ANNUAL RESEARCH REVIEW WORKSHOP

2022-23

Program Area: Crop-Soil-Water Management

VII: AGRONOMY DIVISION

BANGLADESH RICE RESEARCH INSTITUTE

GAZIPUR-1701

Contents

Manpower situation in Agronomy Division (July, 2022 to June, 2023)

Sl.	Name	Position	Comments
1.	Dr. Md. Shahidul Islam	CSO & Head	365 Days
2.	Dr. Md Abu Bakar Siddique Sarker	PSO	365 Days
3.	Dr. Md. Khairul Alam Bhuiyan	PSO	365 Days
4.	Shah Ashadul Islam	SSO	365 Days (Deputed at RAL)
5.	Mst. Selima Jahan	SSO	200 Days (Transferred to R/S)
6	Dr. Rakiba Shultana	SSO	365 Days
7.	Dr. Amena Sultana	SSO	365 Days
8	Dr. Nasima Akter	SSO	365 Days (Deputed at RAL)
9.	Dr. Md. Masud Rana	SSO	365 Days
10	Dr. Md. Zakaria Ibne Baki	SSO	365 Days
11.	Md. Mostafa Mahbub	SSO	365 Days
12	Mrs. Romana Akter	SO	365 Days
13	Md. Monir Hossen	SA	365 Days
14	Md. Saiful Islam	SA	365 Days
15	Md Momin	SA	365 Days
16	Asmani Khanom	UDA	365 Days
17	Md Somser Ali	LA	346 Days

SUMMARY

1. To achieve satisfactory yield, IR16F1148 should preferably be transplanted on 20^{th}July to 5^{th} August.
2. The optimum transplanting date of BRRI dhan88 and BRRI dhan89 to achieve maximum grain yield at Gazipur is 5^{th} January in Boro season. The average daily yield reduction of BRRI dhan88 and BRRI dhan89 are 86 and 93 kg ha^{-1}, respectively was occurred transplanted after 5^{th} of January.
3. To achieve higher yield in the Rangpur region, BRRI dhan75 should preferably be transplanted on 20^{th} July- 20^{th} August, BRRI dhan87 & BRRI dhan90 on 20^{th} of August and BRRI dhan93 on 20^{th} July- 5^{th} August. BRRI dhan88, BRRI dhan89 and BRRI dhan92 produced higher grain yield on 16 January and 01^{th} February planting.
4. BRRI dhan87 and BRRI dhan95 produced higher grain yield on 5 August to 20 August transplanting in Aman season at BRRI R/S Cumilla.
5. BRRI dhan74 and BRRI dhan89, transplanted on 9^{th} January produced higher grain (5.56 t ha^{-1}, 6.07 t ha^{-1}, respectively) in Barishal region.
6. Additional use of crop residue (30 cm) and vermicompost (2 t ha^{-1}) increases microbial population, nitrogen mineralization and also grain yield in rice.
7. BRRI dhan87 gave the highest grain yield in STB + 20% treatment; whereas, BRRI dhan95 gave the highest grain yield in STB treatment. While it required 15% less nitrogen than BRRI recom. dose. The highest nitrogen use efficiency (%) was found with STB treatment of BRRI dhan96 and STB + 10% treatment with BRRI dhan92, respectively.
8. The highest yield (3.6 t ha^{-1}) was observed in BRRI organic fertilizer combined with BRRI recom. dose than control.
9. In 65 mM salinity level BRRI dhan49 gave 16.3% higher yield with 250 ppm chitosan spray than without spray.
10. In 65 mM salinity level BRRI dhan67 gave 45% higher yield with 250 ppm chitosan spray than without spray.
11. Recommended fertilizer (100%) with Phyto-protectants (ABA) could partially improve the growth, and ameliorates the adverse effects of waterlogging stress on rice.
12. Nitrogen applied 25% as basal + 25% at active tillering stage + 25% at mid tillering stage 25% +25% at before panicle initiation with 120 kg N ha^{-1} produced the highest grain yield, straw yield, higher uptake by grain and straw. The optimum N rate appeared as 100 kg, 109 kg $ha^{-1,}$ and 91 kg ha^{-1} for BRRI hybrid dhan6 with corresponding GSBNM practices respectively. Among them, 100 kg N ha^{-1} was the best for BRRI hybrid dhan6 according to growth stage-based application and scheduling. In Boro season for BRRI hybrid dhan5, N application, @150 kg ha^{-1} 20 % as basal + 30% at active tillering stage + 30% at maximum tillering stage + 20% at booting + 15 % during flowering produced the highest grain yield.
13. Salinity tolerance in BRRI dhan47, BRRI dhan67 and BRRI dhan78 associate with the function of *OsHKT1;1* in maintenance of K^+/Na^+ homeostasis in the tissue. Salinity tolerance in BRRI dhan73 and BRRI dhan99 might associate with both the function of high-affinity K^+ transporter 4 (*OsHKT1;1*) *and* Na^+/H^+ exchangers (*OsNHX1*).
14. The net change in the profit obtained by the GAPs techniques was observed to be 808 Tk./ ha for BRRI hybrid dhan5, 23383 tk. /ha for BRRI dhan100 and 11608Tk./ha for BRRI dhan96. Hence, it can be concluded that the adoption of GAPs practices in rice cultivation is economically viable.
15. For maximizing yield of BRRI, the highest grain yields was obtained from the agronomic based treatment combination of $F_2S_1A_1T_2$ (5.89 t ha^{-1}) followed by $F_2S_1A_2T_1$ (5.16 t ha^{-}) than $F_2S_1A_2T_2$ (4.16 t ha^{-1}) in T. Aman season.
16. In T Aman season, BRRI dhan71, BRRI dhan87 and BRRI dhan52 gave the highest grain yield in the agronomic management combination M_4.
17. The highest grain yield of BRRI dhan94 was achieved from the treatment $F_2A_2S_2T_2$ (6.53 t ha^{-1}) followed by F_1 A_2 S_1 T_2 (t ha^{-1}). For obtaining the highest grain yield, BRRI dhan94 should be sown on 15 July and transplanted with 30 days old seedling.

18. The highest grain yield was observed by BRRI dhan89 in all management treatment followed by BRRI dhan29 than BRRI dhan88. In respect to all management treatment, management 3 than management 2 gave the highest grain yield. Seeding should be done on 1st to 2nd week of December with younger seedling (15 to 25-day old). Upper soil stirring should be done on 20 & 35 DAT. STB fertilizer management should be followed and additionally 1% MoP solution should be sprayed on 30 and 45 DAT**.**
19. BRRI dhan92 gave the highest grain yield with the treatment $F_2S_1A_1$ (8.53 t ha^{-}) followed by $F_1S_1A_1$ (8.24 t ha^{-1}).
20. The salt-tolerance and plant growth-promoting traits revealed that Sat-2, Sat-4, Sat-5 and Sat-6 are potential salt-tolerant PGPR strains that could be considered for further plant inoculation study.
21. Among the four tested bacterial strains Sat-2 and Sat-4 are comparable with the check bacterial strain UPMRB9. Hence, this bacterial strain could be considered as a salt-tolerant strain which can significantly contribute to reducing the salinity stress of rice at the seedling stage.
22. Despite of cultivation of 4 crops in same land, are not harmful in terms of soil fertility if proper agronomic management is given. In T. Aus, T. Aman-Potato-Mungbean cropping pattern showed higher number of total bacterial population (3.05×10^{6} cfu/g dry soil over the Boro-fallow-T. Aman cropping pattern.
23. Penoxulam and 2,4- D Amine could control Azolla about 80% compared to untreated pots in the irrigated rice field.
24. The floristic diversity of the soil weed seed bank was higher in the depth of 0-5 and 5-10 cm depth in the month of September and October. The cyperaceous family had the highest species in number under different weed management techniques followed by broadleaf and grassy weeds.
25. The retention time of bensulfuron-methyl, thiamethoxam, chlorantraniliprole and tricyclazole were 2.14-2.25, 1.85, 2.22 and 2.14 min, individually. Among the 30 samples from different matrix (clean rice, straw and soil), pesticide residues were found only in 10 grain and straw samples from double dose of pesticides treated plot. No residues were found in soil matrix.
26. The retention time of bensulfuron methyl, ethoxy sulfuron ethyl and pendimethalin were 2.23, 2.43 and 35.55 min, individually. Among the soil samples bensulfuron methyl, ethoxy sulfuron ethyl have been detected up to 30 DAT and pendimethalin have been detected up to 20 DAT.
27. During reporting year (T. Aman 2022 and Boro 2022-23), fifty-one herbicides of twenty different groups were evaluated and 45 herbicides showed >80% efficacy with satisfactory weed control efficiency.
28. Application of pre or post emergence herbicide and BRRI Weeder both produced the higher grain yield than Farmers' practice at Tahirpur, Sunamganj.

