan28, BRRI dhan28 and BRRI dhan81. BRC297-15-1-1-1 performed better than the check varieties.

Advanced line adaptive research trial (ALART)

Fifteen ALARTs were conducted under T. Aus, T. Aman and Boro seasons. One ALART in T. Aus; eight ALARTs in T. Aman and six ALARTs in Boro season were conducted to develop rice varieties.

Proposed variety trial (PVT)

Six PVTs were conducted under T. Aus, T. Aman and Boro seasons. In T. Aus season, one PVT's (I-003 and I-004), two PVTs in T. Aman (I-005 to I-009) and three PVTs in Boro season (I-010 to I-017) were conducted to develop rice varieties.

CROP-SOIL-WATER MANAGEMENT

Yield maximization of BRRI dhan71 through adjustment of plant population and seedling age at variable planting time

The experiment was conducted at BRRI RS, Rangpur during T. Aman, 2019 season to adjust plant spacing and optimum age of seedling for achieving higher yield of BRRI dhan71. The experiment was laid down in randomized complete block design (RCBD) with three replications. The treatments were: Seedling age (A_1= 15, A_2= 20, A_3= 25 and A_4 = 30 days) and spacing (S_1= 20 × 20, S_2 = 20 × 15 and S_3 = 15 × 15 cm). Transplanting was done on 30 July, 15 and 30 August 2019. BRRI dhan71 produced more panicle with S_3 at all seedling age and it was higher at 30 July planting. It also produced more panicles with A_{30} at all spacing and plantings. Higher yield was observed at 15 August planting with all seedling age irrespective of spacing. Grain yield was lower at 30 July planting due to sterility caused by rainfall and high temperature at flowering (Table 4).

Table 4. Effect of seedling age and spacing on panicle/hill and yield of BRRI dhan71, T. Aman, 2019 BRRI RS, Rangpur.

Age (day)	Spacing (cm)	Panicle/hill			Panicle/m^2			Grain yield (t ha^{-1})		
		30 Jul	15 Aug	30 Aug	30 Jul	15 Aug	30 Aug	30 Jul	15 Aug	30 Aug
	20 × 20	10	8	7	245	200	175	4.30	5.74	5.07
15	20 × 15	7	8	5	241	265	167	4.05	5.57	5.48
	15 × 15	7	6	5	311	267	222	4.80	6.07	6.06
	20 × 20	10	9	6	250	225	150	4.72	5.73	5.44
20	20 × 15	8	7	5	265	233	167	3.87	5.66	5.25
	15 × 15	7	7	5	311	311	222	4.34	5.97	5.75
	20 × 20	10	9	7	250	225	175	5.18	5.87	5.27
25	20 × 15	8	8	5	265	265	167	4.32	5.36	5.35
	15 × 15	7	7	4	311	311	178	4.88	5.97	5.92
	20 × 20	10	10	8	250	250	200	5.39	5.95	5.61
30	20 × 15	9	9	6	300	300	200	4.55	6.06	5.42
	15 × 15	7	7	5	311	311	222	4.58	6.03	5.82
Lsd 0.05		1.119	1.285	0.829	40.172	48.677	30.664	1.298	0.757	0.793

Effect of N and K fertilizer management on growth and yield of mechanically transplanted Boro rice in light textured soil of Rangpur

The experiment was conducted at BRRI RS, Rangpur during Boro, 2019-2020 season to determine suitable N and K fertilizer management option for mechanically transplanted rice. The experiment was laid down in RCBD with three replications. The management options were- Mg_1 = N-P-K-S-Zn = 138-20-82-20-3.6 kg ha^{-1} (Urea was applied at three equal splits (20DAT + 40DAT + 60DAT and Mop was applied at 2/3 as basal and 1/3 with 3rd top dress of urea), Mg_2 = N-P-K-S-Zn = 159-20-82-20-3.6 kg ha^{-1} (15% higher N than Mg_1) (Urea was applied at four equal splits (20DAT + 40DAT + 60DAT + 75DAT and Mop was applied at 2/3 as basal and 1/3 with 3rd top dress of urea), Mg_3 = N-P-K-S-Zn = 152-20-90-220-3.6 kg ha^{-1} (10% higher N and K than Mg_1) (Urea was applied at four equal splits (20DAT + 40DAT + 60DAT + 75DAT and Mop was applied at 2/3 as basal and 1/3 with 3rd top dress of urea). Seeding and transplanting of BRRI dhan89 was done on 2 and 27 January 2020 using rice transplanter. BRRI dhan89 produced about 0.7 t ha^{-1} higher yield with Mg_2 and Mg_3 over Mg_1 due to more number of grains and panicle (Table 5). For achieving higher yield, Mg_3 is better than Mg_2 in light textured soil of Rangpur region.

Effect of polythene cover on seedling quality and its carryover effect on field duration and yield

The experiment was conducted at BRRI RS, Rangpur during Boro, 2019-2020 season to develop a farmers' friendly seedling protecting technique from cold for northern part of Bangladesh. The experiment was laid down in RCBD with three replications. The treatments were: **T_1**: Day polythene cover (10:00 am to Sunset), **T_2**: Night polythene cover (Sunset to sunrise), **T_3**: Day-night polythene cover but partial opening at both sides and **T_4**: No polythene cover (Traditional seedbed). Sprouted seeds of BRRI dhan88 and BRRI dhan89 (80g m^{-2}) were seeded in the puddled seedbed on 1 and 15 December 2019. Seedbed size was 1.0m X 3.0m. Seedbed was covered by transparent polythene from seeding to 30 DAS (days after seeding). Seedlings were hardened from 30 DAS to 45 DAS. Seedling age of uncovered seedbed (control) was also of 45 days. No fertilizer was used in seedbed. Forty-five-day-old seedlings were transplanted at a spacing of 20 cm × 20 cm with one seedling per hill at 15 and 30 January 2020.

Seedling strength had much higher at 1 December seeding than 15 December seeding in both the tested varieties. Normal seedbed (T_4) had higher seedling strength in BRRI dhan88 followed by day-night polythene cover (T_3) at 1 December seeding but it had statistically higher in T_3 followed by T_4 and T_2. Day cover (T_1) had lowest seedling

Table 5. Effect of N and K management options on yield and ancillary characters of BRRI dhan89 using rice transplanter Boro 2019-20 BRRI RS, Rangpur.

Treatment	TGD (day)	Panicle/m^2	Grain/Panicle	Grain Yield (t ha^{-1})
Mg_1	152	356	73	7.80
Mg_2	154	384	97	8.57
Mg_3	154	388	82	8.61
Lsd (0.05)	ns	30.22	ns	0.786

strength in both the varieties. At 15 December seeding, both night cover and day-night cover had higher seedling strength in both the varieties. Day cover had also the lowest seedling strength in both the varieties. Seedling strength had lower at 15 December seeding than 1 December seeding might be due to lower GDD and prevailing low temperature (below 10°C) for more number of days after seeding up to transplanting (Table 6).

Seedling mortality had much higher at 30 January planting than 15 January planting in both the tested varieties. At 15 January planting, it was higher in control seedbed with both the varieties. Day cover and night cover had similar seedling mortality and day-night (T_3) had the lowest mortality with both the varieties. At 30 January planting, it was also higher in control seedbed in case of both the varieties followed by day cover and night cover. BRRI dhan89 showed the lowest seedling mortality with day-night cover (T_3). Seedling mortality was higher at 30 January planting than 15 January planting might be due to prevailing low temperature (below 10°C) for more number of days after transplanting (Table 7).

Taller seedling was obtained at 15 January planting but plant height was higher at 30 January planting in case of both the varieties. Both the plantings with day-night polythene cover treatment (T_3) produced significantly tallest seedling followed by day polythene cover (T_3) in both the varieties but it didn't reflect on plant height. Normal seedling (T_4) had the lowest seedling height. There was no significant difference in plant height at both the plantings in both the varieties. Both the varieties produced higher number of panicles at 30 January planting and BRRI dhan88 produced more number of panicle with all the treatments at both the plantings than BRRI dhan89. There was no significant difference in grain yield at both the plantings in both the varieties. BRRI dhan89 produced higher grain yield due to longer growth duration and it was higher at 30 January planting (Tables 8 and 9). Day-night polythene cover treatment (T_3) reduced growth duration by 2-3 days than the other treatments.

Effect of aged seedling on yield of Boro rice in northern region of Bangladsh

The experiment was conducted at BRRI RS, Rangpur during Boro 2019-2020 season to find out optimum seedling of Boro rice for northern part of Bangladesh. The experiment was laid down in RCBD with three replications. BRRI dhan88 and BRRI dhan89 were transplanted using different seedling age at 15 January with a spacing of 20 cm x 20 cm with two seedlings per hill (Table 10). BRRI dhan88 and BRRI dhan89 produced similar grain yield with all seedling ages (35-65 days). Although total growth duration was higher in A_{65} but field duration was lower than younger seedling but produced similar grain yield.

Table 6. Effect of polythene cover of seedbed on seedling strength, Boro, 2019-2020 Rangpur.

Treatment	Seedling strength (mg/cm) DS: 1 December 2019		Seedling strength (mg/cm) DS: 15 December 2019	
	BRRI dhan88	BRRI dhan89	BRRI dhan88	BRRI dhan89
Day cover (T_1)	4.40	4.76	1.95	2.01
Night cover (T_2)	5.56	6.12	2.51	3.01
Day-night cover (partial opening at both sides) (T_3)	5.83	8.56	2.50	4.04
No polythene cover (Traditional seedbed) (T_4)	6.14	6.15	0.96	2.88
GDD	749° days		710° days	

Table 7. Effect of polythene cover of seedbed on seedling mortality, Boro, 2019-2020, Rangpur.

Treatment	Seedling mortality (%) at 25 DAT TP: 15 Jan 2020		Seedling mortality (%) at 25 DAT TP: 30 Jan 2020	
	BRRI dhan88	BRRI dhan89	BRRI dhan88	BRRI dhan89
Day cover (T_1)	5.2	3.0	20.2	29.9
Night cover (T_2)	5.2	3.0	18.7	20.2
Day-night cover (partial opening at both sides) (T_3)	4.5	1.5	17.9	9.0
No polythene cover (Traditional seedbed) (T_4)	7.5	7.5	23.9	23.1

Table 8. Effect of polythene cover treatment in seedbed on yield and ancillary characters at 15 January planting, Boro 2019-2020 BRRI RS, Rangpur.

Treat	Seedling height (cm)	Pl. height (cm)	Panicle m^{-2}	Duration (day)	Yield (t ha^{-1})	Seedling height (cm)	Plant height (cm)	Panicle m^{-2}	Duration (day)	Yield (t ha^{-1})
	BRRI dhan88					BRRI dhan89				
T_1	15.9	88.3	297	154	6.67	16.8	107.6	266	166	7.35
T_2	13.5	86.2	286	153	6.62	14.7	107.1	278	166	7.52
T_3	22.3	87.5 87.5	277	152	6.50	22.2	105.4	255	163	7.63
T_4	11.4	90.1	297	153	6.78	13.0	107.9	276	166	7.68
Lsd $_{o.o5}$	1.05	ns	18.7	ns	ns	1.87	ns	16.79	ns	ns

Table 9. Effect of polythene cover treatment in seedbed on yield and ancillary characters at 30 January planting, Boro 2019-2020 BRRI RS, Rangpur.

Treat*	Seedling height (cm)	Pl. height (cm)	Panicle m^{-2}	Duration (day)	Yield (t ha^{-1})	Seedling height (cm)	Plant height (cm)	Panicle m^{-2}	Duration (day)	Yield (t ha^{-1})
	BRRI dhan88					BRRI dhan89				
T_1	14.9	94.8	354	151	6.99	15.4	114.7	307	164	7.99
T_2	12.0	94.7	347	150	7.18	13.3	114.9	299	164	8.08
T_3	16.0	95.9	353	149	7.42	17.3	114.9	293	161	8.29
T_4	10.4	94.8	352	150	7.24	10.4	115.3	303	163	7.96
Lsd$_{o.o5}$	1.12	ns	ns	ns	ns	1.29	ns	ns	ns	ns

*T_1= Day polythene cover, T_2= Night polythene cover, T_3= Day-night polythene cover (partial opening at both sides), T_4 = No polythene cover (Traditional seedbed)

Among the treatments (T_1-T_3), day-night polythene cover (partial opening at both sides) (T_3) is farmers' friendly because it is hassle free, less labor consuming (cost effective) and risk free.

Table 10. Effect of seedling age on yield and ancillary characters, Boro 2019-2020, BRRI RS, Rangpur.

Seedling age (day)	BRRI dhan88			BRRI dhan89		
	Field duration (day)	TGD (day)	Yield (t ha^{-1})	Field duration (day)	TGD (day)	Yield (t ha^{-1})
A_{65}	105	170	6.93	113	178	7.98
A_{60}	106	166	6.83	115	175	7.92
A_{55}	107	162	6.92	117	172	7.93
A_{50}	108	158	6.95	118	166	7.85
A_{45}	111	156	6.87	119	164	7.67
A_{40}	114	154	6.98	121	161	7.96
A_{35}	118	153	7.02	123	158	7.74
Lsd $_{o.o5}$			ns			ns

TGD = Total growth duration.

SOCIO-ECONOMIC

Stability analysis of BRRI varieties at BRRI RS, Rangpur in T. Aus, T. Aman and Boro season during 2019-20

Seventy-five of BRRI developed varieties were evaluated during T. Aus (10), T. Aman (42) and Boro (43) season at the BRRI RS following RCBD with three replications.

TECHNOLOGY TRANSFER

Technologies dissemination workshop

BRRI RS, Rangpur organized one workshop for T. Aman during the reporting period. The aim of the workshop was sustainable rice production in this region through adoption of BRRI developed technologies. Around 130 participants attended the workshop. Additional Secretary of MoA, The DG, directors and senior scientists of BRRI, the DG and directors of DAE, AD, DD, UAO, RSCO, DSCO of Rangpur-Dinajpur region, scientists from NARS, BADC and BMDA personnel, different NGO extension personnel, farmers, electronic and print media personnels also attended the workshop.

Promotional activities for the former enclave's farmer

BRRI RS, Rangpur conducted 10 varietal demonstration programmes for the dissemination of BRRI developed latest varieties in Dashiarchora, Fulbari, Kurigram (Former enclave). Moreover, BRRI RS, Rangpur also arranged four farmers training on modern rice production technologies where 60 farmers participated. These programmes will be continued in future.

Demonstration (variety/technology)

A total of 79 demonstrations under different projects were conducted in Rangpur-Dinajpur region during the reporting period.

RS Rangpur (GOB). A total of 64 varietal demonstrations were conducted at different locations of Rangpur-Dinajpur region. In T. Aus, BRRI dhan48 and BRRI dhan82, in T. Aman, BRRI dhan52, BRRI dhan70, BRRI dhan71, BRRI dhan75, BRRI dhan79, BRRI dhan80 and BRRI dhan87; and in Boro, BRRI dhan74, BRRI dhan81, BRRI dhan84, BRRI dhan86, BRRI dhan89, BRRI dhan92, BRRI hybrid dhan3 as well as BRRI hybrid dhan5 were used. Farmers were very much interested about these newly released BRRI varieties.

TRB project. Nine varietal demonstrations were conducted in nine upazilas under nine districts in Rangpur-Dinajpur region during the reporting period. Eight varieties viz BRRI dhan49, BRRI dhan52, BRRI dhan71, BRRI dhan75, BRRI dhan79, BRRI dhan80 and BRRI dhan87 and Guti swarna were used in T. Aman season. BRRI dhan28, BRRI dhan29, BRRI dhan58, BRRI dhan67, BRRI dhan81, BRRI dhan84, BRRI dhan88, BRRI dhan89 and BRRI dhan92 were used in Boro season. In T. Aman, BRRI dhan52, BRRI dhan71, BRRI dhan75 and BRRI dhan87 and in Boro season BRRI dhan67, BRRI dhan81, BRRI dhan84 and BRRI dhan89 were choosen by the farmers due to grain appearance, high yield and less disease incidence (Tables 11 and 12).

Table 11. Grain yield of head to head trials under TRB project in Rangpur region, T. Aman, 2019.

Location	Grain yield (t ha^{-1})							
	BRRI dhan49	BRRI dhan52	BRRI dhan71	BRRI dhan75	BRRI dhan79	BRRI dhan80	BRRI dhan87	Guti swarna
Kawnia, Rangpur	4.5	5.43	-	-	4.57	-	-	5.97
Pirganj, Thakurgaon	4.71	5.00	-	-	4.82	-	-	4.82
Polashbari, Gaibandha	4.94	-	5.03	4.84	-	4.73	5.76	5.43
Rajarhat, Kurigram	4.67	4.96	-	-	5.12	-	-	4.79
Debiganj, Panchagarh	4.52	-	4.62	4.55	-	4.42	5.41	5.12

Table 12. Grain yield of Head to Head trials under TRB project in Rangpur region, Boro 2019-2020.

Location	Grain yield (t ha^{-1})								
	BRRI dhan28	BRRI dhan67	BRRI dhan81	BRRI dhan84	BRRI dhan88	BRRI dhan29	BRRI dhan58	BRRI dhan89	BRRI dhan92
Nawabganj, Dinajpur	5.98	6.61	6.95	6.00	6.18	-	-	-	-
Pirganj, Thakurgaon	5.39	5.92	5.85	5.63	5.54	-	-	-	-
Polashbari, Gaibandha	-	-	-	-	-	5.58	5.37	6.04	5.32
Phulbari, Kurigram	-	-	-	-	-	6.98	6.66	7.37	7.05

SPIRA project. Six demonstrations were conducted in six locations during T. Aman and Boro season 2019-20. Three varieties viz BRRI dhan87, BRRI hybrid dhan3 and BRRI hybrid dhan5 were tested (Tables 13 and 14). In T. Aman, BRRI dhan87 produced the highest yield (6.15 t ha^{-1}) with 130 days growth duration. On the other hand, yield performance of BRRI hybrid dhan3 was the highest (9.60 t ha^{-1}) at Rangpur Sadar, followed by BRRI hybrid dhan5 (7.70 t ha^{-1}) at Pirganj, Rangpur in Boro season.

Strengthening of environment friendly insect pest research for increasing yield (Entomology project)

During Boro season, a technology was demonstrated for insect pest recommended (BRRI management and farmers' practices) using BRRI dhan29 at sadar, Nilphamari. It was found that BRRI management practices performed better than the farmers' practices.

Training and field day. Thirteen farmers' training on modern rice production technology was conducted at different upazilas of Rangpur-Dinajpur region in collaboration with DAE. A total of 400 farmers were trained through this programme. This training programme was very much helpful to minimize knowledge gap on modern rice production technologies. Twelve in-house training were arranged at the programs BRRI regional station to improve the capability in office management of the office staff. Eight 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. A total of 250 kg seeds and seedlings of different photosensitive varieties viz BR22, BRRI dhan34 and Nizarsail were distributed among the flood affected farmers in Kawnia-Rangpur, Chilmari-Kurigram and Gaptoli-Bogura.

Seed production and dissemination in July 2019-June 2020

A total of 975 kg, 5,284 kg and 3,997 kg TLS were produced in T. Aus, T. Aman and Boro season, respectively. A total of 1,830 kg breeder seed (BRRI dhan71 and BRRI dhan87) was produced in T. Aman and 5,750 kg breeder seed (BRRI dhan58 and BRRI dhan89) was also produced in Boro season. Moreover, a total of 7,580 kg breeder seed was sent to the GRS Division. In three seasons, 3,224 kg TLS was distributed among the farmers for dissemination in Rangpur-Dinajpur region. Table 15 presents variety-wise production and distribution information.

Table 13. Grain yield of varietal demonstration under SPIRA project in Rangpur region, T. Aman, 2019.

Location	Variety	Growth duration (day)	Yield (t ha^{-1})
Phulbari, Kurigram	BRRI dhan87	130	6.15
Khanshama, Dinajpur	BRRI dhan87	128	5.85
Pirganj, Rangpur	BRRI dhan87	127	6.10

Table 14. Grain yield of varietal demonstration under SPIRA project in Rangpur region, Boro 2019-2020.

Location	Variety	Growth duration (day)	Yield (t ha^{-1})
Sadar, Rangpur	BRRI hybrid dhan3	149	9.60
sadar, Gaibandha	BRRI hybrid dhan3	152	7.50
Pirganj, Rangpur	BRRI hybrid dhan5	156	7.70

Table 15. Variety-wise seed production and distribution during T. Aus 2019, T. Aman 2019 and Boro 2019-20, BRRI RS, Rangpur.

Variety	Amount (kg)		Sold (TLS-kg)	Send to GRS (Breeder-kg)	Distribution of TLS (kg)
	TLS	Breeder seed			
		T. Aus, 2019			
BRRI dhan48	512	-	200	-	312
BRRI dhan82	272	-	100	-	172
BRRI dhan83	30	-	30	-	-
BRRI dhan85	161	-	161	-	-
BRRI hybrid dhan7	-	-	-	-	100
Total	975	-	491	-	584
		T. Aman, 2019			
BR22	667	-	-	-	-
BRRI dhan34	614	-	444	-	-
BRRI dhan49	197	-	197	-	-
BRRI dhan52	102	-	102	-	-
BRRI dhan66	124	-	124	-	-
BRRI dhan70	75	-	125	-	-
BRRI dhan71	378	1,550	378	1,050	-
BRRI dhan72	89	-	89	-	-
BRRI dhan75	170	-	170	-	300
BRRI dhan79	48	-	448	-	-
BRRI dhan80	72	-	72	-	-
BRRI dhan87	2195	280	3740	-	1550
BRRI dhan90	48	-	48	-	200
BRRI dhan93	137	-	137	-	-
BRRI dhan95	160	-	160	-	-
BRRI hybrid dhan4	-	-	-	-	50
BRRI hybrid dhan6	-	-	-	-	400
Binasail	38	-	-	-	-
Naizarsail	330	-	-	-	-
Total	5,284	1,830	6,234		2500
		Boro, 2019-2020			
BR16	-	-	67	-	-
BRRI dhan28	-	-	12	-	-
BRRI dhan29	-	-	27	-	-
BRRI dhan48	227	-	-	-	-
BRRI dhan50	-	-	206	-	-
BRRI dhan58	650	2,750	580	2,750	-
BRRI dhan63	-	-	465	-	-
BRRI dhan74	-	-	4	-	-
BRRI dhan81	455	-	7	-	-
BRRI dhan82	195	-	-	-	-
BRRI dhan84	390	-	-	-	20
BRRI dhan86	-	-	640	-	-
BRRI dhan88	455	-	793	-	-
BRRI dhan89	1105	3,000	1583	3,000	20
BRRI dhan92	520	-	-	-	-
BRRI hybrid dhan3	-	-	-	-	50
BRRI hybrid dhan5	-	-	-	-	50
Total	3,997	5,750	4,434	5,750	140
Grand total	10,256	7,580	11,159	7,580	3,224

BRRI RS, Satkhira

SUMMARY

In line stage trial (LST), 836 entries were selected from 5,342 populations in T. Aman 2019, while in Boro 2019-20, a total of 4,745 entries were collected from 16 crosses. Under observational trial (OT), 47 and 200 entries were selected in T. Aman 2019 and Boro 2019-20, respectively.

In T. Aman 2019, four preliminary yield trials (PYT) were conducted, where IRSSTN-SVIN381-18, IRSSTN-SVIN363-18, IRSSTN-SVIN428-18, IRSSTN-SVIN395-18, IRSSTN-SVIN408-18, BR10426-9-5-3B2, BR10440-2-9-3, BR10424-1-1-1, BR10434-7-10-1B1 and BR10432-7-4-4B2 lines performed better than the check varieties. In Boro 2019-20, four PYTs were conducted, where BR9907-7-4-8, TP30698, TP30637, IR15T1375, IR15T1448 and BR 11723-4R-172 lines performed better than the check varieties.

In T. Aman 2019, under secondary yield trial (SYT), IR103899-9-1-AJY2 and BR9536-2-1-7 lines produced higher yield than the check BRRI dhan54.

In T. Aman 2019, under regional yield trial (RYT) for saline tolerant rice, the entries BR9743-5-7-10, IR112453-B-BAY10-3-1 and TP30642 gave higher yield than check varieties. In RYT for ZER, BR10001-94-2-B, BR7528-2R-19-16-RIL-33 and BR7528-2R-19-16-RIL-59 entries produced higher yield over BRRI dhan72. In Boro 2019-20, under RYT for FBR-1, tested genotypes of IR100004-19-B-1 and BR8902-38-7-1-1-1-1 had significant yield advantage than BRRI dhan81. In RYT for FBR-2, the entries BRH11-2-4-9B, BRH11-2-1-3-8B and BRH9-7-4-1B performed better than BRRI dhan63. In RYT for PQR, Habubalam performed better over the check of BRRI dhan50. In RYT for ZER, the entry IR105837-8-95-2-1 performed better than the three checks of BRRI dhan28, BRRI dhan74 and BRRI dhan84. In RYT for saline tolerant rice, the entries BR9626-B-2-3-15, BR9621-B-2-3-22, BR9627-1-3-1-10, IR104002-CMU28-CMU1-CMU3 and BR9620-2-4-1-5 produced higher yield than the check varieties of BRRI dhan28, BRRRI dhan67 and BINAdhan-10.

Under advanced yield trial (AYT), BR9625-B-2-4-9, BR9625-B-2-4-8 and IR96184-24-1-1-AJY2 lines performed over the check varieties in Boro 2019-20.

In T. Aman 2019, for ALART-BIO, none of the entries performed better than the check of BRRI dha87, while all of the entries obtained higher yield than the check of BRRI dhan71. In ALART-ZER, none of the entries performed better than the check varieties of BRRI dhan87 and BRRI dhan72, where the entry BR8442-12-1-3-1-B7 produced higher yield than BRRI dhan49. In Boro 2019-20, for ALART-ZER, the entry IR99285-1-1-1-P2 gave higher yield than the check of BRRI dhan84. In ALART-BBRR, all the entries, except BR(Bio)11447-3-10-7-1 gave higher yield over the check variety of BRRI dhan28, while none of the entries performed better than the check variety of BRRI dhan58.

In T. Aus 2019, application of 80 kg N ha^{-1} was found optimum dose for higher yield irrespective of variety. For irrigation experiment, when water level was 15 cm below form the surface resulted in the highest yield for BR26 and BRRI dhan82, while BRRI dhan48 performed better in rainfed condition. In T. Aus season, transplanting on 10 May produced the highest yield.

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 @ 5.0 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 appear as economically profitable for rice cultivation at Satkhira.

BRRI dhan48 among the Aus varieties, while in T. Aman, most of the tested varieties and among the Boro varieties, BRRI hybrid dhan3, BRRI hybrid dhan5, BRRI dhan67 and BRRI dhan89 appeared as good yielder in stability analysis at BRRI RS farm, Satkhira.

BRRI hybrid dhan5 produced the highest yield over the other tested hybrid rice varieties at Debhata and Assasuni of Satkhira district in Boro 2019-20 season.

In integrated rice-fish culture, BR10 performed better (5.13 t ha^{-1}) than BRRI dhan73 (4.30 t ha^{-1}), while BR10, BRRI dhan30 and BRRI

dhan79 produced similar yield (5.15-5.35 t ha^{-1}) under stagnant water environment.

Under head to head trial, irrespective of location, BRRI dhan87 produced the highest yield (6.69 t ha^{-1}) followed by BRRI dhan49 (5.83 t ha^{-1}) during Aman 2019.

A total of 28.11 tons of breeder seed of different T. Aman and Boro rice varieties were produced and sent to the GRS Division. In addition, 32.06 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 87 demonstrations (Aus, Aman and Boro) were conducted during 2019-20 under SPDP programme. We arranged fourteen farmers' training (455 farmers) and ten field days and attended one agricultural fair during the requesting period 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. Existing Boro (BRRI dhan28) - Fallow - T. Aman (BRRI dhan49) cropping pattern was successfully replaced by Mustard (BARI Sharisa-14) - Boro (BRRI dhan81/BRRI dhan86) - T. Aman (BRRI dhan75) cropping pattern with about 38% higher REY. Vegetable production is one of the virtuous initiatives of the farm household to increase the nutritional level of family members' and cash income of the farm household especially lead to advancement to empower the female family members as well. In poultry system, Sonali chicken, Khaki Campbell duck and Turkey rearing under scavenging system seems to be a good option to increase farmers' income, egg consumption and egg selling. Inclusion of vegetable production on gher bund increase the productivity at significant level. Goat rearing is also a multi-functional farming component with high returns as all of the given goats have produced kids and all farmers have sold these kids for income generation. Fish polyculture in ghers as well as ponds have increased the daily fish consumption among the farmers and increased income of the household farmers. Planting fruit trees in households and establishing mini orchards are auspicious to increase the productivity through exploitation of the existing resources.

VARIETY DEVELOPMENT

Line stage trial (LST)

In T. Aman 2019, a total of 778 entries were selected from 4656 tested populations at BRRI RS, Satkhira farm and 58 entries were selected from 686 populations at Debhata, Satkhira based on their phenotypic appearance and salt tolerance ability**.** In Boro 2019-20, a total of 4,745 entries from 16 crosses were transplanted in the field of BRRI farm, Satkhira to select suitable genotypes having salt tolerance ability.

Observational trial (OT)

In T. Aman 2019, a total of 28 and 19 entries were selected from 100 tested entries under an observational trial at Koyra and at Debhata sites respectively. In Boro 2019-20, a total of 1,291 entries were evaluated against four checks of BRRI dhan28, BRRI dhan67, BRRI dhan89 and Binadhan-10 at BRRI RS farm, Satkhira. Two hundred entries were selected as advanced line for further improvement.

Preliminary yield trial (PYT) in T. Aman 2019

A total of 20, 26, 25 and 28 genotypes were evaluated in PYT-1, PYT-2, PYT-3 and PYT-4, respectively at different sites in Satkhira and Khulna districts against three checks of BR11, BRRI dhan54 and BRRI dhan73 during T. Aman 2019.

PYT-1. IRSSTN-SVIN381-18 (4.68 t ha^{-1}) and IRSSTN-SVIN363-18 (5.83 t ha^{-1}) yielded higher than the check varieties at Koyra and Assasuni, respectively. IRSSTN-SVIN428-18 (4.14 t ha^{-1}), IRSSTN-SVIN395-18 (3.89 t ha^{-1}) and IRSSTN-SVIN408-18 (3.78 t ha^{-1}) yielded higher than the check varieties at Kaliganj site.

PYT-2. In Kaliganj, all entries were damaged due to high salinity. At BRRI farm, BR10426-9-5-3B2 (5.78 t ha^{-1}), BR10440-2-9-3(5.77 t ha^{-1}), BR10424-1-1-1 (5.65 t ha^{-1}), BR10434-7-10-1B1 (5.35 t ha^{-1}) and BR10432-7-4-4B2 (5.12 t ha^{-1}) produced more yield with shorter growth duration (116-121 days) than the check varieties of BR11 (3.28 t ha^{-1}) and BRRI dhan73 (4.81 t ha^{-1}). At Assasuni, none of the entries performed better than the check varieties.

PYT-3. At Assasuni, BR10425-1-3-4 (5.16 t ha^{-1}), BR10430-7-4-5B2 (5.16 t ha^{-1}) and BR10441-

5-1-2 (5.15 t ha^{-1}) yielded higher than BRRI dhan73 (4.18t ha^{-1}). Their growth duration (119 to 124 days) was shorter than BRRI dhan73 (130 days) and BRRI dhan54 (132 days).

PYT-4. All entries were lodged by Bulbul cyclone (9 to 11 November 2019) during flowering stage at BRRI farm due late transplanting, while BR10441-10-15-4 yielded (4.17 t ha^{-1}) higher than check varieties at Assasuni site.

Preliminary yield trial (PYT) in Boro 2019-20

A total of 26 and 27 genotypes were evaluated in PYT-1, PYT-2 and PYT-3 at four different sites in Satkhira and Khulna districts against three checks of BRRI dhan28, BRRI dhan67 and Binadhan-10. In contrast, 20 genotypes were evaluated in PYT-4 at two sites in Satkhira against four checks of BRRI dhan29, BRRI dhan67, BRRI dhan89 and Binadhan-10.

PYT-1. At Koyra, BR10188-10-1-18 (7.23 t ha^{-1}), BR9915-1-2-4 (7.08 t ha^{-1}) and BR10187-1-4-12 (7.01 t ha^{-1}) gave significantly higher yield than BRRI dhan67 (6.35 t ha^{-1}) and Binadhan-10 (6.78t ha^{-1}). At Kaliganj, most of the entries were damaged due to high salinity. However, BR10187-1-6-13, BR9901-1-3-10, BR9907-7-4-8, BR9907-3-4-12, BR9918-2-6-1 and BR9918-10-4-5 yielded 0.5 t ha^{-1} to 1.0 t ha^{-1}. At Assasuni, none of the entries produced higher yield than BRRI dhan67 (5.15 t ha^{-1}). In BRRI farm, BR9907-7-4-8 (7.60 t ha^{-1}) produced significantly higher yield than all the check varieties.

PYT-2. At Koyra, TP30698 (7.63 t ha^{-1}) produced significantly higher yield than check varieties. Most of the entries were damaged due to high salinity at Kaliganj site. However, TP22025 and TP1231were selected based on their salinity tolerance label in whole life cycle. None of the entries performed better than BRRI dhan67 and Binadhan-10 at Assasuni. In BRRI farm, TP30637 (7.15 t ha^{-1}) yielded significantly higher yield than the other check varieties.

PYT-3. At Koyra, none of the entries produced higher yield than the check varieties. At Assasuni, IR15T1375 (5.73 t ha^{-1}) produced higher yield than the check varieties. In BRRI farm, IR15T1448 (7.70 t ha^{-1}) yielded significantly higher yield than all check varieties. At Kaliganj, all entries were damaged due to high salinity.

PYT-4. Among all entries, BR 11723-4R-172 (11.17 t ha^{-1}) produced higher yield than all the check varieties in BRRI farm. However, its growth duration (167 days) was longer than BRRI dhan89 (152 days). At Kaliganj, some entries escaped salinity at vegetative stage but failed to flowering as high salinity.