PLANTING PRACTICES

Exp.1: Effect of time of planting on the yield of submergence tolerance PVT genotype

PI: Md. M Rana, CI: M Z I Baki

Introduction

Planting date may play the deciding role in the productivity of rice. Rice performs significantly better when planted in optimal settings with favorable temperatures and adequate soil moisture. Planting too early in T. Aman season often causes reduced yields and grain quality as the reproductive phase coincides with the high temperature stress and rice grain yield and quality are negatively affected. Planting too late can expose the crop to cold temperature and result in higher spikelet sterility and low yield. Thus, choosing the right timing for transplanting under specific agro-climatic conditions is the key to successful rice cultivation. The present experiment aimed to determine the appropriate planting schedule of BRRI developed submergence tolerance PVT genotype.

Materials and methods

The experiment was conducted at the farm of Bangladesh Rice Research Institute, Gazipur during T. Aman, 2022 season. One PVT genotype (IR16F1148) along with two check varieties (BRRI dhan71 and BINA dhan11) were used as test materials. The 20-day-old rice seedlings were transplanted in the field at six scheduled times (20th June, 5th July, 20th July, 5th August, 20th August and 5th September). It was a factorial experiment conducted in a Spilt-plot design (main plot-time of planting; sub plot-variety) with three replications. The field was fertilized with urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate at 180, 87, 112, 75 and 10 kg ha^{-1}, respectively. All agronomic practices were performed uniformly for all the treatments. Maturity of rice occurred at different times irrespective of planting time and test entries. Harvesting was done depending upon the maturity (80%) of the tested entries. The harvested rice was then dried, threshed and cleaned and necessary data were collected. The collected data were compiled and tabulated for statistical analysis. Data were analyzed statistically for analysis of variance (ANOVA).

Results and discussion

The tested materials yielded low transplanted on 20th of June due to severe bird damage (**Table 1**). The PVT genotype IR16F1148 gave the highest grain yield than tolerant check BINA dhan11 in all the transplanting dates except 20th August and 5th September. The susceptible check BRRI dhan71 matured 3-5 days earlier and gave slightly higher and statistically similar grain yield than IR16F1148 in all the transplanting dates. IR16F1148 yielded the highest with 121 days growth duration transplanted on 20th of July.

Table 1. Effect of planting time on the yield of submergence tolerance PVT genotype

Variety	Date of transplanting											
	20th June		5th July		20th July		5th August		20th August		5th September	
	Yield (t/ha)	GD (Day)	Yield (t/ha)	GD (Day)	Yield (t/ha)	GD (Day)	Yield (t/ha)	GD (Day)	Yield (t/ha)	GD (Day)	Yield (t/ha)	GD (Day)
IR16F1148	1.09	128	4.98	121	**6.51**	121	**6.25**	119	5.78	112	4.58	115
BRRI dhan71(Ck)	1.63	125	5.65	119	5.94	116	**6.40**	113	6.33	107	5.32	111
BINA dhan11(Ck)	0.61	119	3.13	112	5.02	112	5.49	108	**5.99**	106	5.12	110
Lsd $_{(0.05)}$	1.52	7.27	2.18	2.26	0.86	1.30	1.13	0.17	1.16	1.30	0.95	1.30
CV(%)	21.0	2.6	15.7	0.9	6.60	0.5	8.40	0.0	8.50	0.5	8.40	0.5

Conclusion

In conclusion, to achieve satisfactory yield, IR16F1148 should preferably be transplanted on 20thJuly to 5th August.

Expt.2: Yield Loss Assessment of Rice under Late Planting Condition

PI: M M Rana, CI: M B Hossain, M Sh Islam, R Shultana, U A Naher and M Maniruzzaman

Introduction

Changes in rice yields are closely related to meteorological factors such as altered temperature and precipitation regimes as well as phenological factors like tillering, panicle initiation, anthesis, and maturity (Zhao *et al.,* 2016). The findings of various studies have demonstrated that the maximum yield potential of rice is usually achieved when the crop is exposed to the most appropriate temperature range that may be managed by sowing at the right time (Mannan *et al.*, 2012; Patel *et al.*, 2019; Cerioli *et al.*, 2020). In Bangladesh, Boro is the dry-season irrigated rice seeded from November to early February and harvested between April and June (Shelley *et al.*, 2016). Planting too early in Boro season lowers yields since the reproductive phase corresponds with cold injury, and occasionally panicles can't develop properly, which increases spikelet sterility (Mannan *et al.,* 2012). Planting too late may expose the crop to heat stress and speedy wind, which increases spikelet sterility and lowers rice yields. Thus, choosing the right timing for transplanting under specific agro-climatic conditions is the key to successful rice cultivation. This study aims to identify an optimal planting window of BRRI dhan88 and BRRI dhan89 and to determine the average loss when the tested varieties are planted outside the optimal date.

Materials and methods

The experiment was conducted at the farm of Bangladesh Rice Research Institute, Gazipur during Boro season, 2022-23. The 35-day-old seedlings of BRRI dhan88 and BRRI dhan89 were transplanted in the field on eight scheduled times at a 15-day interval, starting on 20th November, 2022. It was a factorial experiment conducted in a spilt-plot design with three replications. The field was fertilized with urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate at 300, 100, 168, 113 and 11 kg ha^{-1}, respectively. All agronomic practices were performed uniformly for all the treatments. Time series data on agronomic parameters including seedling biomass, leaf number of seedlings, and tiller number per plant were collected at a 15-day interval. Maturity of rice occurred at different times irrespective of planting time and test varieties. Harvesting was done depending upon the maturity (80%) of the tested entries. The harvested rice was then dried, threshed, and cleaned and necessary data were collected. The collected data were compiled and tabulated for statistical analysis. Data were analyzed statistically for analysis of variance (ANOVA).

Results and discussion

Planting time significantly influenced the grain yields, and the highest yields of both the varieties were observed in transplanting on 5th January (**Table 2**). **Figure 1** analyses the crop growth duration response to mean seasonal temperature. The growth duration of BRRI dhan88 and BRRI dhan89 decreased by 16 and 11 days, respectively, per 1°C temperature rise. Elevated temperatures directly affected the grain yield of BRRI dhan88 and BRRI dhan89. A strong relationship was found between the number of days exposed to high temperatures (>30°C) and grain yield. The highest grain yield was found when BRRI dhan88 and BRRI dhan89 exposed to high temperatures (>30°C) for 53 and 74 days, respectively **(Figure 2).** A clear relationship was observed between later plantings and reduced yields. When BRRI dhan88 and BRRI dhan89 are transplanted after 5th January the average daily yield losses are 86 and 93 kg ha^{-1}, respectively **(Figure 3)**. The decrease was due to the shorter crop duration and spikelet sterility caused by increased temperature. Previous studies also suggested that the yield losses in rice planted later are related to the shorter length of the vegetative growth during which plants accumulate less dry matter reducing yield potential (Slaton *et al*., 2003).