Secondary yield trial (SYT) in T. Aman 2019

In SYT, 11 genotypes were evaluated against BRRI dhan54 and BRRI dhan73 at four different sites of Satkhira and Khulna districts. In all sites, some entries were fully damaged and other entries yielded lower for Bulbul cyclone. At Koyra site, most of the entries produced higher yield than BRRI dhan73 (2.82 t ha^{-1}). At Assasuni, TP30651 (3.67 t ha^{-1}) and BR9536-2-1-7 (3.59 t ha^{-1}) yielded higher than BRRI dhan54 (3.34 t ha^{-1}) and BRRI dhan73 (3.30 t ha^{-1}). At Kaliganj, IR15T1349 (3.74 t ha^{-1}), IR103499-B-2-AJY1 (3.61 t ha^{-1}) and IR103899-9-1-AJY2 (3.46 t ha^{-1}) performed better than BRRI dhan54 (2.78 t ha^{-1}) and BRRI dhan73 (3.30 t ha^{-1}). No entries yielded higher than BRRI dhan54 (5.17 t ha^{-1}) at BRRI RS farm, Satkhira, though IR103899-9-1-AJY2 (4.59t ha^{-1}), BR9536-2-1-7 (4.23t ha^{-1}) and IR15T1448 (3.88t ha-1) showed higher yield than BRRI dhan73 (3.45t ha-1).

Regional yield trial (RYT) during T. Aman, 2019

In RYT for saline tolerant rice, 17 genotypes were evaluated against two checks of BRRI dhan54 and BRRI dhan73 at four different sites of Satkhira and Khulna districts (Table 1). At Koyra, BR9743-5-7-10 (4.94 t ha^{-1}), IR112453-B-BAY10-3-1 (4.11 t ha^{-1}) and TP30642 (4.16 t ha^{-1}) yielded higher than all the check varieties (Table 1). No entries performed better than BRRI dhan54 (4.47 tha-1), where TP30656 (4.42 t ha-1), BR9743-5-7-10 (3.92 t ha^{-1}) and IR15T1376 (3.84 t $ha^{-1)}$ showed higher yield over BRRI dhan73 (3.40 t ha^{-}1) at Assasuni site. No yield advantage was found compared to the tested varieties at Kaliganj and BRRI farm (Table 1). However, none of the entries produced statistically higher yield compared to the check varieties in HYR, RLR, DRR and DTR (Table 2). In RYT for ZER, BR10001-94-2-B, BR7528-2R-19-16-RIL-33 and BR7528-2R-19-16-RIL-59 entries produced higher yield than the check variety of BRRI dhan72, but similar yield with BRRI dhan49. (Table 2).

Table 1. Performance of different saline tolerant entries under RYT at Koyra, Assasuni, Kaliganj and BRRI RS, Satkhira during T. Aman 2019.

Designation	Yield (t ha^{-1})			
	Koyra	Assasuni	Kaliganj	BRRI farm
BR10045-15-23-5	3.81	3.32	3.52	2.57
BR10061-B-1-2-1	2.04	3.45	3.57	2.48
BR9743-5-7-10	4.94	3.92	3.27	2.55
BR9747-5-3-11	3.78	3.72	3.32	2.89
BR9747-13-2-18	3.81	3.73	3.40	3.32
IR108128-B-1-AJY2-B-1	3.83	3.21	3.95	2.41
IR15T1305	3.56	*	3.55	2.69
IR15T1469	3.65	*	3.29	2.38
IR15T1451	3.33	*	3.28	2.62
IR15T1408	2.33	4.09	3.49	3.27
IR15T1376	4.04	3.84	3.36	2.03
IR108158-B-2-AJY1-1	3.76	*	3.65	2.48
IR112453-B-BAY10-3-1	4.11	3.75	3.47	2.31
TP30642	4.16	3.44	3.73	1.98
TP30656	3.57	4.42	3.26	3.51
TP30649	3.91	4.00	3.29	3.29
IR 87870-6-1-1-1-1-B	3.98	2.83	3.58	*
BRRI dhan73 (ck)	3.79	3.40	3.22	2.96
BRRI dhan54 (ck)	3.61	4.47	3.32	3.48
$LSD_{0.05}$	0.29	0.34	0.14	0.16
CV (%)	8.01	9.20	4.33	6.13

* = Lodging caused by cyclone

Table 2. Performance of different entries under RYT at BRRI RS, Satkhira during T. Aman 2019.

Entry/Variety	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})	Remarks
		RYT-HYR		
BR(Bio)103-AC4-1-3	92	109	4.64	10% Rat Damage
BR(Bio) 103-AC9-1-3	95	112	3.83	50% Rat Damage
BRRI dhan71 (ck.)	91	112	2.81	65% Rat Damage
BRRI dhan87 (ck.)	114	123	5.53	
$LSD_{0.05}$	9.02	2.75	1.25	
CV (%)	4.60	1.22	14.92	
		RYT-RLR-1		
BR9571-2-2-5-2-1	119	128	4.49	
BR9571-28-1-1-1-1	116	120	4.57	
BR9571-28-2-1-2-1	123	128	4.32	20% Rat Damage
BR9571-28-2-4-1-1	117	122	2.97	70% Rat Damage
BR9571-28-2-5-1-1	125	124	4.44	
BR9571-4-1-2-2-1	125	126	4.67	
BR9571-4-2-6-1-1	103	124	2.19	75% Rat Damage
BRRI dhan49 (ck.)	101	128	4.50	
BRRI dhan87 (ck.)	119	124	5.07	
$LSD_{0.05}$	1.58	ns	0.75	
CV (%)	0.78	0	10.43	
		RYT-RLR-2		
BR9571-13-1-9-1-1	124	125	4.60	
BR9571-28-4-1-2-1	125	124	3.41	40% Rat Damage
BR9573-31-1-2-5-1	128	134	3.46	40% Rat Damage
BR9573-36-1-3-2-1	123	135	3.65	40% Rat Damage
BR9574-15-3-4-2-1	123	132	3.87	40% Rat Damage
BR9574-3-3-1-1-1	114	125	4.59	
BR9574-9-5-3-1-1	106	131	4.26	20% Rat Damage
BRRI dhan49 (ck.)	101	131	4.54	
BRRI dhan87 (ck.)	115	126	4.73	20% Rat Damage
$LSD_{0.05}$	1.26	0.60	0.52	
CV (%)	0.62	0.27	7.29	

Table 2. Continued

		RYT-DRR		
BR10390-22-2-1-5	105	130	3.99	25% Rat damage
BR10393-2-2-2 (RTV)	122	124	4.58	5% Goat Damage
BR10393-2-2-2-3(RTV)	124	122	5.13	
BR10393-4-1-3-4(RTV)	120	124	5.02	
BR10395-22-3-5(Blast)	117	119	2.58	70% Rat Damage
BR10397-4-1-2	102	126	5.44	
BRRI dhan49 (ck.)	102	128	5.36	
BRRI dhan87 (ck.)	118	123	4.69	20% Rat Damage
$LSD_{0.05}$	3.98	0.71	1.01	
CV (%)	2.00	0.33	12.58	
		RYT-ZER		
BR9871-29-1-1-B	122	126	4.60	
BR9871-29-1-3-B	140	134	4.31	20% Rat Damage
BR9868-19-40-3-B	144	132	5.22	
BR10001-94-2-B	104	126	5.52	
BR7528-2R-19-16-RIL-33	101	125	5.51	
BR7528-2R-19-16-RIL-59	103	125	5.43	
BRRI dhan49 (ck.)	103	130	5.46	
BRRI dhan72 (ck.)	121	122	4.17	
$LSD_{0.05}$	2.17	NS	0.93	
CV (%)	1.06	0	10.6	
		RYT-DTR		
IR98841-GAZ-4-2-1-2	122	113	4.43	
IR98849-GAZ-2-2-4-1	120	115	3.86	40% Rat Damage
IR98841-GAZ-8-1-3-1	125	118	5.02	
IR98929-GAZ-1-2-1-1	121	118	5.07	
IR98841-GAZ-8-1-1-2	105	120	4.06	
IR98816-GAZ-3-2-1-2	120	117	3.49	50% Rat Damage
IR98973-GAZ-3-2-5-1	107	119	5.05	
IR98777-GAZ-13-1-2-4	119	119	4.55	
IR9880-GAZ-5-1-1-2	123	125	4.22	
BRRI dhan56 (ck.)	102	120	4.04	30% Rat Damage
BRRI dhan66 (ck.)	126	123	4.79	
BRRI dhan71 (ck.)	125	120	4.27	20% Rat Damage
$LSD_{0.05}$	2.62	0.87	1.13	
CV (%)	1.31	0.43	15.20	
		RYT-IRR		
BR10035-6-2-5	105	112	2.48	60% Rat Damage
BR9880-40-1-3-34	105	102	4.30	
BR9887-17-2-2-22	114	102	4.13	20% Rat Damage
BR9880-2-2-2-1	119	125	4.55	
BR9888-1-2-2-5	102	102	4.13	
BR10039-13-3-4	115	133	4.01	30% Rat Damage
BR9880-27-4-1-18	109	103	4.80	
BR9881-24-2-2-25	104	133	4.07	20% Rat Damage
BR9881-1-4-2-10	106	103	4.72	
BR9881-17-2-2-22	120	102	4.56	
BR9880-45-2-2-38	130	103	4.26	
SWARNA (LAL)	111	119	3.52	50% Rat Damage
BRRI dhan33	97	133	3.91	40% Rat Damage
T27A (Local ck.)	149	132	3.60	
$LSD_{0.05}$	3.69	1.56	0.66	
CV (%)	1.94	0.81	9.66	

Regional yield trial (RYT) during Boro 2019-20

Six RYTs were conducted at BRRI RS farm, Satkhira during Boro 2019-20 (Table 3). In RYT for FBR-1, tested genotype of IR100004-19-B-1 and BR8902-38-7-1-1-1-1 had significant yield advantage with seven and ten days shorter growth duration, respectively than the check variety of BRRI dhan81. In RYT for FBR-2, the entry BRH11-2-4-9B, BRH11-2-1-3-8B and BRH9-7-4-1B performed better with eight, nine and 12 days higher growth duration respectively than the check variety of BRRI dhan63. In RYT for PQR, Habubalam performed better than the check of BRRI dhan50. In RYT for ZER, the entry IR105837-8-95-2-1 performed better than the three checks of BRRI dhan28, BRRI dhan74 and BRRI dhan84.

RYT for saline tolerant rice in Boro 2019-20

Fifteen genotypes were evaluated in RYT-1 and 14 genotypes in RYT-2 at four different sites of Satkhira and Khulna districts against three checks of BRRI dhan28, BRRI dhan67 and Binadhan-10. All the entries were damaged due to high salinity at Kaliganj site (Table 4). Figure 1 presents the salinity data.

RYT-1. At Koyra and Assasuni, none of the entries performed better than the check varieties. In BRRI farm BR9626-B-2-3-15 (7.45 tha^{-1}) and BR9621-B-2-3-22 (7.14 tha^{-1}) produced significantly higher yield than the check varieties of Binadhan-10 (6.30 tha^{-1}) and BRRI dhan67 (6.14 tha^{-1}) (Table 4).

RYT-2. At Koyra, BR9627-1-3-1-10 (6.60 t ha^{-1}) performed better than the check of BRRI dhan67 (5.88 t ha^{-1}) and BRRI dhan28 (5.13 tha^{-1}), while BR9620-2-7-1-1 (6.02 t ha^{-1}) and BR9156-4-1-7-9 (5.54 t ha^{-1}) gave higher yield than the check of BRRI dhan28 (5.13 tha^{-1}). At Assasuni, IR104002-CMU28-CMU1-CMU3 (5.44 t ha^{-1}) yielded higher than BRRI dhan67 (4.70 tha^{-1}) and BRRI dhan28 (3.91 tha^{-1}). At BRRI farm, BR9620-2-4-1-5 (6.91 tha^{-1}) produced higher yield than all check varieties (Table 4).

Advanced yield trial (AYT) in Boro 2019-20

Sixteen genotypes were evaluated against three checks of BRRI dhan28, BRRI dhan67 and Binadhan-10 in AYT at four different sites of Satkhira and Khulna districts during Boro 2019-20.

At Koyra, BR9625-B-2-4-9 (7.82 t ha^{-1}) produced significantly higher yield than all the check varieties while, IR 96184-24-1-1-AJY2 (6.98 t ha^{-1}) and IR 103854-8-3-AJY 1(6.83 t ha^{-1}) produced higher yield than BRRI dhan67 (6.23 t ha^{-1}). At BRRI farm, BR9625-B-2-4-8 (8.60 t ha^{-1}) and IR 96184-24-1-1-AJY2 (8.12 t ha^{-1}) produced higher yield than all the check varieties.

Advanced line adaptive research trial (ALART) during T. Aman 2019

In T. Aman 2019, three ALARTs were conducted for BIO, zinc enriched rice (ZER) and rainfed lowland rice (RLR) (Table 5). ALART-RLR was destroyed completely due to high rainfall and water logging. In ALART-BIO, none of the entries performed better than the check of BRRI dha87, but all the entries produced higher yield than the check of BRRI dhan71. In ALART-ZER, none of the entries performed better than the check varieties of BRRI dhan87 and BRRI dhan72.

ALART during Boro 2019-20

Five ALARTs for premium quality rice (PQR), zinc enriched rice (ZER), insect resistant rice (IRR), blast resistant rice (BRR) and bacterial blight resistant rice (BBRR) were conducted during Boro 2019-20 at farmers' field in three locations (Jugorajpur, Kamalnagar, Koikhali, Satkhira sadar) of Satkhira district (Table 6). ALART for ZER, IR99285-1-1-1-P2 produced higher yield (7.60 t ha^{-1} in 153 days) than the check variety of BRRI dhan84 (6.57 t ha^{-1} in 139 days). In ALART for BBRR, all the entries except BR(Bio)11447-3-10-7-1 produced higher yield over the check variety of BRRI dhan28 (6.27 t ha^{-1}), while no one performed better than the check variety of BRRI dhan58 (7.31 t ha^{-1}). None of the entries performed better than the respective check in all other ALART experiment.

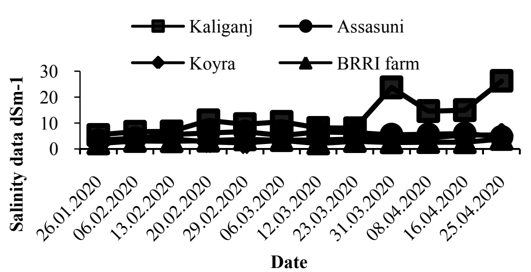

Fig. 1. Water Salinity at Kaliganj, Assasuni, Koyra and BRRI Satkhira during Boro 2019-20.

Table 3. Performance of different entries under RYT at BRRI RS, Satkhira during Boro 2019-20.

Entry/Variety	Plant height (cm)	Growth duration (days)	Yield (t ha^{-1})
	RYT-FBR		
IR100740-89-B-2	90	150	5.79
BR8899-17-1-1-1-1	101	147	7.07
TP30433	92	151	6.51
IR100004-19-B-1	103	147	7.26
IR100722-B-B-B-B-16	96	150	6.64
BR8905-17-2-3-3-1-1	81	150	4.96
TP26717	96	148	6.74
BR8905-17-2-3-3-1-4	93	154	6.39
BR8902-38-7-1-1-1-1	103	150	7.22
TP29654	76	149	6.25
BRRI dhan58 (ck)	96	148	6.94
BRRI dhan81 (ck)	97	140	6.17
BRRI dhan89 (ck)	106	157	7.16
$LSD_{0.05}$	4.27	2.24	0.66
CV (%)	2.70	1.04	6.00
	RYT2-FBR		
BRH11-9-11-4-5B-HR3	90	147	6.16
BRH11-2-1-3-8B	105	154	7.00
BRH11-2-4-9B	102	153	7.54
BRH9-7-4-1B	108	157	6.99
BRH13-2-4-6-4B	91	147	6.35
IR 12A 177	94	152	6.47
BRRI dhan63 (ck)	84	145	6.13
BRRI dhan58 (ck)	100	149	7.02
$LSD_{0.05}$	5.72	2.71	0.57
CV (%)	3.37	1.02	4.86
	RYT-Com		
BRC297-15-1-1-1	101	147	6.43
BRC302-2-1-2-1	106	145	6.02
BRC269-15-1-1-3	89	147	5.60
BRC298-18-2-3	101	149	5.67
BRC302-18-1-2-1	97	147	6.09
BRRI dhan28 (ck)	88	141	6.19
BRRI dhan58 (ck)	99	149	7.10
BRRI dhan81 (ck)	95	141	6.15
$LSD_{0.05}$	4.52	1.66	0.57
CV (%)	2.66	0.65	5.30
	RYT-PQR		
BR9713-3-4-4-6	96	154	5.56
BR8526-38-2-1-HR1	101	155	6.00
LataBalam	98	153	6.39
HabuBalam (RLR)	93	155	6.64
BRRI dhan50 (ck)	87	150	6.00
BRRI dhan63 (ck)	83	145	6.26
BRRI dhan81 (ck)	96	141	6.25
$LSD_{0.05}$	5.34	1.76	0.53
CV (%)	3.22	0.65	4.84
	RYT-ZER		
BR8912-12-6-1-1-1-1	97	152	6.19
IR105837-8-45-1-1	103	154	6.61
IR105837-8-95-2-1	115	153	7.25
BRRI dhan28 (ck)	90	139	6.31
BRRI dhan29 (ck)	98	155	7.09
BRRI dhan74 (ck)	91	144	6.32
BRRI dhan84 (ck)	99	140	6.29
$LSD_{0.05}$	5.34	1.67	0.71
CV (%)	3.01	0.63	6.00
	RYT-IRR		
BR9667-54-2-2-97	114	153	6.34

Table 3. Contined

BR9669-21-2-1-19	103	152	6.56
BR9669-23-3-2-23	113	154	5.83
BR9669-15-3-2-31	100	150	5.35
BR9880-27-4-1-18	107	160	5.84
BR9891-19-2-2-8	102	154	6.31
BR9891-11-2-2-20	103	149	5.25
BR9891-17-2-2-23	90	153	6.44
BR9891-8-2-1-41	109	154	5.76
BR9891-18-1-2-7	95	153	5.91
BRRI dhan58	99	149	6.52
T27A (T.Ck)	123	149	3.39
$LSD_{0.05}$	4.9	2.3	0.5
CV (%)	2.8	0.9	5.1

Table 4. Performance of different saline tolerant entries under RYT at Koyra, Assasuni and BRRI RS, Satkhira during Boro 2019-20.

Entry/Variety	Yield (ton ha^{-1})		
	Koyra	Assasuni	BRRI Farm
		RYT-1	
BR9154-2-7-1-2	4.07	4.64	5.38
BR9156-4-1-7-9	5.47	4.61	7.02
IR92860-33-CMU1-1-CMU2-AJYB	4.69	4.77	5.29
BR9620-4-3-2-2	5.48	5.20	4.50
BR9621-B-2-3-22	5.98	5.30	7.14
BR9625-B-1-4-6	5.66	4.72	6.68
BR9626-B-2-3-15	6.12	5.10	7.45
BR9627-1-3-1-10	5.86	**	6.81
IR 103512-B-AJY 2-2	5.12	4.95	5.31
IR 104002-CMU 28-CMU 1-CMU 3	5.57	4.69	2.59
IR 103854-8-3-AJY 1	5.18	5.81	4.79
IR 103499-B-2-AJY 1	5.13	5.14	6.93
IR89331-32-3-1-3-2-2	*	*	*
IR92860-33-CMU1-1-CMU2-AJYB	5.21	4.64	6.09
IR93915-82-CMU2-2-CMU3-AJYB	*	*	*
BRRI dhan28	4.24	4.00	5.75
BRRI dhan67	5.59	5.33	6.14
Binadhan--10	6.15	5.04	6.30
$LSD_{0.05}$	0.58	NS	0.92
CV (%)	5.02	7.71	7.26
		RYT-2	
BR9620-2-7-1-1	6.02	4.94	6.41
BR9625-4-1-2-8	5.17	4.59	6.23
BR9626-1-2-12	5.30	5.10	5.26
IR 100638-6-CMU 3-CMU 1	5.37	3.19	4.95
IR 96184-24-1-1-AJY2	5.39	3.54	3.45
IR 103512-B-AJY 2-2	5.21	3.92	4.73
IR 104002-CMU 28-CMU 1-CMU 3	4.74	5.44	4.68
IR 103854-8-3-AJY 1	4.98	4.71	4.91
BR9620-2-4-1-5	5.23	4.75	6.91
BR9621-B-1-2-11	4.01	4.39	4.25
BR9621-4-3-2-30	*	*	*
BR9156-4-1-7-9	5.54	4.30	5.95
BR9621-B-2-3-22	4.25	5.36	6.14
BR9627-1-3-1-10	6.60	4.16	6.72
BRRI dhan28 (S. ck)	5.13	3.91	5.03
BRRI dhan67 (R. ck)	5.88	4.70	6.28
Binadhan-10 (R. ck)	6.27	4.79	5.66
$LSD_{0.05}$	0.37	0.69	0.53
CV (%)	3.31	7.29	4.61

*= Germination failed, **= Seedling shortage

Table 5. Performance of different genotypes under ALART during T. Aman 2019

Entry/Variety	PH (cm)	Growth Duration (days)	Grain yield (t ha^{-1})
		ALART-BIO	
BR(Bio)9786-BC_2-161-1-2	113	116	5.67
BR(Bio)9786-BC_2-80-1-1	119	116	4.93*
BRRI dhan71 (ck.)	116	114	3.96*
BRRI dhan87 (ck.)	125	123	5.43
CV (%)	2.48	0.38	8.55
$LSD_{(0.05)}$	5.85	0.88	0.85
		ALART-ZER	
BR8436-7-4-2-3-1	112	114	4.26
BR8442-12-1-3-1-B7	119	124	5.41
IR90210-100-2-3-1-P4	118	115	4.29
BRRI dhan49 (ck.)	102	125	4.52
BRRI dhan72 (ck.)	116	128	5.31
BRRI dhan87 (ck.)	130	125	5.76
CV (%)	2.08	0.45	10.43
$LSD_{(0.05)}$	4.40	1.00	0.93

*= Rat damage

Table 6. Performance of different genotypes under ALART during Boro 2019-20.

Genotype	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
	ALART (PQR)		
BR8862-29-1-5-1-3	103	151	6.77
BR8995-2-5-5-2-1	122	155	6.47
BRRI dhan50 (ck)	91	152	6.73
CV (%)	1.32	0.35	2.53
$LSD_{0.05}$	3.17	1.20	-
	ALART (ZER)		
IR99285-1-1-1-P2	109	153	7.60
BRRI dhan29 (ck)	118	157	7.66
BRRI dhan84 (ck)	123	139	6.57
CV (%)	2.11	0.39	2.06
$LSD_{0.05}$	5.59	1.31	0.34
	ALART (IRR)		
BR8340-5-6-1	115	150	6.70
BRRI dhan58 (ck)	105	148	7.28
* T27A (R. ck)	109	138	6.19
CV (%)	1.64	0.36	1.85
$LSD_{0.05}$	4.06	1.20	0.28
	ALART (BRR)		
HR(Path)-11	149	158	6.64
Path2441	109	155	6.66
BR(Path)12452-BC3-16-19	103	158	6.48
BRRI dhan58 (Std ck)	105	149	7.46
BRRI dhan29 (Std ck)	106	157	7.51
CV (%)	3.38	0.24	2.00
$LSD_{0.05}$	7.28	0.69	0.27
ALART (BBRR)			
BR8938-19-4-3-1-1-P2-HR3	110	141	6.76
BR9651-15-2-1-4	97	143	6.57
BR(Bio)11447-1-28-14-3	99	139	6.61
BR(Bio)11447-3-10-7-1	101	131	6.37
BRRI dhan28 (Sus ck)	95	138	6.27
BRRI dhan58 (Std ck)	100	148	7.31
CV (%)	2.59	0.29	1.73
$LSD_{0.05}$	4.74	0.75	0.20

* BRRI dhan28 was planted instead of T27A (R. Ck) in ALART for IRR as it was not provided from BRRI, Gazipur due to germination failure.

Determination of economic fertilizer rate for popular transplant Aus varieties

Application of 80 kg N ha^{-1} was found optimum dose for higher yield irrespective of variety, where BRRI dhan48 showed some yield advantage under 60 kg N ha^{-1}.

Effect of irrigation management on growth and yield of T. Aus rice cultivation during 2019

An experiment was conducted at BRRI RS farm to determine the best irrigation practice for T. Aus rice cultivation. Irrigation at water level standing below 15 cm from the surface level produced the highest yield for BR26 and BRRI dhan82, while BRRI dhan48 performed better than the others in rainfed condition.

Effect of planting time on growth and yield of popular transplanted Aus varieties

Tested variety of BR26, BRRI dhan48 and BRRI dhan82 produced higher yield transplanted on 10 May and later on the yield level were decreased markedly.

Missing element trial

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 2019 and Boro 2019-20 seasons (Table 7). The yield reduction due to N omission from complete fertilizer was 27% and 50% in T. Aman 2019 and Boro 2019-20 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 (Table 8) and at BRRI RS farm, Satkhira (Table 8) during Boro 2019-20. There was a positive effect of fertilizer sources on the grain yield, although the magnitude varied with varieties and locations. Combination of ash and manure @ 5.0 t ha^{-1} + 70% RF significantly increased rice yield compared to farmer's practice (FP) and RF in both the locations. Application of urea briquette and OCP fertilizer had significant additive effect over FP. There was no significant variation between the varieties at BRRI farm, while, BRRI dhan67 (salinity tolerant) significantly increased rice yield compared to BRRI dhan88 (salinity non-tolerant) at Kaliganj site.

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% and 40 % more of the recommended N dose (124 kg ha^{-1}) significantly increased the grain yield of BRRI dhan67. Figure 2 presents water salinity of the experimental plot.

Table 7. Effect of missing element on grain yield and panicle number of BRRI dhan87 during T. Aman 2019 and BRRI dhan67 in Boro 2019-20.

Treatments	T. Aman 2019			Boro 2019-20		
	Panicle m^{-2}	Grain yield (t ha^{-1})	Yield decrease (%) due to missing nutrient	Panicle m^{-2}	Grain yield (t ha^{-1})	Yield decrease (%) due to missing nutrient
PKSZn (-N)	181	4.30	27	282	3.62	50
NKSZn (-P)	198	5.33	9	323	6.88	6
NPSZn (-K)	218	5.23	11	328	6.76	7
NPKZn (-S)	221	5.22	11	333	7.09	3
NPKS (-Zn)	218	5.31	10	330	6.83	6
NPKSZn	228	5.88	-	346	7.28	-
Control	175	3.95	33	261	3.29	55
CV (%)	44.044	1.107		25.07	0.838	
LSD (0.05)	7.51	7.72		2.79	4.92	

Table 8. Effects of fertilizers sources and varieties on grain yield in Kaliganj and BRRI RS farm, Satkhira during Boro season 2020.

Fertilizer	GY (t/ha) of Kaliganj, Satkhira		GY (/ha) of BRRI farm, Satkhira	
	BRRI dhan67	BRRI dhan88	BRRI dhan67	BRRI dhan88
Farmers' practice	5.28	3.29	5.43	5.03
UDP	5.76	3.81	6.28	5.53
OCP fertilizer	5.60	3.77	6.24	5.24
Recommended fertilizer	5.54	3.57	5.74	5.17
Ash 3 (t ha^{-1}) + 100% NPKSZn	5.72	4.06	6.10	5.80
Ash & Manure (1:1) @ 5.0 t ha^{-1} +70% NPKSZn	5.94	4.39	6.60	6.08
LSD (0.05)	0.697	0.772	0.897	0.663
CV (%)	4.37	7.14	5.22	4.28

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 60% more of the recommended K dose (60 kg ha^{-1}) significantly increased the yield of BRRI dhan67. Figure 2 presents water salinity date of the experimental plot.

Effect of FLORA on rice growth and yield

Application of FLORA (Nitrobenzene) at different rates in combination with chemical fertilizer significantly influenced the growth and yield of BRRI dhan89 at BRRI farm, Satkhira. The highest tiller and panicle number with higher grain yield (6.99 t ha^{-1}) was found in T_1 (RF+ FLORA @ 2 mL/L), which was statistically similar to the recommended fertilizer. However, FLORA application was not economically profitable for rice production.

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI varieties during 2019-20

In Aus 2019, BRRI dhan48 produced the highest yield (5.09 t ha^{-1}), which was statistically similar to BRRI dhan42, BRRI dhan43, BRRI dhan65, BRRI dhan82 and BRRI dhan83. In T. Aman 2019, among the short duration varieties, BRRI dhan87 produced the highest yield (5.70 t ha^{-1}), which was statistically similar to BRRI dhan71, BRRI dhan72 and BRRI hybrid dhan6. Among the medium duration rice varieties, BRRI dhan49, BRRI dhan52, BRRI dhan70, BRRI dhan79 and BRRI dhan80 produced. Among the long duration rice varieties, BR11 produced the highest yield (5.35 t ha^{-1}), which was statistically similar to BR4, BR10, BR23, BRRI dhan30, BRRI dhan44, BRRI dhan76 and BRRI dhan77. However, in Boro 2019-20 season, among the long duration rice varieties BRRI dhan89 produced the highest yield (6.51 t/ha). BRRI hybrid varieties performed better than inbreed varieties, where BRRI hybrid dhan5 produced the highest yield (8.43 t ha^{-1}).

Selection of suitable hybrid rice genotypes under saline prone areas

The experiment was conducted at farmer's field during Boro 2019-20 season in three salinity affected areas namely Assasuni, Debhata and Kaliganj of Satkhira district (Table 10). Six BRRI hybrid rice varieties (BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI hybrid dhan4, BRRI hybrid dhan5, BRRI hybrid dhan6 and BRRI hybrid dhan7) were evaluated against one BRRI inbred (BRRI dhan67) and five other hybrid varieties (Janokraj, Heera, Tejgold, SL-8 and IT).

Both in Assasuni and Debhata sites, BRRI hybrid dhan5 produced the highest yield (8.06-8.40 t ha^{-1}) followed by BRRI hybrid dhan3 (7.19-8.15 t ha^{-1}). In Kaliganj, none of the tested varieties survived due to high salinity. Figure 3 presents water salinity data of different experimental plots.

Table 9. Evaluation of increased nitrogen and potassium rates for Boro rice cultivation in saline areas of Kaliganj during Boro 2019-20.

For N experiment		For K experiment	
Treatment	Grain yield (t ha^{-1})	Treatments	Grain yield (t ha^{-1})
N_{124} (RD)	3.99 bc	K_{60} (RD)	4.41 b
N_{149} (20 % more of RD)	4.28 ab	K_{72} (20 % more of RD)	4.36 b
N_{174} (40 % more of RD)	4.54 a	K_{84} (40 % more of RD)	4.27 b
N_{200} (60 % more of RD)	3.79 c	K_{96} (60 % more of RD)	5.12 a
CV (%)	5.04	CV (%)	4.62

Table 10. Performance of different hybrid rice genotypes under saline prone areas tested at Assasuni, Debhata, Kaliganj, Satkhira during Boro 2019-2020.

Genotype	**Assasuni**			**Dabhata**		
	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})	Plant height (cm)	Growth duration (day)	Yield (t ha^{-1})
BRRI hybrid dhan2	97	142	6.82	84	142	7.46
BRRI hybrid dhan3	100	140	7.19	92	141	8.15
BRRI hybrid dhan4	97	139	5.83	92	141	6.38
BRRI hybrid dhan5	101	141	8.06	94	142	8.40
BRRI hybrid dhan6	101	141	6.74	94	141	7.68
BRRI hybrid dhan7	99	143	5.95	92	145	6.44
Janokraj	101	143	5.90	90	143	6.70
Heera	99	138	6.75	84	139	7.65
Tejgold	98	140	5.71	91	140	6.47
SL-8	98	139	5.53	91	139	6.31
BRRI dhan67	101	143	5.43	104	142	5.94
IT	98	142	5.85	90	143	6.78
CV (%)	2.10	0.33	3.08	1.07	0.24	3.18
$LSD_{0.05}$	-	0.77	0.32	1.66	0.56	0.37

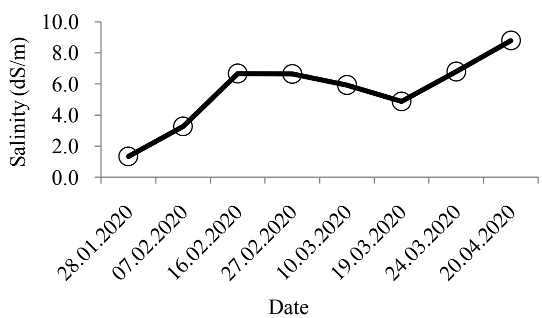

Fig. 2. Water Salinity of experimental plots at Kaliganj during Boro 2019-20.

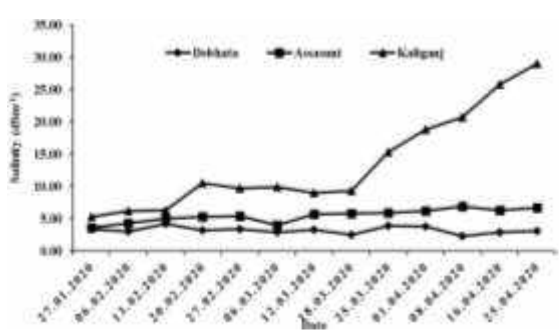

Fig. 3. Soil water salinity of different experimental plots at Assasuni, Debhata and Kaliganj, Satkhira during Boro 2019-20.

Validation of BRRI developed rice varieties

In integrated rice-fish culture, BR10 performed better (5.13 t ha^{-1}) than BRRI dhan73 (4.30 t ha^{-1}), while BR10, BRRI dhan30 and BRRI dhan79 produced similar yield (5.15-5.35 t ha^{-1}) in stagnant water environment.

Head to head trial

The experiment was conducted at Balitha, Khoddobatra, Haroddha and Kaliganj of Satkhira in T. Aman 2019. Irrespective of location, BRRI dhan87 produced the highest yield (6.69 tha^{-1}) followed by BRRI dhan49 (5.83 tha^{-1}).