Table 2. Effect of planting time on the yield of BRRI dhan88 & BRRI dhan89

Variety	Grain Yield (t ha^{-1})							
	Date of transplanting							
	20th November	5th December	20th December	5th January	20th January	5th February	20th February	5th March
BRRI dhan88	3.46	4.47	6.58	**7.61**	5.96	4.35	3.36	2.41
BRRI dhan89	4.34	5.70	7.38	**8.45**	6.49	5.10	4.17	2.59
Lsd $_{(0.05)}$	3.51	0.99	1.89	0.44	1.50	1.89	0.82	3.57
CV (%)	12.5	5.6	7.8	1.6	7.0	11.6	6.3	11.2

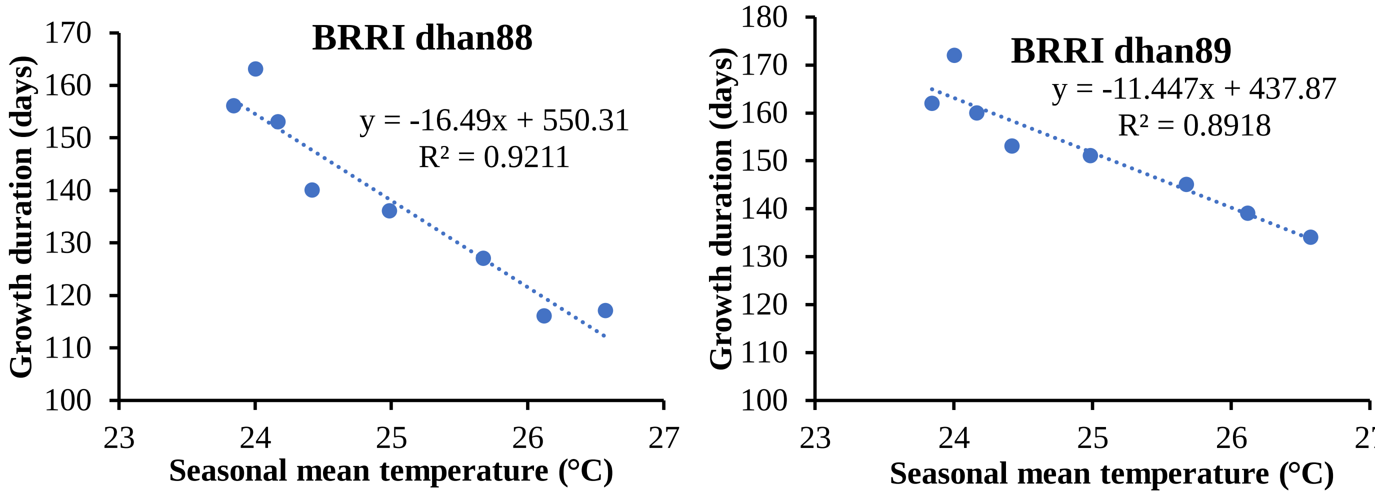


Figure 1. Relationship between seasonal mean temperature and growth duration of BRRI dhan88 and BRRI dhan89

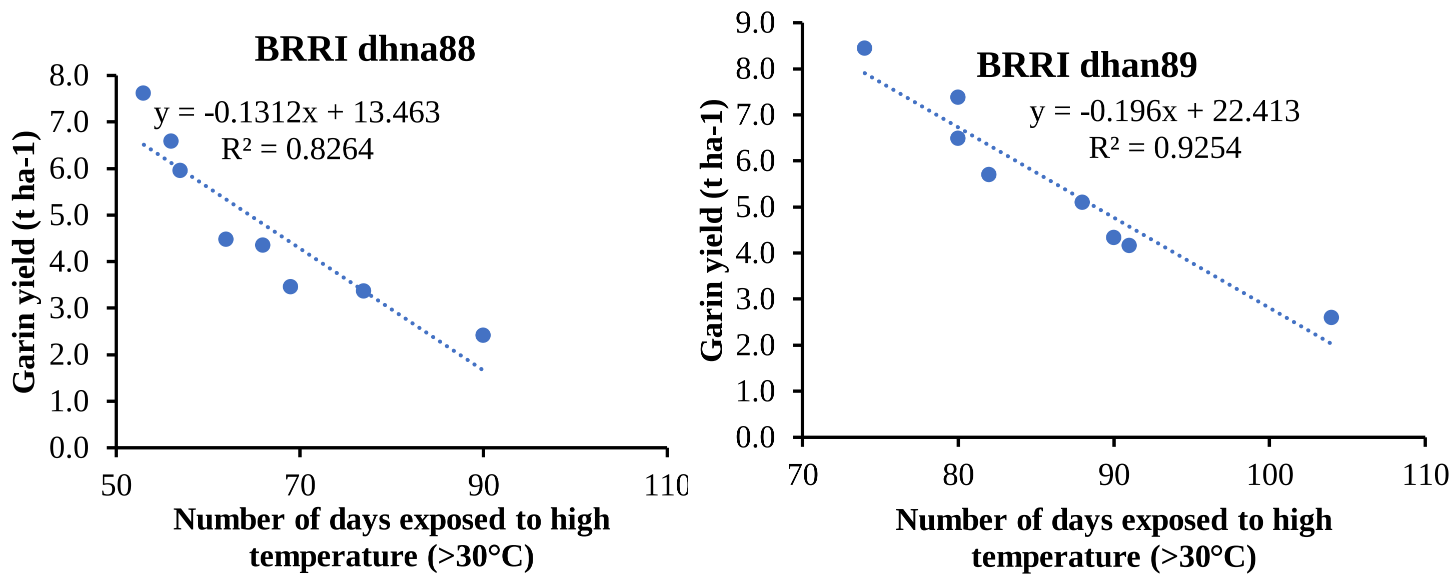


Figure 2. Relationship between number of days exposed to number of days exposed to high temperature (>30°C) and grain yield of BRRI dhan88 and BRRI dhan89

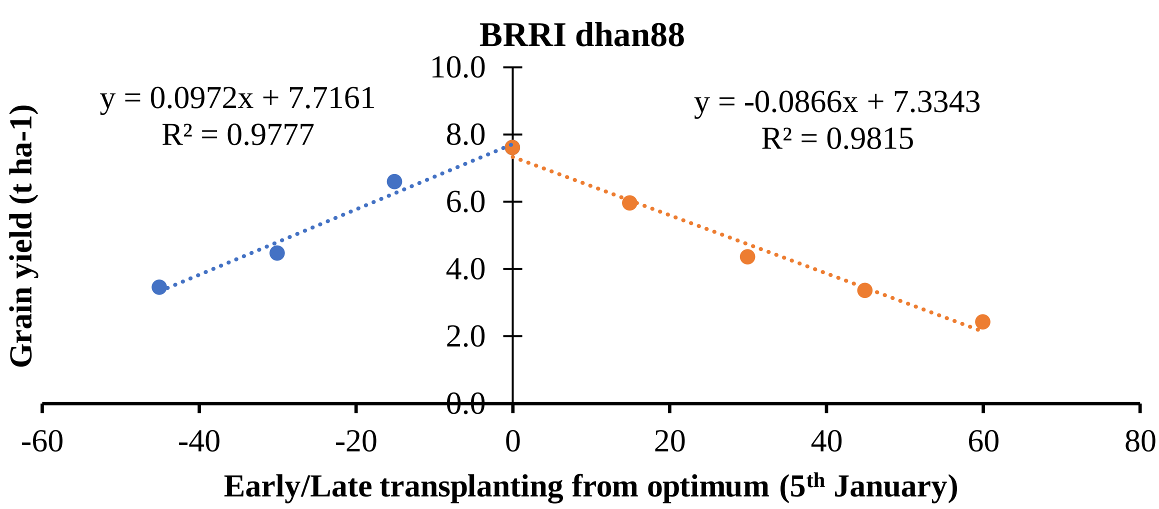


Figure 3 a. Relationship between grain yields of BRRI dhan88 to early/late transplanting