Seed production and dissemination

A total of 28.11 tons of breeder seed of different Aman and Boro rice varieties were produced and sent to GRS division. In addition, 32.06 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

Fourteen farmers' trainings on rice production technology, quality seed production and preservation were conducted to train up 455 farmers of Satkhira, Khulna and Jashore districts. A total of ten 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

Farming systems research and development activities were initiated under the BARC coordinated sub-project of PBRG, NATP-2 at south western coastal ecosystem of Bishnupur union, Kaliganj, Satkhira.

Existing Boro (BRRI dhan28) - Fallow - T. Aman (BRRI dhan49) cropping pattern was successfully replaced by Mustard (BARI Sharisa-14) - Boro (BRRI dhan81/BRRI dhan86) - T. Aman (BRRI dhan75) cropping pattern. The existing cropping pattern had a REY of 10.42 t ha^{-1}, which was increased by 14.91 t/ha and 13.84 t/ha in the improved patterns respectively. We introduced four crops in cropping pattern (Mustard - Boro - Jute - T. Aman) in the project site and it has increased the REY to 21.47 t ha^{-1}.

In homestead vegetables production, higher yield was obtained from Papaya (729 kg/65 dec.) in homestead areas, while in nearby homestead areas had maximum yield from potato (1840 kg/68 dec.).

Fish polyculture in both ghers and mini ponds increased farm family income and fish consumption. The annual average fish consumption from the mini ponds and ghers were 53 kg and 74 kg respectively. Improvement the productivity of gher system proved highly profitable with inclusion of vegetable production on gher bund.

In poultry system Sonali chicken, Khaki Campbell duck and Turkey rearing under semi scavenging system seems to be a good option to increase farmers' income and family consumption. Cooperative farmers' success to Turkey production encouraged other farmers in the locality for adopting Turkey rearing. Goats reared as easy maintenance livestock component are becoming highly profitable for the farmers. Farmers are selling their goat kids regularly for income generation and improving their livelihood.

Mini orchards of mango, jujube and litchi were established in nearby homestead with integration of vegetables. Fruit tree plantation in households ensured maximum utilization of farm areas.

Based on the support of inputs and technologies of different component, farmers were able to maximized the farm productivity, improved their dietary value as well as developed a pathway for income generation to improve their livelihood.

BRRI RS, Sonagazi

SUMMARY

Regional Yield trials (RYT) were conducted at experimental field of BRRI RS, Sonagazi to test the yield performance of superior breeding lines. A total of 106 breeding lines were tested under this trial during the reporting period from which nine lines were found better than the checks regarding grain yield and yield contributing characters. Breeding lines were supplied from Plant breeding and Biotechnology Divisions. Ten lines along with standard checks BR26, BRRI dhan48 and BRRI dhan82 were tested during Aus from which two advanced lines BR8781-16-10-3B and BR9006-54-1-3-2 were recommended for advanced trial. During T. Aman season two rainfed lowland rice (RLR), one zinc enriched rice (ZER), one high yielding rice (HYV), one drought tolerant Rice (DTR), one disease resistant rice (DRR) were evaluated under on-station condition from which seven RYTs were supplied from Plant Breeding Division and one RYT were supplied from Biotechnology Division. The DRR lines BR10397-4-1-2 were selected for advanced trial. The RLR lines BR9571-13-1-9-1-1 and BR9573-31-1-2-5-1 were selected for advance trial. On the basis of growth duration, yield and yield contributing characters the ZER advanced line BE10001-94-2-B were found better than check variety. No line from DTR and HYV (Biotechnology) were selected for advanced trial during Aman 2019. In Boro 2019-20 favourable Boro rice (FBR) BRC-297-15-1-1-1 and BRH9-7-4-1B and Premium quality rice (PQR) BR8526-38-2-1-HR1 lines were selected for advance trial.

On-farm demonstrations were conducted under SPDP during Aus, Aman and Boro seasons. Number of total demonstrations was 72 and direct beneficiary farmers were about 200 from which 150 tons quality seeds produced and retained by the farmers were about 90 tons. During the reporting period, BRRI regional station Sonagazi produced 15.00 tons of breeder seeds during Aman 2019 and Boro 2019-20 seasons. All the Breeder seeds of different varieties were sent to Genetic Resource and Seed Division, BRRI, Gazipur. A total of 1,529 kg truthfully labeled seeds (TLS) of BRRI dhan48, BRRI dhan82, BRRI dhan83 and BRRI dhan85 were produced during T. Aus and 6,955 kg truthfully labeled seeds (TLS) of BR11, BRRI dhan34, BRRI dhan49, BRRI dhan76, BRRI dhan78 and BRRI dhan82 were produced during T. Aman 2019 seasons. During Boro 2020 a total of 1,000 kg of truthfully labeled seed (TLS) of BRRI dhan28, BRRI dhan29, BRRI dhan67 and BRRI dhan89 were produced. Thirteen farmer's trainings were arranged with the participation of 520 farmers. Twelve field days were arranged in selected demonstration sites at crop maturity stage where nearly 2,650 people participated and shared knowledge about modern rice production technology.

VARIETY DEVELOPMENT

Regional yield trial (RYT): Plant breeding (Aus 2019)

Seven genotypes BR9013-28-2-3, BR8781-16-10-3B, BR9005-53-1-1, BR9006-40-2-3-1, BR 9006-54-1-3-2, BR 8775-23-1-2 and BR8781-16-1-3-2-P2 along with two checks BRRI dhan48 and BRRI dhan82 were tested at BRRI RS, Sonagazi experimental farm, Feni during Aus 2019 with three replications.

The advanced lines BR9013-28-2-3, BR8781-16-10-3B, BR9005-53-1-1, BR9006-40-2-3-1, BR 9006-54-1-3-2, BR 8775-23-1-2 and BR8781-16-1-3-2-P2 produced 4.83, 5.74, 4.39, 5.45, 5.63, 4.43 and 5.45 t ha^{-1}, respectively (Table 1). The advanced lines BR8781-16-10-3B and BR9006-40-2-3-1 produced higher yield than the standard checks. Based on the yield performance the above lines may be recommended for advanced trial.

RYT: Plant breeding during Aus 2019

Three advanced lines BR8490-5-1-4-4, BR9011-62-2-1-2 and BR9011-25-4-1-3 along with standard check BR26 were tested at BRRI RS, Sonagazi farm Feni during Aus 2019 with three replications. The advanced lines BR8490-5-1-4-4, BR9011-62-2-1-2 and BR9011-25-4-1-3 produced grain yield 3.63, 4.23 and 3.93 t ha^{-1}, respectively. Based on the yield performance, none of the tested lines performed better than the standard checks (Table 2).

Table 1. Performance of some breeding lines in regional yield trial (RYT), plant breeding during T. Aus 2019 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR 9013-28-2-3	103	110	4.83
BR8781-16-10-3B	105	113	5.74
BR9005-53-1-1	96	109	4.39
BR9006-40-2-3-1	105	108	5.45
BR 9006-54-1-3-2	95	107	5.63
BR 8775-23-1-2	99	119	4.43
BR8781-16-1-3-2-P2	105	118	5.45
BRRI dhan 48 (ck.)	96	112	5.43
BRRI dhan82 (ck.)	102	107	5.12
$LSD_{0.05}$	2.719	NS	0.395
CV (%)	1.563	NS	4.422

Table 2. Performance of some breeding lines under RYT plant breeding in Aus 2019 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR8490-5-1-4-4	101	114	3.63
BR9011-62-2-1-2	102	119	4.23
BR9011-25-4-1-3	106	115	3.93
BR26 (ck)	105	118	4.12
$LSD_{0.05}$	1.762	NS	0.392
CV (%)	0.848	NS	4.926

RYT: Development of disease resistant rice during T. Aman 2019

Six advanced lines BR10397-4-1-2, BR10390-22-2-1-5, BR10393-2-2-2-3, BR10393-4-1-3-4, BR10393-2-2-2 and BR10395-22-3-5 along with the checks, BRRI dhan49 and BRRI dhan87 were tested at BRRI RS, Sonagazi farm Feni during Aus 2019 with three replications. The advanced lines BR10397-4-1-2 produced 6.49 t/ha grain yield that was higher than the standard check BRRI dhan49 and BRRI dhan87 (Table 3). Based on the yield performance BR10397-4-1-2 may be recommended for advanced trial.

RYT-1: Development of rainfed lowland rice during T. Aman 2019

Seven advanced lines BR9571-2-2-5-2-1, BR9571-28-2-1-2-1, BR9571-4-1-2-2-1, BR9571-4-2-6-1-1, BR9573-28-1-1-1-1, BR9573-28-2-4-1-1 and BR9573-28-2-5-1-1 along with check the BRRI dhan49 and BRRI dhan87 were tested at BRRI RS, Sonagazi farm Feni during T. Aman 2019 with three replications. The advanced lines BR9571-2-2-5-2-1, BR9571-28-2-1-2-1, BR9571-4-1-2-2-1, BR9571-4-2-6-1-1, BR9573-28-1-1-1-1, BR9573-28-2-4-1-1 and BR9573-28-2-5-1-1 produced 5.49, 4.50, 5.01, 4.41, 3.38, 4.81 and 5.34 t/ha grain yield respectively. Based on the yield performance, none of the tested lines performed better than the standard checks (Table 4).

RYT-2: Development of rainfed lowland rice during T. Aman 2019

Seven advanced lines BR9571-13-1-9-1-1, BR9571-28-4-1-2-1, BR9573-31-1-2-5-1, BR9573-36-1-3-2-1, BR-9574-15-3-4-2-1, BR9574-3-3-1-1-1 and BR9574-9-5-3-1-1 along with standard checks BRRI dhan49 and BRRI dhan87 were tested at BRRI RS, Sonagazi farm Feni during T. Aman 2019 with three replications. The advanced lines BR9571-13-1-9-1-1 and BR9573-31-1-2-5-1 produced grain yield 6.22 and 6.41 t ha^{-1} respectively which was higher than what of the standard checks.

Based on the yield performance, these tested lines may be recommended for advanced trial (Table 5).

RYT: Zinc enriched rice (ZER) during T. Aman 2019

Six advanced breeding lines BR7528-28-19-16-RIL-33, BE9871-29-1-3-B, BE7528-2R-19-16-RIL-59, BE10001-94-2-B, BR-9868-19-40-3-B and BR9871-29-1-1-B along with two checks BRRI dhan49 and BRRI dhan72 were tested at BRRI RS, Sonagazi farm, Feni during T. Aman 2019 with three replications. The advanced line BE10001-94-2-B produced yield of 6.12 t/ha that was higher than the standard checks (Table 6). So, this line may be recommended for further trial.

RYT: development of drought tolerant rice during T. Aman 2019

Nine advanced lines IR98777-Gaz-13-1-2-4, IR9880-Gaz-5-1-1-2, IR98816-GAZ-32-1-2, IR98841-GAZ-4-2-1-2, IR988414-GAZ-8-1-1-2, IR98841-AZ-8-1-3-1, IR98849-GAZ-2-2-4-1, IR98929-GAZ-1-2-1-1 and IR98973-GAZ-3-2-5-1along with three standard checks checks BRRI dhan56, BRRI dhan66 and BRRI dhan71 were tested at BRRI RS, Sonagazi farm Feni during T. Aman 2019 with three replications. The advanced lines IR98777-Gaz-13-1-2-4, IR9880-Gaz-5-1-1-2, IR98816-GAZ-32-1-2, IR98841-GAZ-4-2-1-2, IR988414-GAZ-8-1-1-2, IR98841-AZ-8-1-3-1, IR98849-GAZ-2-2-4-1, IR98929-GAZ-1-2-1-1 and IR98973-GAZ-3-2-5-1 produced 4.84, 3.62, 4.75, 4.99, 4.91, 4.83, 4.66, 5.30 and 3.35 t/ha of grain yield respectively.

None of the tested lines performed better than the standard checks (Table 7).

Table 3. Performance of some breeding lines under RYT, development of disease resistant rice during T. Aman 2019 at BRRI regional station, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR10397-4-1-2	100	132	6.49
BR10390-22-2-1-5	100	131	5.21
BR10393-2-2-2-3	109	130	4.62
BR10393-4-1-3-4	113	132	5.64
BR10393-2-2-2	122	130	4.96
BR10395-22-3-5	106	128	4.05
BRRI dhan49 (ck)	99	136	5.63
BRRI dhan87 (ck)	123	129	5.40
$LSD_{0.05}$	1.808	NS	0.427
CV (%)	0.947	NS	4.636

Table 4. Performance of some breeding lines under RYT-1 development of rainfed lowland rice during T. Aman 2019 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9571-2-2-5-2-1	122	130	5.49
BR9571-28-2-1-2-1	123	127	4.50
BR9571-4-1-2-2-1	123	128	5.01
BR9571-4-2-6-1-1	108	124	4.41
BR9573-28-1-1-1-1	122	127	3.38
BR9573-28-2-4-1-1	127	126	4.81
BR9573-28-2-5-1-1	125	128	5.34
BRRI dhan49 (ck)	104	136	5.51
BRRI dhan87 (ck)	123	128	6.20
$LSD_{0.05}$	2.975	NS	0.470
CV (%)	1.437	NS	5.472

Table 5. Performance of some breeding lines under RYT-2, development of rainfed lowland rice in T. Aman 2019 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9571-13-1-9-1-1	122	137	6.22
BR9571-28-4-1-2-1	124	136	4.44
BR9573-31-1-2-5-1	135	135	6.41
BR9573-36-1-3-2-1	120	137	5.34
BR-9574-15-3-4-2-1	116	133	5.55
BR9574-3-3-1-1-1	101	134	4.49
BR9574-9-5-3-1-1	101	132	5.27
BRRI dhan49 (ck)	96	136	5.47
BRRI dhan87 (ck)	121	129	5.61
$LSD_{0.05}$	3.537	NS	0.676
CV (%)	1.775	NS	7.201

Table 6. Performance of some breeding lines under RYT (ZER) during T. Aman 2019 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR7528-28-19-16-RIL-33	138	134	5.44
BE9871-29-1-3-B	98	135	5.01
BE7528-2R-19-16-RIL-59	135	130	5.86
BE10001-94-2-B	123	132	6.12
BR-9868-19-40-3-B	101	135	5.47
BR9871-29-1-1-B	99	133	4.75
BRRI dhan49 (ck)	100	133	5.14
BRRI dhan72 (ck)	117	128	5.56
$LSD_{0.05}$	3.232	0.358	0.401
CV (%)	1.619	0.154	4.217

Table 7. Performance of some breeding lines under (RYT), drought tolerant rice during during T. Aman 2019 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
IR98777-Gaz-13-1-2-4	125	118	4.84
IR9880-Gaz-5-1-1-2	106	120	3.62
IR98816-GAZ-32-1-2	107	122	4.75
IR98841-GAZ-4-2-1-2	106	118	4.99
IR988414-GAZ-8-1-1-2	112	119	4.91
IR98841-AZ-8-1-3-1	115	120	4.83
IR98849-GAZ-2-2-4-1	99	116	4.66
IR98929-GAZ-1-2-1-1	114	117	5.30
IR98973-GAZ-3-2-5-1	114	119	3.35
BRRI dhan56 (ck)	117	112	3.49
BRRI dhan66 (ck)	117	117	4.56
BRRI dhan71 (ck)	110	118	5.22
$LSD_{0.05}$	3.732	2.822	0.459
CV (%)	1.972	1.412	5.968

RYT: high yielding rice, Bio during T. Aman 2019

Three advanced lines BI(Bio)10376-AC4-1-3, BI(Bio)10376-AC9-1-3 and BI(Bio)10376-AC11-1-3 along with the check BRRI dhan71 were tested at BRRI RS, Sonagazi farm Feni during T. Aman 2019 with three replications. The advanced lines BI (Bio) 10376-AC4-1-3, BI (Bio) 10376-AC9-1-3 and BI (Bio) 10376-AC11-1-3 produced grain 3.83, 4.41 and 4.65 t ha^{-1} respectively.

None of the tested lines performed better than the standard checks (Table 8).

RYT: ZER during Boro 2019-20

Three advanced lines BR8912-12-6-1-1-1-1 (7.75 t ha^{-1}), IRI05837-8-45-1-1 (7.50 t ha^{-1}) and IRI05837-8-95-2-1 (5.85 t ha^{-1}) along with four checks BRRI dhan28, BRRI dhan29, BRRI dhan74 and BRRI dhan84 were tested at BRRI RS, Sonagazi farm Feni during Boro 2019-20 with three replications.

None of the tested lines performed better than standard checks (Table 9).

RYT: Favourable Boro rice-Cumilla) in Boro 2019-20

Five advanced lines BRC-297-15-1-1-1, BRC-302-2-1-2-1, BRC-269-15-1-1-3, BRC-298-18-2-3 and BRC-302-18-1-2-1 along with the checks BRRI dhan28, BRRI dhan58 and BRRI dhan81 were tested at BRRI RS, Sonagazi farm Feni during Boro 2019-20 with three replications. The advanced line BRC-297-15-1-1-1 produced 7.44 t/ha grain yield which is higher than that of the standard checks (Table 10).

This advanced line may be recommended for further trial.

RYT-2: Favourable Boro rice, during Boro 2019-20

Six advanced lines BRH11-9-11-4-5B-HR3, BRH11-2-1-3-8B, BRH11-2-4-9B, BRH9-7-4-1B, BRH13-2-4-6-4B and IR 12A177 along with checks BRRI dhan58 and BRRI dhan63 were tested at BRRI RS, Sonagazi farm Feni during Boro 2019-20 with three replications. The advanced line BRH9-7-4-1B produced 7.30 t/ha grain yield which is higher than standard checks (Table 11).

This advanced line may be recommended for further trial.

(RYT: Premium quality rice) during Boro 2019-20

Four advanced lines BR9713-3-4-4-6, BR8526-38-2-1-HR1, Lata Balam and Habu Balam with checks BRRI dhan50, BRRI dhan63 and BRRI dhan81 were tested at BRRI RS, Sonagazi farm Feni during Boro 2019-20 with three replications. The advanced line BR8526-38-2-1-HR1 produced 7.15 t/ha grain yield which is higher than standard checks (Table 12).

This advanced line may be recommended for further trial.

RYT: Favorable Boro Rice) during Boro, 2019-20

Four advanced lines IR1000740-89-B-2, BR8899-17-1-1-1-1-1, TP30433, IR100004-19-B-1, IR100722-B-B-B-B-16, BR8905-17-2-3-3-1-1, TP26717, BR8905-17-2-3-3-1-4, BR8902-38-7-1-1-1-1 and TP29654 along with checks BRRI dhan58, BRRI dhan81 and BRRI dhan89 were tested at BRRI RS, Sonagazi farm Feni during Boro 2019-20 with three replications.

None of the tested lines performed better than standard checks (Table 13).

On-farm evaluation of breeding lines through advanced lines adaptive research trial (ALART)

ALARTs were conducted during T. Aus 2019 in Sonagazi, Feni which had four genotypes including one standard checks BRRI dhan42, BRRI dhan43, BRRI dhan83 and BRRI dhan48 (ck).

Three categories of ALART were conducted during T. Aman 2019 such as, rainfed lowland rice (RLR), zinc enriched rice (ZER) and ALART Biotechnology. The trials were conducted at Fulgazi, Feni.

Five categories of ALARTs were also conducted during Boro 2019-20 season such as PQR, ZER, IRR, BRR and BBRR at Fulgazi, Feni.

All recommended and suggested agronomic management practices were provided in 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. Collected results with reports were submitted to Adaptive Research Division of BRRI HQ, which were analyzed and reported.

Table 8. Performance of some breeding lines under RYT (high yielding rice, Bio) in T. Aman 2019 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BI(Bio)10376-AC4-1-3	96	113	3.83
BI(Bio)10376-AC9-1-3	99	115	4.41
BI(Bio)10376-AC11-1-3	96	119	4.65
BRRI dhan71 (ck)	111	118	4.92
$LSD_{0.05}$	2.558	NS	0.363
CV (%)	1.275	NS	4.078

Table 9. Performance of some breeding lines (RYT-ZER) in Boro 2019-20 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR8912-12-6-1-1-1-1	102	151	7.75
IRI05837-8-45-1-1	91	144	7.50
IRI05837-8-95-2-1	106	151	5.85
BRRI dhan28 (ck)	89	138	6.05
BRRI dhan29 (ck)	96	154	8.01
BRRI dhan74 (ck)	95	143	6.01
BRRI dhan84 (ck)	101	136	5.94
$LSD_{0.05}$	2.835	NS	0.350
CV (%)	1.641	NS	2.922

Table 10. Performance of some breeding lines in regional yield trial (RYT-Favourable Boro rice-Cumilla) during Boro 2019-20 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BRC-297-15-1-1-1	106	148	7.44
BRC-302-2-1-2-1	110	148	6.08
BRC-269-15-1-1-3	101	146	6.54
BRC-298-18-2-3	104	150	5.66
BRC-302-18-1-2-1	120	147	6.85
BRRI dhan28 (ck)	92	140	5.52
BRRI dhan58 (ck)	96	147	7.13
BRRI dhan81 (ck)	97	139	6.33
$LSD_{0.05}$	3.29	NS	0.702
CV (%)	1.82	NS	6.219

Table 11. Performance of some breeding lines in regional yield trial (RYT-2, Favourable Boro rice) during Boro, 2019-20 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BRH11-9-11-4-5B-HR3	91	142	6.53
BRH11-2-1-3-8B	101	151	7.13
BRH11-2-4-9B	96	153	6.40
BRH9-7-4-1B	103	151	7.30
BRH13-2-4-6-4B	92	144	7.16
IR 12A177	95	142	6.92
BRRI dhan63 (ck)	86	141	6.60
BRRI dhan58 (ck)	99	146	7.06
$LSD_{0.05}$	3.766	NS	0.530
CV (%)	2.248	NS	4.390

Table 12. Performance of some breeding lines in regional yield trial (RYT- Premium quality Rice), during Boro, 2019-20 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
BR9713-3-4-4-6	105	153	5.80
BR8526-38-2-1-HR1	103	152	7.15
Lata Balam	97	150	5.68
Habu Balam	88	151	5.56
BRRI dhan50 (ck)	81	151	5.73
BRRI dhan63 (ck)	85	145	6.61
BRRI dhan81 (ck)	97	141	6.34
$LSD_{0.05}$	3.166	NS	0.363
CV (%)	1.899	NS	3.326

Table 13: Performance of some breeding lines in regional yield trial (RYT- Favorable Boro rice), during Boro, 2019-20 at BRRI RS, Sonagazi.

Designation	Plant height (cm)	Growth duration (day)	Grain yield (t ha^{-1})
IR1000740-89-B-2	87	147	8.00
BR8899-17-1-1-1-1-1	Germination failure		
TP30433	89	150	6.94
IR100004-19-B-1	Germination failure		
IR100722-B-B-B-B-16	Germination failure		
BR8905-17-2-3-3-1-1	91	147	7.48
TP26717	96	149	7.13
BR8905-17-2-3-3-1-4	97	151	7.41
BR8902-38-7-1-1-1-1	95	149	7.31
TP29654	91	145	6.95
BRRI dhan58 (ck)	97	148	7.10
BRRI Dhan81 (ck)	Germination failure		
BRRI dhan89 (ck)	97	158	7.82
$LSD_{0.05}$	NS	NS	0.285
CV (%)	5.473	NS	2.242

PEST MANAGEMENT

Survey and monitoring of rice diseases

Survey was carried out at farmers' fields of Laxmipur, Noakhali, Feni, Cox'sbazar, Chattogram and Khagrachari districts both in T. Aman 2019 and Boro 2019-20. Sites were selected with the suggestion and collaboration of Upazila Agricultural Officer (UAO) of Department of Agricultural Extension (DAE). Sub Assistance Agricultural Officer (SAAO) of concern block helped in site selection who were the front line workers and very much familiar to the farmers as well as their fields.

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 different locations due to fluctuation of environmental conditions during Aman season. BRRI dhan28 and BRRI dhan29 were affected moderately by blast during Boro season. Others were also affected in different degrees such as BRRI dhan58, BRRI dhan67 and BRRI dhan81. 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 from July 2019 to June 2020 at the experimental field of BRRI RS, Sonagazi, Feni. The abundance of leaf roller (LR), stem borer (SB), rice bug (RB), green leafhopper (GLH), grasshopper (GH), mole cricket (MC), field cricket (FC), and stink bug (SB) were found in the light trap during the reporting period.

SOCIO-ECONOMIC AND POLICY

Stability analysis of BRRI developed Aus rice varieties

Ten Aus rice varieties were evaluated during Aus 2019 at BRRI RS, Sonagazi farm. Among them, BRRI hybrid dhan48 ranked top in terms of yield (5.34 t ha^{-1}) followed by BRRI dhan82 (4.68 t ha^{-1}). BR21, BRRI dhan24, BRRI dhan65 were found as low yielding varieties and the grain was yield 2.88, 3.22 and 3.27 t ha^{-1} respectively.

Stability analysis of BRRI developed T. Aman rice varieties

Forty-two Aman rice varieties were evaluated during Aman 2019 at BRRI RS, Sonagazi farm. Among them, BRRI hybrid dhan4 ranked top in terms of yield (6.51 t ha^{-1}) followed by BRRI dhan87 (6.48 t ha^{-1}). BR5, BRRI dhan38, BRRI dhan57 were found as low yielding varieties and the yields ranged from 3.05 to 3.53 t ha^{-1}.

Stability analysis of BRRI developed Boro rice varieties

Forty-three Boro varieties were evaluated during Aus 2019 at BRRI RS, Sonagazi farm. Among them, BRRI hybrid dhan5 ranked top in terms of yield (8.37 t ha^{-1}) followed by BRRI hybrid dhan2 (7.93), BRRI dhan92 (7.84 t ha^{-1}) and BRRI dhan74 (7.16 t ha^{-1}). BR2 and BR17 were the low yielding varieties and the grain yield ranged from 3.86 to 4.15 t ha-1.

TECHNOLOGY TRANSFER

Seed production and dissemination program (SPDP) during T. Aus 2019

The demonstrations were conducted in 11 upazilas of six districts (Noakhali, Feni, Chattagram, Rangamati, Bandorban and Khagrachori) during T. Aus 2019. BRRI dhan48, BRRI dhan65, BRRI dhan82 and BRRI dhan83 were used as cultivar in those upazilas considering land suitability and seed availability. The demonstration area of each upzila was 1/2 bighas belonging to more than one farmer. A detailed research programme along with primary and final data sheets were sent to concern upazila agriculture office before conducting the trial. Seeds, fertilizers and signboards were supplied from BRRI, Sonagazi for the demonstrations. Data on growth duration, grain yield, total production, retained seeds, knowledge sharing and motivated farmers were recorded.

The highest grain yield was found in BRRI dhan48 (5.45 t ha^{-1}) at Mirsori upazila of Chattogram district followed by BRRI dhan82, BRRI dhan83 and BRRI dhan65. A total of 9,500 kg seeds produced in demonstrated areas from which 2,825 kg seeds were retained by the farmers for next year cultivation. The knowledge gained farmers were 1,715 and motivated farmers were 1,945 who decided for next year cultivation.

Seed production and dissemination programme (SPDP) during T. Aman 2019

The demonstrations on SPDP were conducted in 16 upazilas of eight districts of jurrisdicted areas of BRRI regional station, Sonagazi during T. Aman season under core program. BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan71, and BRRI dhan87 were used as cultivar in different upazilas considering land suitability, agro-ecology and seed availability. Thirty-nine demonstrations were conducted in 53 farmers' fields having two big has of each variety.

The total seed production of BRRI dhan41, BRRI dhan44, BRRI dhan46, BRRI dhan71 and BRRI dhan87 were 4325 kg, 4066 kg, 2890 kg, 3024 kg and 1420 kg respectively whereas retained seeds were 1512 kg, 1180 kg, 2150 kg, 1285 kg and 551 kg of those varieties respectively.

The demonstrations on SPDP were conducted in three upazilas of three districts of jurrisdicted areas of BRRI RS, Sonagazi during T. Aman season under SPIRA project. BRRI dhan71 and BRRI dhan87 were used as cultivar in those upazilas considering land suitability, agro-ecology and seed availability. The total seed production of BRRI dhan71 and BRRI dhan87 were 5,350 kg and 6,560 kg whereas retained seeds were 3,050 kg and 4,120 kg of those varieties respectively.

Seed production and dissemination programme (SPDP) during Boro season 2019-20

The demonstrations on SPDP were conducted in five upazilas of four districts of jurrisdicted areas of BRRI RS, Sonagazi during Boro season under core programme. BRRI dhan58 and BRRI dhan67 were used as cultivar in different upazilas. A total of 20 demonstrations were conducted in farmers' fields having two bighas of each variety.

The total seed production of different varieties was 25,500 kg and farmers retained 13,450 kg of seeds for next year cultivation and distribution to other interested farmers. The knowledge gained farmers were 8,500 and motivated farmers were 5,500 for different varieties demonstrated in farmers fields.

The demonstrations on SPDP were conducted in three upazilas of three districts (Feni, Laxmipur and Noakhali) of BRRI RS, Sonagazi during Boro 2019-20 season under SPIRA project. BRRI dhan67 and BRRI dhan74 were used as cultivar in those upazilas. The total seed production of BRRI dhan67 and BRRI dhan74 were 15,050 kg and motivated farmers were 2,337 for those varieties demonstrated in farmers fields.

Head to head adaptive trial under TRB project during Aman 2019

Five varietal demonstrations were conducted under four upazilas of Feni (Sonagazi, Fulgazi, Dagonbhuiyan) and Chattagram (Mirsorai) districts during Aman 2019. Five varieties *viz* BRRI dhan49, BRRI dhan71, BRRI dhan75, BRRI dhan80 and BRRI dhan87 were used in this adaptive trial. BRRI dhan87 yielded higher (6.01-6.16 t ha^{-1}) in almost all locations followed by BRRI dhan49 and BRRI dhan71.

Farmer's training

Farmers' trainings were arranged in Noakhali, Feni, Chattagram, Coxes bazar and Rangamati 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. Thirteen farmers trainings on 'Modern Rice production technology' were conducted in five different districts during the reporting period. In every batch of farmers training 40 farmers and 10 DAE field stuffs participated in which they were trained up with rice production technology in different ecosystem especially on tidal submergence, salinity and favourable environment. A total of 520 farmers and DAE staffs were trained during the reporting period.

Field day

Field days were arranged for awareness building and to 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 person (farmers, researchers, extension service providers, local leaders, public representatives and administrative people etc.) were invited in a field day. A total of 12 field days were arranged during Aus, T. Aman and Boro season. Nearly 2,650 progressive farmers, local leaders, DAE field stuff, public representatives and NGO workers participated in those occasions.

ENRICHMENT OF SEED STOCK

Production of truthfully labeled Seed (TLS)

Truthfully labeled seed (TLS) production activities were undertaken at BRRI research field during Aus 2019, Aman 2019 and Boro 2019-20. 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 RS, 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 1,529 kg, 6,955 kg and 1,000 kg respectively.

Production of breeder seed

Nucleus seeds were supplied from BRRI's GRS Division for breeder seed production during Aman and Boro seasons. BR11, BRRI dhan34, BRRI dhan41 and BRRI dhan80 were cultivated during Aman season whereas BRRI dhan28 and BRRI dhan29 during Boro season. Total amount breeder seed produced during Aman and Boro were 8.5 tons and 6.5 tons respectively. All produced seeds were sent to GRS Division of BRRI, Gazipur.

BRRI RS, Kushtia

SUMMARY

During Aus 2019, BR9006-54-1-3-2 showed significant higher yield than the check BRRI dhan82 in RYT and BRRI dhan48 (ck) were comparatively better (4.84 t ha^{-1}) than BRRI dhan42, BRRI dhan43 and BRRI dhan83 in ALART.

A total of eight (8) RYT and three ALART were conducted during the T. Aman 2019. For the development of insect resistant rice, two lines (BR9881-24-2-25 and BR9880-27-4-1-18) were found significantly higher yield than the local and standard checks with no severe insect infestation. BR8887-26-8-2-3 significantly outyielded local and standard checks in RYT of premium quality rice. With very short growth duration (120 days). In ALART zinc enriched rice BR8436-7-4-2-3-1 yielded higher than the standard check but lower than zinc enriched rice BRRI dhan72. In most of the experiments, BRRI dhan87 (were used as standard check) outyielded the tested entries, and in some cases the tested lines/genotypes yielded very near to BRRI dhan87 but failed to perform statistically significant during T. Aman 2019 season in Kushtia region and hopefully it may be the new mega variety for T. Aman season in near future.

In Boro 2019-20 seasons, six RYTs and two ALARTs were conducted where BR8899-17-1-1-1-1-1 out-yielded BRRI dhan81 at same growth duration, BR8905-17-2-3-3-1-1 and BR8902-17-2-3-3-1-4 performed better than BRRI dhan58 and BRRI dhan89 as for long duration varieties in RYT1, FBR trial. The insect resistant lines (BR9891-18-1-2-7, BR9669-23-3-2-23, BR9669-21-2-1-19 and BR9667-54-2-2-97) produced significantly higher yield than all the checks without severe insect infestation. The two tested lines (BRC302-2-1-2-1 and BRC269-15-1-1-3) of RYT, FBR (Cumilla) yielded more than BRRI dhan58 with nine days earlier growth duration.

The performance of the Maize + Potato – T. Aus –T. Aman pattern produced the highest rice equivalent yield (31.56 t ha^{-1}) followed by Mustard + Pumpkin – T. Aus – T. Aman pattern (19.23 t ha^{-1}) which was superior to the existing pattern Maize – Fallow – T. Aman having very low productivity (11.78 t ha^{-1}) recorded in Kushtia. In T. Aman 2019 trial, among 42 varieties the highest yielder was BRRI hybrid dhan6 and among 43 tested varieties the highest yield was obtained from BRRI hybrid dhan3 under stability analysis of BRRI varieties during Boro 2019-20. In the reporting year, 13 batches (420 farmers) of 'farmers training' were organized. 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 2019

Regional yield trial

Among the seven genotypes and two standard checks, BR9006-54-1-3-2 was found as the highest yielder (5.2 t ha^{-1}) with 106 days growth duration (Table 1) which also showed statistically significant yield difference with the check variety BRRI dhan82 (3.47 t ha^{-1}).