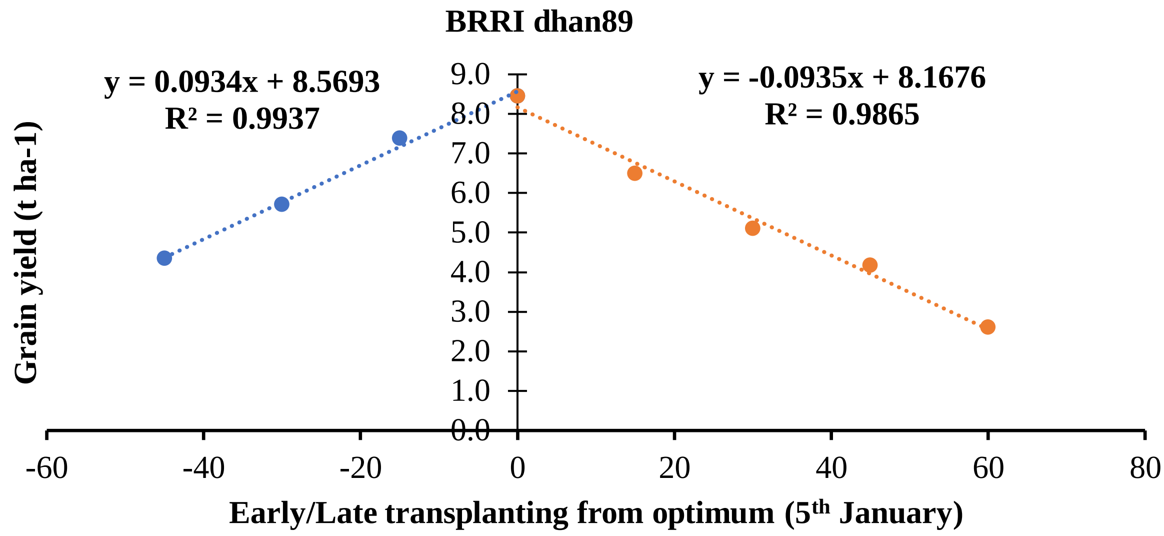


Figure 3 b. Relationship between grain yields of BRRI dhan89 to early/late transplanting

Conclusion

The optimum transplanting date of BRRI dhan88 and BRRI dhan89 to achieve maximum grain yield at Gazipur is 5th January. The average daily yield reduction of BRRI dhan88 and BRRI dhan89 are 86 and 93 kg ha^{-1}, respectively was occurred transplanted after 5th January.

Expt.3: Effect of time of planting of newly developed BRRI varieties at BRRI R/S Rangpur

PI: M K H Tarek, CI: M R Hasan, M M Rana and M Sh Islam

Introduction

Establishment of crop at the right time plays vital role in the performance of rice. Specific agro-climatic conditions of different regions influence the planting time of a variety. So, experiments were conducted at the BRRI Farm, Rangpur both in T. Aman and Boro seasons, 2022-2023 for newly released varieties for transplanting under specific agro-climatic conditions.

Aman, 2022

The experiment was conducted at BRRI regional station farm, Rangpur aimed to identify a suitable planting window of BRRI dhan75, BRRI dhan87, BRRI dhan90 and BRRI dhan93 duration cultivars to maximize grain yield. The selected varieties were planted at five different dates at 15 days' interval from July 05th to September 05th. Twenty-five days-old seedlings were transplanted following split-plot design, placing planting date in the main plots and varieties in the sub-plots with three replications. All agronomic practices were performed uniformly for all the treatments. Data of agronomic parameters i.e. panicle number m^{-2}, grains panicle^{-1} and yield were collected at harvest. Results showed that there was a significant effect of date of transplanting on the yield of potential of the tested varieties in T. Aman season (**Table 3 & 4**). Early transplanting of BRRI dhan75 (5th July to 20th of August) gave greater number of Panicles m^{-2}, grains panicle^{-1} and grain yield than the delayed transplanting. BRRI dhan87 and BRRI dhan90 transplanted on 20th of August produced higher grain yield (**Table 4**). BRRI dhan93 gave higher yield on 20th July to 05 august. In conclusion, to achieve appreciable better yield in the Rangpur region, BRRI dhan75 should preferably be transplanted on 20th July- 20th August, BRRI dhan87 & BRRI dhan90 on 20th of August and BRRI dhan93 on 20th July – 05th August.

Table 3. Effect of planting time on the Panicles m^{-2} and grains panicle^{-1} of rice, T. Aman, 2022, BRRI Rangpur

Variety	Date of transplanting									
	Panicles m^{-2}					Grains panicle^{-1}				
	05th July	20th July	05th Aug	20th Aug	05th Sep	05th July	20th July	05th Aug	20th Aug	05th Sep
BRRI dhan75	283	257	275	267	175	218	187	176	174	200
BRRI dhan87	250	242	258	233	200	154	171	198	160	163
BRRI dhan90	258	258	242	258	250	322	338	336	386	341
BRRI dhan93	292	267	267	248	258	255	229	210	216	161
CV (%)	12.7					9.0				
Lsd $_{(0.05)}$	45					25.7				

Table 4. Effect of planting time on the GDD accumulation and yield of rice, T. Aman, 2022, BRRI Rangpur

Variety	Date of transplanting									
	GDD					Grain yield (t ha^{-1})				
	05th July	20th July	05th Aug	20th Aug	05th Sep	05th July	20th July	05th Aug	20th Aug	05th Sep
BRRI dhan75	1950.7	2011.9	1928.8	1962.5	1941.5	3.01**	5.38	5.37	5.43	4.67
BRRI dhan87	2315.7	2285.3	2294.2	2264.4	2192.5	4.14*	4.06*	4.53*	6.05	4.79
BRRI dhan90	2309.9	2193.5	2125.4	2049.7	1856.8	2.57*	3.60	3.65	4.81	4.13
BRRI dhan93	2441.7	2385.3	2353.3	2299.5	2180.5	2.51*	5.46	5.42	4.83	1.97**
CV (%)	1.2					9.1				
Lsd $_{(0.05)}$	9.2					1.01				

*Lodging **Bird damage

Boro, 2022-23

In *Boro* season, Varieties BRRI dhan88, BRRI dhan89 and BRRI dhan92 tested to find out the optimum planting date. Forty-five days old seedling was transplanted during 16 December to 16 February at 15-days interval. Single seedlings were transplanted at 20 x 20 cm spacing. The treatments were distributed in a split-plot design, placing planting date in the main plots and varieties in the sub-plots with three replications. Results indicated that grain yield of rice was higher for BRRI dhan89 and all the varieties produced higher grain yield on 16 January and 01th February planting (**Table 5 & 6**).

Table 5. Effect of planting time on the panicles m^{-2} and grains panicle^{-1} of rice, Boro, 2022-23, BRRI Rangpur

Variety	Date of transplanting									
	Panicles m^{-2}					Grains panicle^{-1}				
	16th Dec	01th Jan	16th Jan	01th Feb	16th Feb	16th Dec	01th Jan	16th Jan	01th Feb	16th Feb
BRRI dhan88	328	297	220	300	402	118	120	177	153	104
BRRI dhan89	280	291	248	271	288	167	124	163	155	150
BRRI dhan92	287	293	251	325	315	141	121	134	147	126
CV (%)	13.1					14.4				
Lsd $_{(0.05)}$	53.6					26.4				

Table 6. Effect of planting time on the GDD accumulation and yield of rice, Boro, 2022-23 season, BRRI R/S Rangpur

Variety	Date of transplanting									
	GDD					(t ha^{-1})				
	16th Dec	01th Jan	16th Jan	01th Feb	16th Feb	16th Dec	01th Jan	16th Jan	01th Feb	16th Feb
BRRI dhan88	1701	1675	1631	1619	1679	5.4	5.2	5.2	6.7	5.2
BRRI dhan89	2041	1942	1927	1937	1967	5.6	5.5	7.6	7.7	5.3
BRRI dhan92	2047	1965	1966	1992	2012	6.0	5.4	7.0	7.4	5.1
CV (%)		1.7						9.2		
Lsd $_{(0.05)}$		1.4						0.83		

Expt.4: Effect of planting time on growth and grain yield of newly released BRRI varieties at BRRI R/S Cumilla

PI: T Ferdous, CI: R Shultana, M Sh Islam and R Islam

Introduction

Establishment of crop at the right time plays vital role in the performance of rice. Specific agro-climatic conditions of different regions influence the planting time of a variety. So, experiments were conducted at the BRRI Farm, Cumilla both in T. Aman and Boro seasons, 2022-2023 for newly released varieties for transplanting under specific agro-climatic conditions.