ALART of transplant Aus

The mega variety BRRI dhan48 (ck) produced comparatively higher yield (4.84 t ha^{-1}) among all the tested varieties, BRRI dhan42, BRRI dhan43 and BRRI dhan83 (Table 2).

T. AMAN 2019

Regional yield trial (RYT-1) Biotech.

All genotypes BR (Bio) 10376-AC-1-3, BR (Bio) 10376-AC-9-1-3 and BR (Bio) 10376-AC-11-3-1 were 2-7 days earlier than BRRI dhan71 (ck.) but not outyielded the checks (Table 3).

Regional yield trial, BB, RTV and blast resistant lines (RYT-2)

The standard check variety BRRI dhan87 performed better (5.26 t ha^{-1}) than all the tested lines (Table 4). But only the genotypes BR10397-4-1-2 yielded 5.12 t ha^{-1} that is very near to BRRI dhan87 with higher grains per panicle. However, no disease infection was found in any of the lines but the yield was not found satisfactory either rice tungro virus (RTV) or blast resistant lines.

RYT: Insect resistant rice (IRR)

Among the tested genotypes, BR9881-24-2-25 and BR9880-27-4-1-18 yielded almost similar 5.13 t ha^{-1} and 5.10 t ha^{-1} respectively (Table 5). The yields of these two lines were significantly higher than all the local and standard checks. No severe infestation of insects was found in the trial plots.

Table 1. Performance of some Aus advance lines in RYT Aus, 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Yield (t ha^{-1})
BR9013-28-2-3	106	115.40	290	22.77	4.28
BR8781-16-10-3B	106	119.20	254	20.53	4.55
BR9005-53-1-1	105	120.67	335	18.75	5.05
BR9006-40-2-3-1	106	114.60	283	23.31	4.02
BR9006-54-1-3-2	106	102.93	389	19.19	5.20
BR8775-23-1-2	116	109.87	233	26.71	2.30
BR8781-16-1-3-2-P2	116	115.53	245	27.10	3.27
BRRI dhan48 (ck)	106	109.07	333	22.83	4.57
BRRI dhan82 (ck)	102	126.27	299	22.41	3.47
$LSD_{0.05}$	1.09	6.94	34.11	1.51	0.76
CV (%)	0.6	3.6	6.7	3.9	10.8

DS- 21 Apr 2019 DT- 11 May 2019

Table 2. Performance of some broadcast Aus rice varieties in ALART, T. Aus 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Yield (t ha^{-1})
BRRI dhan42	106	115.07	360	21.75	4.08
BRRI dhan43	112	110.33	351	20.52	4.09
BRRI dhan83	118	121.17	299	20.17	3.52
BRRI dhan48 (ck)	112	105.53	345	22.65	4.84
$LSD_{0.05}$	NS	5.2	26.08	NS	0.35
CV (%)	-	2.30	3.86	7.31	4.23

DS- 21 Arp 2019 DT- 16 May 2019

Table 3. Performance of some advanced breeding lines in (RYT-1) Biotech, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Yield (t ha^{-1})
BR (Bio)10376-AC-1-3	111	91.80	219	27.41	3.33
BR (Bio)10376-AC-9-1-3	113	93.13	242	26.89	3.85
BR (Bio) 10376-AC-11-3-1	116	95.20	238	24.93	3.19
BRRI dhan71 (ck)	118	122.13	200	24.42	4.62
$LSD_{0.05}$	1.15	4.35	39.8	1.97	0.61
CV (%)	0.50	2.20	8.9	3.80	8.10

DS-7 Jul 2019 DT- 2 Aug 2019

Table 4. Performance of some disease resistant (BB, RTV and Blast) lines in RYT, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Yield (t ha^{-1})
BR10397-4-1-2	132	105.13	251	19.84	5.12
BR10390-22-2-1-5	131	105.93	282	25.19	4.09
BR10393-2-2-2-3 (RTV)	132	116.53	219	28.74	4.10
BR10393-4-1-3-4 (RTV)	130	118.20	228	29.51	4.28
BR10393-2-2-2 (RTV)	131	125.20	213	27.63	4.07
BR10395-22-3-5 (Blast)	129	114.20	243	29.08	3.79
BRRI dhan49 (Std. ck)	133	104.47	269	20.66	4.49
BRRI dhan87 (Std. ck)	130	123.40	223	25.14	5.26
$LSD_{0.05}$	1.37	5.02	39.14	0.96	0.68
CV (%)	0.60	2.50	9.4	2.10	8.80

DS- 4 Jul 2019 DT- 25 Jul 2019

Table 5. Performance of insect resistant rice (IRR) lines in RYT, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Yield (t ha^{-1})
BR9880-40-1-3-34	132	99.87	239	19.76	4.75
BR9880-45-2-2-38	134	95.80	270	20.28	4.20
BR9881-1-4-2-16	133	98.67	262	19.53	4.94
BR9881-17-2-2-22	133	99.80	260	19.70	4.39
BR9881-24-2-25	134	101.53	288	19.43	5.13
BR9880-27-4-1-18	129	112.73	218	24.70	5.10
BR9880-2-2-2-1	130	107.27	227	23.41	4.61
BR9887-17-2-2-22	122	117.93	206	21.76	4.01
BR9888-1-2-2-5	124	124.13	18/9	23.09	4.48
BR-10035-6-2-5	117	106.73	149	22.43	3.90
BR10039-13-3-4	127	114.93	207	24.94	3.76
Swarna (Local)	135	92.40	248	18.41	3.70
BRRI dhan33 (ck)	144	101.67	152	24.70	3.10
T27A (Local ck)	119	137.67	174	23.98	2.63
$HSD_{0.05}$	1.06	9.52	43.48	2.28	1.03
CV (%)	0.5	5.3	11.7	6.2	14.7

DS- 4 Jul 2019 DT- 23 Jul 2019

Regional yield trial, Rainfed lowland rice (RLR-1)
All the tested lines yielded lower than the check variety BRRI dhan87 (4.98 t ha^{-1}) (Table 6). BR9571-4-1-2-2-1 and BR9573-28-2-5-1-1 produced higher yield (4.69 and 4.54 t ha^{-1} respectively) than BRRI dhan49 (ck.) but that was not significant.

Regional yield trial, rainfed lowland rice (RLR-2)
It was observed from the trial that one of the tested lines BR9574-15-3-4-2-1 produced significantly higher yield (4.06 t ha^{-1}) than check BRRI dhan87 (3.77 t ha^{-1}) (Table 7). But all genotypes appeared with a longer growth duration than both the checks.

Regional yield trial, drought tolerant rice (DTR)
None of the tested lines performed significantly higher than the checks BRRI dhan66 and BRRI dhan71 (Table 8). IR98816-GAZ-3-2-1-2 showed slightly higher yield (4.08 t ha^{-1}) than BRRI dhan56 (3.86 t ha^{-1}).

Regional yield trial, zinc enriched rice (ZER)
Among the tested lines, BR7528-2R-19-16-RIL-33 yielded slightly higher (4.65 t ha^{-1}) than the check varieties BRRI dhan49 and BRRI dhan72 (4.32 t ha^{-1} and 4.62 t ha^{-1}) (Table 9). However, none of the advanced lines yielded significantly higher than the checks.

Regional yield trial, premium quality rice (PQR)
Among seven genotypes BR8887-26-8-2-3 significantly outyielded (4.86 t ha^{-1}) local and the standard checks (Table 10) with a short growth duration (120 days).

Advanced line adaptive research trial (ALART) Biotechnology
Emerging mega variety BRRI dhan87 (ck) outyielded (5.41 t ha^{-1}) both of the tested lines (Table 11). BR (Bio) 9786-BC2-161-1-2 yielded (5.25 t ha^{-1}) very near to BRRI dhan87 but failed to perform statistically significant.

ALART rainfed lowland rice (RLR)
None of the tested lines yielded higher than BRRI dhan87 (ck.) (4.91 t ha^{-1}) (Table 12). But BR8521-30-3-1 and BR8441-38-1-2-2 yielded higher (4.28 and 4.41 t ha^{-1}) than BRRI dhan49.

ALART zinc enriched rice (ZER)
BR8436-7-4-2-3-1 yielded higher (4.9 t ha^{-1}) than the check BRRI dhan49 and BRRI dhan87 (4.52 and 4.5 t ha^{-1}) but lower than zinc rice BRRI dhan72 (5.07 t ha^{-1}) (Table 13).

BORO 2019-20
Regional yield trial 1, favorable Boro rice (FBR)
BR8899-17-1-1-1-1-1 out-yielded (8.0 t ha^{-1}) the check variety BRRI dhan81 (7.0 t ha^{-1}) with same

growth duration (Table 14). However, BR8905-17-2-3-3-1-1 and BR8902-17-2-3-3-1-4 performed (8.5 & 8.8 t ha^{-1}) better than BRRI dhan58 & BRRI dhan89 (long duration varieties).

RYT: 2 Favourable Boro rice (FBR)

It was observed from the RYT2, the two checks (BRRI dhan63 and BRRI dhan58) performed well and none of the tested lines showed significant difference over the checks (Table 15).

RYT: Insect resistant rice (IRR)

Among the tested lines BR9891-18-1-2-7 was found highest yielder (7.5 t/ha) over the checks and others genotypes. The yield of BR9669-23-3-2-23, BR9669-21-2-1-19 and BR9667-54-2-2-97 were significantly higher than the checks (Table 16) and the growth duration was similar as check BRRI dhan58. No severe infestation of insects was found in the trial plots.

RYT: Premium quality rice (PQR)

Among the tested genotypes, BR8526-38-2-1-HR1 was the highest yielder (8.9 t ha^{-1}) with growth duration than the check varieties (Table 17).

RYT: Zinc enriched rice (ZER)

Among the tested lines BR8912-12-6-1-1-1-1 yielded higher (7.4 t ha^{-1}) than all of check varieties and the growth duration was recorded between BRRI dhan29 and BRRI Dhan74. None of the genotypes showed significant yield difference than the checks (Table 18).

RYT: Favorable Boro rice Cumilla (FBR)

It was observed from the trial that two of the tested lines (BRC302-2-1-2-1 and BRC269-15-1-1-3) performed better than all the checks and growth duration of the lines were same as BRRI dhan81 and shorter than BRRI dhan28 and BRRI dhan58 (Table 19).

ALART premium quality rice (PQR)

Table 20 shows that none of the premium genotypes yielded higher than the popular variety of BRRI dhan50 (ck) (5.3 t ha^{-1}). BR8995-2-5-5-2-1 showed very irregular flowering as well as at maturity. Grain type of BR8862-29-1-5-1-3 and BR8995-2-5-5-2-1 was slender and fine respectively.

ALART zinc enriched rice (ZER)

The tested line IR99285-1-1-1-P2 yielded higher (7.33 t ha^{-1}) than the check BRRI dhan84 (6.60 t ha^{-1}) (Table 21). But the highest yielder in the trial was the check BRRI dhan29 (8.23 t ha^{-1}). Grain quality of the line was medium slender with uniform flowering and maturity. Due to its long growth duration acceptability of the line in Kushtia region was very poor.

Table 6. Performance of some rainfed lowland rice (RLR-1) lines, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	1000 grain wt. (g)	Yield (t ha^{-1})
BR9571-2-2-5-2-1	129	121	222	14.6	3.47
BR9571-2-8-2-1-2-1	130	124	217	17.24	4.16
BR9571-4-1-2-2-1	130	123	235	19.01	4.69
BR9571-4-2-6-1-1	125	112	220	19.08	3.62
BR9573-28-1-1-1-1	120	122	216	17.50	3.31
BR9573-28-2-4-1-1	120	122	206	18.81	3.33
BR9573-28-2-5-1-1	128	121	252	19.54	4.54
BRRI dhan49 (ck)	130	100	266	19.31	4.16
BRRI dhan87 (ck)	124	126	214	25.02	4.98
$LSD_{0.05}$	1.15	6.94	40.96	2.47	0.67
CV (%)	0.5	3.4	10.4	7.6	9.7

DS- 7 Jul 2019 DT- 1 Aug 2019

Table 7. Performance of some rainfed lowland rice (RLR-2) lines, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR9571-13-1-9-8-1	138	110.87	277	16.25	3.31
BR9571-28-4-1-2-1	138	110	226	18.96	2.32
BR9573-31-1-2-5-1	139	122.27	202	18.42	3.63
BR9573-36-1-3-2-1	143	112.27	226	14.35	3.47
BR9574-15-3-4-2-1	142	106.80	250	22.20	4.06
BR9574-3-3-1-1-1	132	95.93	254	19.94	3.02
BR9574-9-5-3-1-1	135	103.60	246	21.68	3.75
BRRI dhan49 (ck)	133	98.00	252	22.23	3.98
BRRI dhan87 (ck)	129	115.47	223	25.28	3.77
$LSD_{0.05}$	0.46	7.92	29.71	4.04	0.22
CV (%)	0.2	4.2	7.1	11.7	3.6

DS- 7 Jul 2019 TGW: Thousand grain weight DT- 6 Aug 2019

Table 8. Performance of some drought tolerant rice (DTR) lines, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
IR98777-GAZ-13-1-2-4	118	120.20	226	23.05	3.67
IR9880-GAZ-3-2-1-2	119	101.47	227	25.57	3.67
IR98816-GAZ-3-2-1-2	117	114.60	211	25.92	4.08
IR98841-GAZ-4-2-1-2	118	108.67	219	22.33	3.79
IR98841-GAZ-8-1-3-1	118	111.33	198	22.24	3.33
IR98841-GAZ-8-1-3-1	120	114.93	242	22.82	3.69
IR98849-GAZ-2-2-4-1	113	96.93	222	24.30	3.26
IR98929-GAZ-1-2-1-1	123	112.93	228	23.83	3.97
IR98973-GAZ-3-2-5-1	114	111.20	191	27.83	3.06
BRRI Dhan56 (ck)	113	1178.33	241	22.66	3.86
BRRI Dhan66 (ck)	116	116.80	205	24.83	4.20
BRRI Dhan71 (ck)	119	124.80	199	24.43	4.60
$LSD_{0.05}$	2.66	8.58	37.32	2.96	0.46
CV (%)	1.30	4.50	10.10	7.20	7.30

DS- 13 Jul 2018 TGW: Thousand grain weight DT- 5 Aug 2018

Table 9. Performance of some zinc enriched rice (ZER) lines, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR7528-2R-19-16-RIL-33	137	132.00	238	23.47	4.65
BR9871-29-1-3-B	128	93.20	313	19.97	4.09
BR7528-2R-19-16-RIL-59	135	112.40	220	21.90	4.02
BR10001-94-2-B	132	115.87	178	32.14	4.04
BR9868-29-40-3-B	129	92.87	266	19.79	4.17
BR9871-29-1-1-B	128	94.00	272	19.78	4.12
BRRI dhan49 (ck)	127	93.33	282	19.95	4.32
BRRI dhan72 (ck)	128	108.47	216	29.45	4.62
$LSD_{0.05}$	0.24	19.40	46.52	0.91	0.51
CV (%)	-	10.5	10.7	2.2	6.8

D/S- 13 Jul 2018 TGW: Thousand grain weight D/T- 7 Aug 2018

Table 10. Performance of some premium quality rice (PQR) lines, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR9126-15-3-4-1	124	100.40	271	9.07	3.64
BR9126-15-3-4-2	124	104.47	246	10.10	3.53
BR8887-26-8-2-3	120	125.33	237	15.46	4.86
BR9178-7-2-4-4	139	134.67	243	14.11	3.72
BR8528-2-2-3-HR1	122	117.00	196	19.18	4.54
BR8528-2-2-3-HR2	119	118.07	214	17.72	4.69
BR8882-30-2-5-2	126	120.60	272	14.75	4.27
Kataribhog (L. ck)	132	156.40	245	13.85	2.91
Dinajpur Kataribhog (Local ck)	133	153.47	240	11.98	2.73
BRRI Dhan37 (ck)	139	142.07	239	12.76	3.14
$LSD_{0.05}$	0.85	4.85	33.57	2.15	0.96
CV (%)	0.40	2.2	8.10	9.0	14.8

DS- 16 Jul 2018 TGW: Thousand grain weight DT- 7 Aug 2018

Table 11. Performance of some advanced genotypes (Bio.) in ALART, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grain/Panicle	Yield (t ha^{-1})
BR(Bio)9786-BC2-161-1-2	117	103.92	330	103	5.25
BR(Bio)9786-BC2-80-1-1	118	109.17	335	88	4.73
BRRI dhan71 (ck)	113	121.56	255	70	4.87
BRRI dhan87 (ck)	119	117.61	337	92	5.41
$LSD_{0.05}$	7.76	3.82	55.72	12.60	0.38
CV (%)	2.5	1.7	13.0	7.2	3.8

DS- 13 Jul 2019 DT- 8 Aug 2019

Table 12. Performance of some advanced rainfed lowland rice (RLR) genotypes in ALART, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grain/Panicle	Yield (t ha^{-1})
BR8521-30-3-1	125	107.53	359	123	4.28
BR8441-38-1-2-2	125	106.56	346	99	4.41
BR8526-38-3-2-1-HR2	126	110.58	340	80	3.37
BR8526-38-3-2-1-HR8	127	100.11	349	86	4.14
BRRI dhan49 (ck)	128	89.86	370	100	4.17
BRRI dhan87 (ck)	122	108.17	318	94	4.91
$LSD_{0.05}$	0.57	9.09	43.03	42.80	0.47
CV(%)	0	4.8	7.8	24.3	6.1

DS- 16 Jul 2019 DT- 8 Aug 2019

Table 13. Performance of some advanced zinc enriched rice (ZER) genotypes in ALART, T. Aman 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grains/Panicle	Yield (t ha^{-1})
V1=BR8436-7-4-2-3-1	121	95.97	204	77.33	4.90
V2=BR8442-12-1-3-1-B7	126	99.39	337	81.33	4.03
V3=IR90210-100-2-3-1-P4	118	103.06	250	70.0	3.88
V4=BRRI dhan49 (Ck)	127	90.86	333	101.0	4.52
V5=BRRI dhan72 (Ck	125	106.14	276	81.33	5.07
V6=BRRI dhan87 (Ck)	121	107.03	310	72.67	4.50
$LSD_{0.05}$	1.22	5.75	34.35	21.56	0.42
CV(%)	0.5	3.2	6.6	14.7	5.2

DS- 16 Jul 2019 DT- 8 Aug 2019

Table 14. Performance of some favorable boro (FBR) lines in RYT1, Breeding, Boro 2019-20.