Objective: To determine suitable planting time having high yield potential in T. Aman and Boro season in Cumilla region.

Methodology

The experiment was conducted in T. Aman 2022 & Boro 2022-23 at BRRI Regional Station, Cumilla (N 23.66653^0& E 91.15887^0), Bangladesh (AEZ 19, land type-MHL). Newly released T. Aman & Boro varieties were evaluated along with the check in a time series of planting date. During T. Aman Season planting dates 5 July, 20 July, 5 August, 20 August and 5 September, where as Boro varieties were transplanted on 10 December, 25 December, 10 January, 25 January and 10 February with 15 days' interval. Twenty five days old and thirty five days old seedlings were transplanted in T. Aman and Boro Season respectively. 20 × 20 cm spacing was maintained in both seasons. The unit plot size was 4m× 3m. These experiments were laid down in Split-plot design with three replications where planting date in main plot and varieties in sub-plot. In Boro season, fertilizer were applied @145-31-77-13-1.5 kg ha^{-1} N-P-K-S-Zn, respectively and urea was applied in 3 splits at 15, 30 and 45 DAT. Standard management practices were followed for growing the crops. At maturity, the crop was harvested (5 m^2 area) manually at 15 cm above ground level for yield estimation and 16 hills were harvested at the ground level for yield components and straw yield computation from each plot. Grain yield was adjusted at 14% moisture content and straw yield as oven dry basis.

Initial soil fertility status of experimental field: Soil pH 5.87, Soil OM (%) 2.28, Total N (%) 0.10, Exch. K (cmol kg^{-1}) 0.24, Available P (mg kg^{-1}) 5.95, Avail. S (mg kg^{-1}) 26.16, Avail. Zn (mg kg^{-1}) 5.36.

Results

During T. Aman Season 2022, from 05 August to 20 August transplanting, BRRI dhan87 and BRRI dhan95 produced similar grain yield and growth duration (**Table 7 & 8**). After 20 August grain yield decreasing but growth duration increases gradually. Whereas, in case of BRRI dhan95 growth duration as well as grain yield decreasing from 20 July to 05 September transplanting. BRRI dhan87 showed the highest grain yield in t ha^{-1} in 05 August transplanting but the lowest was found in 10 September (**Table 7**).

Table 7. Effect of time of planting on Grain yield (t ha^{-1}) in T. Aman 2022 season

Varieties	05 July	20 July	05 August	20 August	05 September
BRRI dhan49	3.1	3.9	5.0	5.0	3.1
BRRI dhan75	4.4	4.3	4.4	3.5	2.9
BRRI dhan87	4.0	4.3	5.8	5.1	4.1
BRRI dhan90	2.8	2.7	4.0	3.5	2.8
BRRI dhan95	3.8	4.8	5.6	5.2	4.0
BR22	3.8	4.6	4.5	4.2	3.9
CV%	14.7				
Lsd $_{(0.05)}$	0.84				

Table 8. Effect of time of planting on growth duration in T.Aman 2022 season

Varieties	05 July	20 July	05 August	20 August	05 September
BRRI dhan49	130	133	130	129	131
BRRI dhan75	118	119	118	114	116
BRRI dhan87	126	127	125	126	126
BRRI dhan90	124	126	126	126	127
BRRI dhan95	125	124	122	124	121
BR22	173	162	152	142	131
CV%	3.02				
Lsd $_{(0.05)}$	6.37				

Boro Season 2022-2023:

BRRI dhan89, BRRI dhan92 and BRRI dhan29 produced higher grain yield within 155-158 days in first two planting time (**Table 9**). BRRI dhan88, BRRI dhan96 and BRRI dhan28 showed expected higher yield with varying range of planting time. It was observed that the best Planting time for long varieties (>140 days) was last week of December to first week of January (**Table 10**).

Table 9. Effect of time of planting on Grain yield (t ha^{-1}) in Boro 2022-23 season

Varieties	10 Dec	25 Dec	10 Jan	25 Jan	10 Feb
BRRI dhan88	5.68	5.26	5.32	5.81	5.65
BRRI dhan89	7.43	7.40	6.12	6.17	5.56
BRRI dhan92	6.93	7.68	6.53	5.71	5.38
BRRI dhan96	5.74	6.18	5.49	5.70	5.18
BRRI dhan100	6.5	6.07	6.08	5.97	5.19
BRRI dhan28	5.27	4.65	5.56	5.95	4.40
BRRI dhan29	6.35	7.34	6.07	5.79	5.26
CV %	a) 13.13 b) 9.05				
Lsd $_{(0.05)}$	0.94				

Table 10. Effect of time of planting on growth duration (days) in Boro 2022-23 season

Varieties	10 Dec	25 Dec	10 Jan	25 Jan	10 Feb
BRRI dhan88	138	139	140	136	135
BRRI dhan89	157	156	155	155	153
BRRI dhan92	157	155	153	155	154
BRRI dhan96	137	138	135	134	134
BRRI dhan100	147	147	143	140	142
BRRI dhan28	140	139	138	143	138
BRRI dhan29	158	159	158	150	155
CV%	a) 0.99				
Lsd $_{(0.05)}$	1.06				

Expt. 5: Effect of planting date on the growth and yield of newly developed BRRI varieties in Barishal region

PI: M Sohel, CI: S A Islam, M Sh Islam and M A Hossain

Introduction

Planting time is an important factor for rice production. Due to late or early planting rice production may be reduced drastically. For finding out the optimum planting time at Boro season in Barishal region, this experiment has conducted.

Objectives

To find out the suitable time of planting of different popular varieties in Barishal.

Materials and methods

The experiment was conducted in Char Badna farm, BRRI R/S Barishal, during Boro 2022-23, aimed at identifying a suitable planting date for short and long duration Boro rice cultivars to maximize grain yield. The selected cultivars were transplanted from 21 December to 261 February. The seedling ages were 35-40 days. The design of experiment was split plot with three replications. The treatment combinations were A. Variety: i. BRRI dhan74, ii. BRRI dhan88 and iii. BRRI dhan89; and B. Planting date: i. seeding date (DS): 16 November and transplanting date (DT): 21 December, ii. DS: 01 December and DT: 6 January, iii. DS: 16 December and DT: 21 January, iv. DS: 01 January and DT: 6 February, v. DS: 16 January and DT: 21 February. Yield and yield components data were collected following standard method. The data were analyzed following the STAR software.

Result and discussion

The results showed that BRRI dhan74 and BRRI dhan89, transplanted on 9th January produced higher grain (5.56 t ha^{-1}, 6.07 t ha^{-1}, respectively) than the delayed transplanting (**Table 11**). In case of BRRI dhan88, transplanting on 21 January yielded higher (6.02 t ha^{-1}). The tested varieties transplanted after 6 February were found to have decreased grain yield substantially (**Table 11**). On the other hand, growth duration of the tested varieties decreased gradually due to transplanting from 29 December to 21 February (**Table 12**).