Variety/ Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
IR100740-89-B-2	158	82.5	307	23.7	7.7
BR8899-17-1-1-1-1-1	153	71.4	239	26.4	8.0
TP30433	164	87.3	254	24.6	8.3
IR10004-19-B-1	148	85.6	250	22.7	5.6
IR100722-B-B-B-B16	157	84.9	300	23.8	7.3
BR8905-17-2-3-3-1-1	156	70.6	317	21.4	6.1
TP26717	156	85.2	322	17.7	7.6
BR8905-17-2-3-3-1-1	167	88.5	325	22.8	8.5
BR8902-17-2-3-3-1-4	164	95.9	313	22.6	8.8
TP29654	154	72.5	278	21.6	7.6
BRRI dhan58 (ck)	163	89.9	319	21.6	8.2
BRRI dhan81 (ck)	149	87.5	311	23.3	7.0
BRRI dhan89 (ck)	169	94.1	281	24.4	8.5
CV (%)	4.11	9.67	10.21	9.19	12.35
LSD (0.05)	4.66	5.83	21.45	1.50	0.67

DS- 28 Nov 2019 TGW: Thousand grain weight DT- 18 Jan 2020

Table 15. Performance of some favorable Boro (FBR) lines in RYT2, Breeding, Boro 2019-20.

Variety/ Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BRH11-9-11-4-5B-HR3	150	90.7	248	16.5	6.4
BRH11-2-1-3-8B	163	103.8	218	24.4	6.0
BRH11-2-4-9B	160	97.3	260	25.5	6.9
BRH9-7-4-1B	162	100.9	200	23.9	5.9
BRH13-2-4-6-4B	159	88.3	274	17.1	6.4
IR2A177	162	86.4	335	23.3	5.6
BRRI dhan63 (ck)	151	78.6	336	22.0	6.0
BRRI dhan58 (ck)	159	94.9	310	22.6	7.0
CV (%)	3.12	8.92	18.74	15.18	7.88
LSD (0.05)	4.50	7.53	46.61	3.04	0.45

DS- 7 Dec 2019 TGW: Thousand grain weight DT- 28 Jan 2020

Table 16. Performance of some insect resistant rice (IRR) in RYT, Boro 2019-20.

Variety/ Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR9667-54-2-2-97	167	108.1	366	23.2	7.1
BR9669-21-2-1-19	165	106.1	330	19.5	7.2
BR9669-23-3-2-23	167	110.5	297	24.0	7.3
BR9669-15-3-2-31	166	100.7	298	23.6	6.9
BR9880-27-4-1-18	167	103.7	341	25.7	6.0
BR9891-19-2-2-8	164	91.5	394	22.6	6.2
BR9891-11-2-2-20	167	90.6	370	21.6	6.8
BR9891-17-22-23	167	103.7	341	25.7	6.0
BR9891-8-2-1-41	164	96.1	344	19.9	6.8
BR9891-18-1-2-7	171	102.5	351	21.2	7.5
BRRI dhan58 (ck)	165	94.9	310	21.9	6.6
CV (%)	1.20	6.61	8.92	9.13	7.54
LSD (0.05)	1.55	5.18	23.62	1.61	0.40

DS- 28 Nov 2019 TGW: Thousand grain weight DT- 26 Jan 2020

Table 17. Performance of some premium quality rice (PQR) lines, Boro 2019-20.

Variety/ Line	Growth Duration (Days)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR9713-3-4-4-6	167	92.3	255.0	27.8	7.9
BR8526-38-2-1-HR1	168	92.2	306.3	15.5	8.9
Lata Balam	163	90.3	288.7	26.5	7.9
Habu Balam	166	84.4	317.7	15.2	7.8
BRRI dhan50 (ck)	163	72.7	408.3	16.2	7.7
BRRI dhan63 (ck)	159	77.0	401.0	20.7	8.7
BRRI dhan81 (ck)	149	81.9	290.3	22.0	7.5
CV (%)	3.98	9.12	18.06	25.37	6.85
LSD (0.05)	6.29	7.51	57.05	5.09	0.54

DS- 28 Nov 2019 TGW: Thousand grain weight DT- 16 Jan 2020

Table 18. Performance of some zinc enriched rice (ZER) lines, Boro 2019.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR8912-12-6-1-1-1-1	166	88.80	376	20.79	7.41
IR105837-8-45-1-1	164	84.13	349	20.84	6.81
IR105837-8-95-2-1	165	88.53	296	21.79	6.16
BRRI dhan28 (Ck)	156	81.93	368	18.47	6.17
BRRI dhan29 (Ck)	168	91.93	368	22.81	7.23
BRRI dhan74 (Ck)	161	81.27	328	23.80	6.83
BRRI dhan84 (Ck)	156	87.33	347	19.95	6.96
$HSD_{0.05}$	NS	NS	72.60	NS	NS
CV(%)	-	4.63	7.32	10.15	8.74

DS- 28 Nov 2019 TGW: Thousand grain weight DT- 20 Jan 2020

Table 19. Performance of some favourable Boro rice (FBR) Cumilla (FBR) in RYT, Boro 2019-20.

Variety/ Line	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BRC297-15-1-1-1	150	93.1	324.0	21.5	6.6
BRC302-2-1-2-1	150	103.0	280.3	23.3	7.0
BRC269-15-1-1-3	157	94.7	319.0	25.9	7.1
BRC298-18-2-3	163	106.9	262.7	21.6	5.7
BRC302-18-1-2-1	159	103.9	288.3	24.6	6.6
BRRI dhan28 (ck)	157	93.1	309.0	22.0	6.6
BRRI dhan58 (ck)	159	93.9	283.7	22.2	7.0
BRRI dhan81 (ck)	149	89.1	272.7	20.9	6.5
CV (%)	3.34	6.62	7.64	7.63	6.61
LSD (0.05)	4.73	5.87	20.38	1.58	0.40

DS- 7 Dec 2019 TGW: Thousand grain weight DT- 29 Jan 2020

Table 20. Performance of some advanced premium quality rice genotypes in ALART, Boro 2019-20.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	TGW (g)	Yield (t ha^{-1})
BR8862-29-1-5-1-3	166	91.00	373	23.68	4.6
BR8995-2-5-5-2-1	169	88.33	385	26.40	4.1
BRRI dhan50 (ck)	165	88.67	406	19.86	5.3
$LSD_{0.05}$	NS	NS	NS	NS	0.6
CV (%)	-	1.88	10.2	9.53	5.25

DS- 4 Dec 2019 TGW: Thousand grain weight DT- 22 Jan 2020

Table 21. Performance of some advanced zinc enriched Rice genotypes in ALART, Boro 2019-20.

Designation	Growth duration (day)	Plant height (cm)	Panicle/m^2	Grain/Panicle	TGW (g)	Yield (t ha^{-1})
IR99285-1-1-1-P2	168	87.67	395	70	24.64	7.33
BRRI dhan29 (ck)	166	103.33	352	88	22.71	8.23
BRRI dhan84 (ck)	156	72.33	440	86	23.71	6.60
$LSD_{0.05}$	NS	4.5	NS	NS	NS	0.9
CV (%)	-	2.26	7.61	10.16	3.18	5.38

D/S- 4 Dec 2019 TGW: Thousand grain weight DT- 22 Jan 2020

CROP-SOIL-WATER MANAGEMENT

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

Among the tested treatments, continuous standing water was found the highest yielder (7.01 t/ha) with 168 days growth duration which showed statistically significant yield difference with AWD condition (15 cm) and simulated irrigation schedule by CROPWAT Model (Table 22).

RICE FARMING SYSTEMS

Validation of high intensity cropping pattern for Kushtia

A study was undertaken in Kushtia during 2018-19 for validation of high intensity cropping pattern to increase the system productivity and income of the farmers through introduction of highly intensified improved cropping patterns. Maize + Potato – T. Aus –T. Aman and Mustard + Pumpkin – T. Aus – T. Aman pattern were introduced against existing Maize – Fallow – T. Aman cropping pattern. Selected cropping patterns were improved through replacing existing low yielding varieties by modern varieties. High yielding variety BRRI dhan71 (T. Aman), Maize (Kaveri), BARI alu-8, BARI sarisha-14, Pumpkin (Thai hybrid-2) was introduced. Maize + Potato – T. Aus –T. Aman pattern produced highest rice equivalent yield (31.56 t ha^{-1}) which was followed by Mustard + Pumpkin – T. Aus – T. Aman pattern (19.23 t ha^{-1}) (Table 23). From the existing pattern Maize – Fallow – T. Aman very low productivity (11.78 t ha^{-1}) was recorded.

SOCIO-ECONOMICS AND POLICY

Stability analysis of BRRI varieties

In T. Aman 2019, among 42 varieties the highest yielder was BRRI hybrid dhan6 (5.8 t ha^{-1}) followed by BRRI dhan87 (5.49 t ha^{-1}) the lowest was BRRI dhan62 (1.71 t ha^{-1}). Lodging was observed at different magnitudes (20%-35%) in case of six varieties namely BR5, BR25, BRRI dhan34, BRRI dhan37 and BRRI dhan38 (Table 24).

In Boro 2019-2020, among 43 tested varieties the highest yield was obtained by BRRI Hybrid dhan3 (8.08 t ha^{-1}) and the lowest by BR17 (4.41 t ha^{-1}). None of the varieties showed lodging during Boro season (Table 25).

TECHNOLOGY TRANSFER

In the reporting year, 13 batches of farmers' training programmes were organized in which 420 farmers participated. Modern rice varieties and relevant technologies were disseminated through field demonstration and seven field days in which more than 700 farmers participated. A total of 36 demonstrations of the BRRI released HYVs were conducted under GoB, SPIRA, Entomology and TRB projects in the farmers field in Kushtia, Chuadanga, Meherpur and Jhenaidah districts. The varieties included 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.

Table 22. Performance of yield in relation to various treatments.

Variety	Treatment	Duration (day)	Yield (t ha^{-1})
BRRI dhan58	T1: Continuous standing water	168	7.01
BRRI dhan58	T2: AWD condition (15 cm)	169	6.40
BRRI dhan58	T3: Simulated irrigation schedule by CROPWAT Model	171	6.08
$LSD_{0.05}$		1.75	0.86
CV(%)		0.6	7.63

DS: 1 Dec 2019 DT: 15 Jan 2020

Table 23. Performance of improved cropping pattern over existing pattern at Kushtia sadar.

Cropping pattern	Yield ($t\ ha^{-1}$)				REY ($t\ ha^{-1}$)
	T. Aman	Maize+Potato	Mustard + Pumpkin	T. Aus	
Maize+Potato - T. *Aus* – T. *Aman*	4.28	10.7+19.8	-	3.28	31.56
Mustard + Pumpkin – T. *Aus* – T. *Aman*	4.14	-	1.2+21.9	3.29	19.23
Maize – Fallow – T. *Aman*	3.88	9.3	-	-	11.78

Table 24. Stability analysis of BRRI varieties, T. Aman 2019.

Variety	Growth duration (day)	Standard growth duration (day)	Yield ($t\ ha^{-1}$)	Standard Yield ($t\ ha^{-1}$)	Rank
BR3	127	145	3.44	4.0	38
BR4	136	145	5.00	5.0	12
BR5	144	150	3.48	3.0	37
BR10	139	150	4.60	5.5	20
BR11	131	145	3.90	5.5	31
BR22	150	150	4.52	5.0	22
BR23	150	150	4.27	5.5	28
BR25	130	135	5.06	4.5	9
BRRI dhan30	133	145	4.84	5.0	16
BRRI dhan31	131	140	5.03	5.0	11
BRRI dhan32	125	130	5.04	5.0	10
BRRI dhan33	107	118	3.89	4.5	32
BRRI dhan34	139	135	2.95	3.5	40
BRRI dhan37	143	140	3.40	3.5	39
BRRI dhan38	142	140	2.87	3.5	41
BRRI dhan39	120	122	4.49	4.5	23
BRRI dhan40	137	145	3.78	4.5	36
BRRI dhan41	131	148	4.40	4.5	27
BRRI dhan44	142	145	4.61	5.5	19
BRRI dhan46	142	150	3.87	4.7	34
BRRI dhan49	128	135	4.57	5.5	21
BRRI dhan51	136	142	3.88	4.5	33
BRRI dhan52	132	140	4.84	5.0	17
BRRI dhan53	124	125	5.11	4.5	8
BRRI dhan54	132	135	4.90	4.5	15
BRRI dhan56	115	110	4.18	4.5	29
BRRI dhan57	108	105	3.79	4.0	35
BRRI dhan62	104	100	1.71	4.5	42
BRRI dhan66	115	113	5.26	4.5	6
BRRI dhan70	128	130	4.49	5.0	24
BRRI dhan71	119	115	4.98	5.5	13
BRRI dhan72	127	125	5.23	6.0	7
BRRI dhan73	120	130	5.42	3.5-6.0	3
BRRI dhan75	115	117	4.42	5.5	26
BRRI dhan76	136	163	3.93	5.0	30
BRRI dhan77	135	155	4.45	5.0	25
BRRI dhan78	131	135	5.36	4.5	4
BRRI dhan79	130	140	4.91	5.5	14
BRRI dhan80	129	130	5.28	5.0	5
BRRI dhan87	126	127	5.49	6.5	2
BRRI Hybrid dhan4	119	118	4.73	6.5	18
BRRI Hybrid dhan6	116	120	5.80	6.5	1
$LSD_{0.05}$			0.59		
CV (%)			8.3		

DS: 10 Jul 2019 DT: 31 Jul 2019

Table 25. Stability analysis of BRRI varieties, Boro 2018-19

Variety	Growth duration (day)	Standard growth duration (day)	Yield (t ha^{-1})	Standard yield (t ha^{-1})	Rank
BR1	161	150	6.53	5.5	17
BR2	161	160	6.18	5.0	29
BR3	164	170	6.21	6.5	27
BR6	159	140	5.46	4.5	38
BR7	164	155	6.61	4.5	13
BR8	162	160	6.16	6.0	30
BR9	164	155	6.25	6.0	26
BR12	167	170	5.32	5.5	42
BR14	163	160	5.79	6.0	36
BR15	150	165	6.49	5.5	19
BR16	150	165	5.92	6.0	34
BR17	150	155	4.41	6.0	43
BR18	165	170	6.26	6.0	25
BR19	165	170	6.45	6.0	20
BR26	165	140	6.53	6.0	16
BRRI dhan27	164	122	6.33	4.5	24
BRRI dhan28	164	140	7.01	6.0	7
BRRI dhan29	167	160	7.35	7.5	6
BRRI dhan35	159	155	6.55	5.0	14
BRRI dhan36	161	140	6.19	5.0	28
BRRI dhan45	157	145	5.35	6.5	40
BRRI dhan47	161	152	6.41	6.0	22
BRRI dhan50	164	155	5.67	6.0	37
BRRI dhan55	164	145	6.02	6.0	32
BRRI dhan58	159	155	6.49	7.0	18
BRRI dhan59	159	153	6.34	7.0	23
BRRI dhan60	162	151	5.32	7.1	41
BRRI dhan61	161	150	6.82	7.3	11
BRRI dhan63	164	148	6.92	7.0	9
BRRI dhan64	147	152	5.40	6.5	39
BRRI dhan67	163	143	6.96	6.0	8
BRRI dhan68	163	149	6.41	7.3	21
BRRI dhan69	166	153	5.93	7.3	33
BRRI dhan74	157	147	6.85	7.1	10
BRRI dhan81	157	143	6.53	6.5	15
BRRI dhan84	154	141	6.10	6.5	31
BRRI dhan86	159	140	5.86	6.5	35
BRRI dhan88	166	143	6.79	7.0	12
BRRI dhan89	162	154	7.49	8.0	3
BRRI dhan92	162	156-160	7.38	8.4	5
BRRI Hybrid dhan2	165	145	7.47	8.0	4
BRRI Hybrid dhan3	168	145	8.08	9.0	1
BRRI Hybrid dhan5	156	145	7.56	9.0	2
$LSD_{0.05}$	1.08		0.28		
CV (%)	1.6		10.4		

DS: 4 Dec 2019 DT: 26 Jan 2020