Table 11. Effect of time of planting on yield of BRRI dhan74, BRRI dhan88, BRRI dhan89 during Boro 2022-23 at BRRI farm, Char Badna, Barishal

Transplanting date	Grain yield (t ha^{-1})		
	BRRI dhan74	BRRI dhan88	BRRI dhan89
21-Dec	4.68	4.51	5.41
6-Jan	5.56	5.02	6.07
21-Jan	5.36	6.02	5.62
6-Feb	4.08	4.24	3.51
21-Feb	0.84	3.08	1.32
CV(%) for DT	2		
CV(%) for Variety	4.7		
Lsd $_{(0.05)}$	0.2948		

Table 12. Effect of time of planting on growth duration of BRRI dhan74, BRRI dhan88, BRRI dhan89 during Boro 2022-23 at BRRI farm, Char Badna, Barishal

Transplanting date	Growth duration (Days)		
	BRRI dhan74	BRRI dhan88	BRRI dhan89
21-Dec	145	145	157
6-Jan	141	135	145
21-Jan	134	124	144
6-Feb	129	124	133
21-Feb	126	119	142
CV(%) for DT		0.2189	
CV(%) for Variety		0.2189	
Lsd $_{(0.05)}$		0.4989	

FERTILIZER MANAGEMENT

Expt. 6: Effect of organic and inorganic source of nutrients on nitrogen mineralization, microbial population and yield of rice

PI: R Akter, CI: N Akter, M M Mahbub and S A Islam

Rationale

Intensive cropping systems with continuous imbalanced use of synthetic fertilizers caused losses in soil organic matter (Sharma *et al.,* 2019) and adversely influence biological communities in soil (Singh, 2018) often leading to unsustainability of crop production systems. Balanced application of different nutrients and integrated nutrient management based on organic manures and mineral fertilizers contributed to soil health maintenance and improvement (Singh, 2018). Organic manures influence the availability of plant nutrients in the soil for plants by changing both the physical and biological characteristics of the soil. It maintain/improve the fertility and health of the soil for sustained crop productivity on a long-term basis (Palm *et al.,* 1997). Considering the above research review, the experiment was undertaken to fulfill the following

Objectives

i) To determine the mineral nitrogen content in different nutrient management soil
ii) To investigate the effect of integrated nutrient management on soil microbial population
iii) To find out the best organic material management practice to improve soil health and rice yield

Materials and methods

The experiment was conducted in Boro season, 2022-23 at Bangladesh Rice Research Institute (BRRI) farm, Gazipur. The experiment was laid out in randomized complete block design with three replications. The treatments were i) BRRI Recommended Dose (BRD), ii) BRD + Crop residue- 30 cm (CR), iii) BRD + Vermi-compost 2 t ha^{-1} (VC) and iv) BRD + Crop residue- 30 cm (CR) + Vermi-compost- 2 t ha^{-1} (VC). Forty-four-days old seedlings of BRRI dhan89 were transplanted on 18 January, 2023 at a spacing of 20 × 20 cm using two seedlings per hill. The soil samples were collected from in-between the place of four hills of rice from 0-15 cm depth by an auger. Soil samplings were done before the day of urea application and at 1, 3, 6, 10 and 15 days after urea application. Ammonium and nitrate content in soil were determined by diffusion method. The enumeration of the microbial population was carried out on agar plates containing appropriate media following serial dilution technique and pour plate method. The data were statistically analyzed using Statistix-10 analytical software. The least significant difference (LSD) at 5% probability was used to compare means of the treatments.

Results and discussion

Total bacteria and fungus found the highest in number in the treatment BRD + CR + VC. The treatment BRD + VC gave higher microbial population than BRD + CR (**Figure 4 & 5**). Vermi-compost is a good sources of nutrients and that provide more substrates for utilization by the microorganisms (Manjunath *et al.,* 2018). Ammonium and nitrate content in soil also found higher where vermicompost and crop residue were applied with BRRI recommended fertilizer dose (**Table 13**). Fertilization with organic fertilizers increases the mass and diversity of the soil microbiota, which is very important for the decomposition of organic matter and plant nutrition (Sivojiene *et al.* 2021). But in case of grains $panicle^{-1}$ and 1000 grains weight was no significant differences among the treatments. The treatment BRD + CR + VC gave 8.3% and 8.1% higher panicle m^{-2} and grain yield than BRD, respectively (**Table 14**). Integrated nutrient management involving conjunctive use of organic, inorganic and crop residues improve the soil productivity (Puli *et al.* 2016).

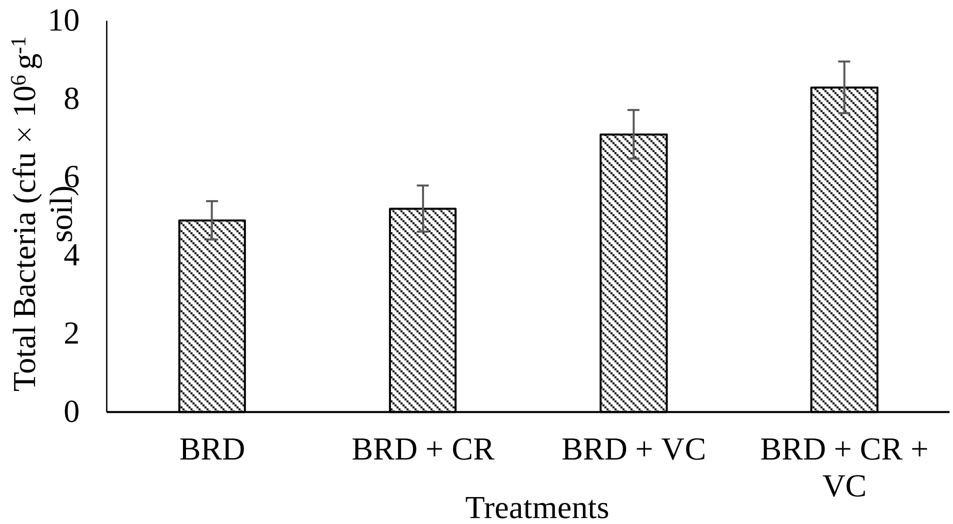


Figure 4. Effect of organic and inorganic source of nutrients on total bacteria in soil
BRD= BRRI Recommended Dose, CR= Crop residue (30cm), VC= Vermicompost (2 t ha^{-1})

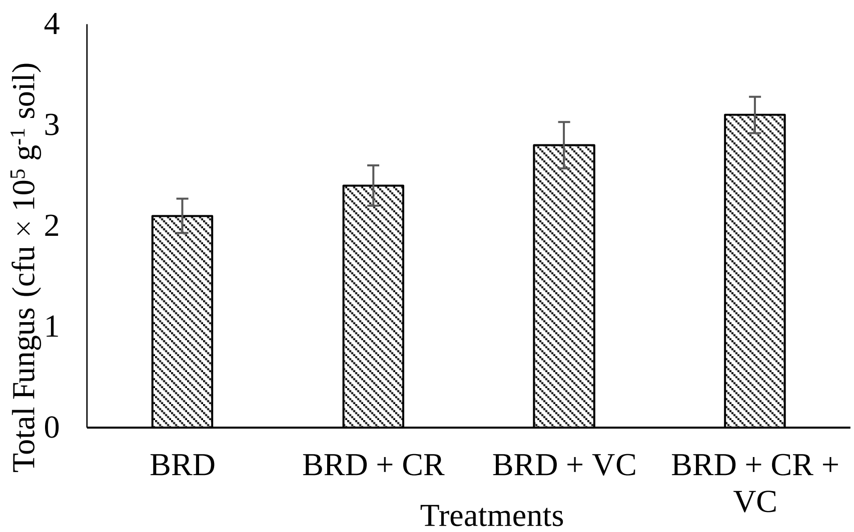


Figure 5. Effect of organic and inorganic source of nutrients on total fungus in soil
BRD= BRRI Recommended Dose, CR= Crop residue (30 cm), VC= Vermicompost (2 t ha^{-1})

Table 13. Effect of organic and inorganic source of nutrients on NH_4^+ and NO_3^- content in soil in Boro 2022-23, BRRI, Gazipur.

Treatments	NH_4^+ content (mg kg^{-1})	NO_3^- content (mg kg^{-1})
BRD	36.2	11.2
BRD + CR	39.1	12.1
BRD + VC	42.4	12.5
BRD + CR + VC	45.3	13.4
$LSD_{(0.05)}$	5.14	1.13
CV%	2.92	1.03

Legends: BRD = BRRI Recommended Dose, CR= Crop residue (30 cm), VC= Vermicompost (2 t ha^{-1})

Table 14. Effect of organic and inorganic source of nutrients on yield and ancillary characters of rice in Boro 2022-23, BRRI, Gazipur.

Treatments	Panicle m^{-2}	Grains panicle^{-1}	1000 GW (g)	Yield (t ha^{-1})
BRD	217	118	23.8	5.94
BRD + CR	229	119	23.8	6.27
BRD + VC	219	120	23.9	6.20
BRD + CR + VC	235	116	24.1	6.42
$LSD_{(0.05)}$	7.91	NS	NS	0.17
CV%	1.76	2.97	0.58	1.38

BRD= BRRI Recommended Dose, CR= Crop residue (30 cm), VC= Vermicompost (2 t ha^{-1})

Conclusion

Additional use of crop residue (30 cm) and vermicompost (2 t ha^{-1}) increases microbial population, nitrogen mineralization and also grain yield in rice.

Expt.7: Effect of different N rates and application methods on growth, yield and nitrogen use efficiency in Rice

PI: M M Mahbub CI: M K A Bhuiyan and R Akter

Nitrogen is one of the most important essential elements for plants and is required in comparatively larger amounts. Nitrogen is often applied to plants to ensure economically viable grain yields in large scale cropping systems. Yield levels presently achieved by Bangladeshi farmers depend on large amounts of N fertilizer. But excess fertilizers can reduce soil fertility. Successful nitrogen management in different growth stage of rice can optimize crop yields.

Objective:

1. To find out the influence of growth stage-based nitrogen application on growth and yield of rice
2. To find out optimum N rate and uptake in grain & straw

Materials and Methods

The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) farm, Gazipur, during T. Aman, 2022 to find out the influence of growth stage-based nitrogen application on growth and yield of rice. N fertilizer was applied on rice plant growth stage basis (According to Ricard and Jony 2005: Louisiana rice production handbook; De datta 1981; Yousida, 1981). Urea was applied 1sttop dress at 1st tillering (Aman=9 DAT, Boro, V_1=13 DAT and V_2=11 DAT); 2nd top dress at mid tillering (Aman=23 DAT, Boro, V_1=29 DAT and V_2=26 DAT) and 3rd top dress before PI stage (Aman=39 DAT, Boro, V_1=48 DAT and V_2=42 DAT). The treatments were during Aman season, 2022; A: Nitrogen level (kg ha^{-1}): N_1: STB (78 kg ha^{-1}), N_2: BRRI recom. (92 kg ha^{-1}), N_3: STB + 10% (86 kg ha^{-1}), N_4: STB + 20% (94 kg ha^{-1}), N_5:Control (N_0); and B. Varieties: V_1: BRRI dhan87 and V_2: BRRI dhan95. During Boro season, 2022-23 the treatments were; A: Nitrogen level (kg ha^{-1}): N_1: STB (V_1=147 kg ha^{-1}, V_2=118 kg ha^{-1}), N_2: BRRI recom. (V_1=138 kg ha^{-1}, V_2=120 kg ha^{-1}), N_3: STB + 10% (V_1=161 kg ha^{-1}, V_2=130 kg ha^{-1}), N_4: STB + 20% (V_1=176 kg ha^{-1}, V_2=141 kg ha^{-1}), N_5: Control (N_0); and B. Varieties: V_1: BRRI dhan92 and V_2: BRRI dhan96. The treatments were distributed in RCB two factor design with three replications. Twenty-seven days-old seedlings were transplanted during Aman season and thirty-five days old seedlings during Boro season at 20 cm x 20 cm spacing. All fertilizers except urea were applied during final land preparation. Irrigation, weeding, disease and insect control were done as and when necessary. Yield data were recorded during harvesting. Statistical analysis was done by CropStat program. Initial soil status of the experimental field was pH = 6.2, Total N = 0.11%, P = 18.6 ppm, K = 0.16 me/100 g soil, S =22.7 ppm and Zn = 2.3 ppm.

Nitrogen content and Nitrogen uptake by rice plants

After harvest grain and straw samples were taken from respective plots and all samples were oven-dried, weighed, ground, and then subsamples were taken for N determination. N content grains and straw was measured by the standard micro-Kjeldahl procedure. N uptake in grain and straw was calculated by following formulae.

$$\text{Nitrogen uptake by grain (kg ha}^{-1}) = \frac{\%\text{ N in grain} \times \text{Grain yield (kg ha}^{-1})}{100}$$

$$\text{Nitrogen uptake by straw (kg ha}^{-1}) = \frac{\%\text{ N in straw} \times \text{straw yield (kg ha}^{-1})}{100}$$

$$\text{NUE (\%)} = \frac{\text{Total N uptake from fertilized plot} - \text{Total N uptake from unfertilized plot}}{\text{Rate of Fertilizer N applied}} \times 100$$

Results and discussion

BRRI dhan87 gave the highest grain yield 5.51 t ha^{-1} and 5.31 t ha^{-1} on STB + 20% and BRRI recommended dose treatment, respectively (**Table 15**) and consequently panicle m^{-2}, grains panicle^{-1} and thousand grain weight also higher in these treatments. Whereas, the lowest grain yield 2.98 t ha^{-1} found in N_0 treatment. BRRI dhan95 gave the highest grain yield 5.10 t ha^{-1} on STB treatment and consequently panicle m^{-2}, grains panicle^{-1} and thousand grain weight also higher in these treatments.

It is observed from **Table 16** that highest N uptake was in STB + 20% and BRRI recom. dose treatment of BRRI dhan87 and STB treatment of BRRI dhan95 in grain. On the other hand, N uptake is higher in STB treatment of BRRI dhan87 and STB + 20% treatment of BRRI dhan95 in straw. Partitioning of N in grain is higher compared to straw in these treatments, hence NHI is higher in these treatments. The highest N harvest index found in STB + 20% and BRRI recom. dose treatment of BRRI dhan87 and STB treatment of BRRI dhan95. **Figure 6** showed that the highest Nitrogen use efficiency (%) was found in STB + 20% and BRRI recom. dose treatment of BRRI dhan87, respectively and in case of BRRI dhan95, highest NUE found in STB treatment. Hence, BRRI dhan87 gave highest grain yield in STB + 20% treatment; whereas, BRRI dhan95 gave highest grain yield in STB treatment. BRRI dhan95 required less nitrogen than BRRI recom. dose.

Table 15. Effect of Nitrogen levels on yield of BRRI dhan87 and BRRI dhan95, T. Aman, 2022, BRRI farm, Gazipur

Variety	Nitrogen application	Panicle m^{-2}	Grains panicle^{-1}	1000 grains wt. (g)	Grain yield (t ha^{-1})
BRRI dhan87	STB dose	228	109	24.67	4.63
	BRRI recom. dose	250	110	24.63	5.31
	STB + 10%	216	106	24.56	4.97
	STB + 20%	255	108	24.26	5.51
	N_0	164	106	24.30	2.98
BRRI dhan95	STB dose	234	104	21.90	5.10
	BRRI recom. dose	227	103	21.83	4.76
	STB + 10%	229	105	21.66	4.86
	STB + 20%	225	103	21.76	4.82
	N_0	187	98	21.40	3.39
$LSD_{(0.05)}$		12.24	2.41	0.74	0.53
CV(%)		5.12	5.94	6.42	6.78

Table 16. Nitrogen (%), uptake and NHI of different treatments, T. Aman season, 2022

Variety	N application	N% in grain	N% in Straw	N uptake grain (kg ha^{-1})	N uptake straw (kg ha^{-1})	N harvest index
BRRI dhan87	STB dose	1.10	0.75	51.28	51.94	49.54
	BRRI recom. dose	1.18	0.68	62.59	45.66	57.84
	STB + 10%	1.09	0.68	54.08	47.51	53.32
	STB + 20%	1.16	0.72	63.95	49.62	56.44
	N_0	1.12	0.68	33.47	46.82	41.73
BRRI dhan95	STB dose	1.10	0.61	56.21	42.54	57.08
	BRRI recom. dose	1.04	0.67	49.57	44.52	52.65
	STB + 10%	1.07	0.67	52.39	45.07	53.83
	STB + 20%	1.04	0.69	50.53	52.96	48.79
	N_0	1.09	0.62	37.24	44.22	45.56
$LSD_{(0.05)}$		0.12	0.11	7.39	9.27	6.77
CV%		6.37	9.70	8.43	11.48	7.64

In boro season, BRRI dhan92 gave the highest grain yield 7.66 t ha^{-1} and 7.17 t ha^{-1} on STB + 10% and STB treatment, respectively (**Table 17**) and consequently panicle m^{-2}, grains panicle^{-1} and thousand grain weight higher in these treatments. The lowest grain yield 3.59 t ha^{-1} found in N_0 treatment. BRRI dhan96 gave the highest grain yield 6.97 t ha^{-1} and 6.71 t ha^{-1} on STB and

BRRI recom. dose treatment, respectively. Whereas, N_0 treatment showed the lowest grain yield 3.34 t ha^{-1}.

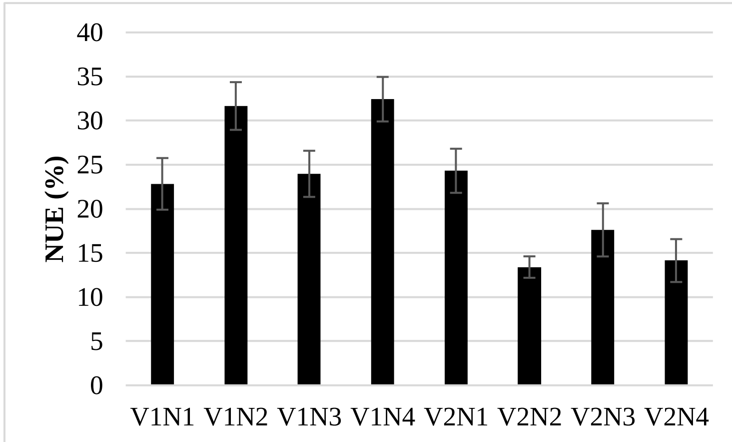


Figure 6: Nitrogen Use Efficiency of Aman varieties

V_1= BRRI dhan87. V_2=BRRI dhan95; N_1: STB (78 kg ha^{-1}), N_2: BRRI recom. (92 kg ha^{-1}), N_3: STB + 10% (86 kg ha^{-1}), N_4: STB + 20% (94 kg ha^{-1}).

Table 18 showed that the highest N uptake was in STB + 10%, STB and BRRI recom. dose treatment of BRRI dhan92; and STB treatment of BRRI dhan96 in both grain and straw. The highest N harvest index observed in STB + 10% treatment of BRRI dhan92 and STB treatment of BRRI dhan96. **Figure 7** showed that the highest Nitrogen use efficiency (%) was found in STB treatment of BRRI dhan96 and STB + 10% treatment of BRRI dhan92, respectively. BRRI dhan92 required more nitrogen than BRRI recom. dose.

Table 17. Effect of Nitrogen levels on yield of BRRI dhan92 and BRRI dhan96, Boro, 2022-23, BRRI farm, Gazipur

Treatments	N rate	Panicle m^{-2}	Grains $panicle^{-1}$	1000 grain wt. (g)	Grain yield (t ha^{-1})
BRRI dhan92	STB	275	113	23.63	7.17
	BRRI recom. dose	268	118	24.20	6.92
	STB + 10%	289	116	24.06	7.66
	STB + 20%	264	120	23.93	6.77
	N_0	193	108	23.66	3.59
BRRI dhan96	STB	294	118	20.43	6.97
	BRRI recom. dose	283	115	20.63	6.71
	STB + 10%	280	117	20.83	6.64
	STB + 20%	276	114	20.66	6.54
	N_0	191	103	19.93	3.34
$LSD_{(0.05)}$		20.12	3.68	1.02	0.70
CV(%)		4.48	5.23	7.46	6.58

Table 18. Nitrogen (%), uptake and NHI of different treatments, Boro season, 2022-23

Variety	N rate	N% in grain	N% in Straw	N uptake grain (kg ha^{-1})	N uptake straw (kg ha^{-1})	N harvest index
BRRI dhan92	STB	1.18	0.80	85.03	61.67	58.11
	BRRI recom. dose	1.22	0.82	84.92	58.94	59.16
	STB + 10%	1.22	0.79	93.56	59.76	61.16
	STB + 20%	1.15	0.75	78.27	52.48	59.90
	N_0	1.08	0.75	38.63	49.39	43.99
BRRI dhan96	STB	1.20	0.78	83.78	56.68	59.16
	BRRI recom. dose	1.14	0.076	76.98	54.19	58.83
	STB + 10%	1.14	0.79	76.30	55.07	58.14
	STB + 20%	1.09	0.73	71.76	55.22	56.66
	N_0	1.07	0.72	35.74	47.06	42.98
$LSD_{(0.05)}$		0.08	0.11	9.69	10.49	3.77
CV%		4.36	8.77	7.80	11.11	3.94

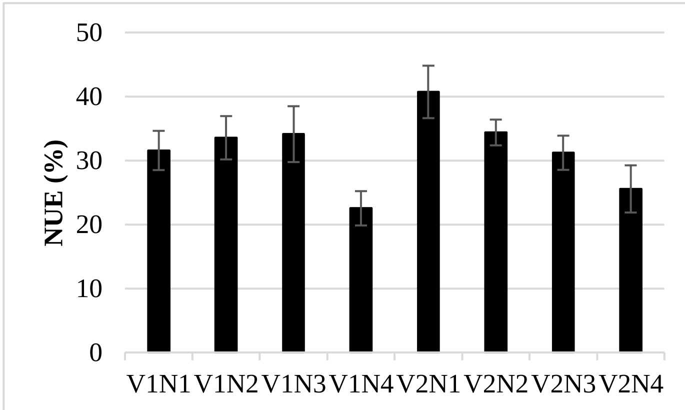


Figure 7: Nitrogen Use Efficiency of Boro varieties

(V_1= BRRI dhan92. V_2=BRRI dhan96, N_1: STB (V_1=147 kg ha^{-1}, V_2=118 kg ha^{-1}), N_2: BRRI recom. (V_1=138 kg ha^{-1}, V_2=120 kg ha^{-1}), N_3: STB + 10% (V_1=161 kg ha^{-1}, V_2=130 kg ha^{-1}), N_4: STB + 20% (V_1=176 kg ha^{-1}, V_2=141 kg ha^{-1})

Expt.8: Effect of BRRI organic fertilizer on growth and yield of BRRI dhan90

PI: A Sultana, CI: R Akter, M K A Bhuiyan and U A Naher,

Rationale

BRRI organic fertilizer was prepared using kitchen waste (79%), chita (unfilled spikelet) biochar (15%), rock phosphate (5%), and a consortium of 10 PGPB (1%) to supplement 30% nitrogen and to replace triple superphosphate (TSP) fertilizer in rice production with an improvement of soil health (Nahar *et. al*, 2021).Maintenance of rice soil health is crucial for obtaining national food security in Bangladesh. However, intensive cropping and continuous use of synthetic fertilizers are responsible for reducing soil organic matter (SOM) content. (Jahiruddin and Satter, 2010). The demand for aromatic rice has dramatically increased over the past two decades due to change in the consumer's preference for better quality rice. The farmers have switched over to high yielding premium quality rice varieties because of the higher profit. Among the fine rice varieties, BRRI dhan90 required low N requirement compared to other HYV. So, an experiment was taken to evaluate the performance of BRRI organic fertilizer on BRRI dhan90.

Materials and Methods

The field experiment was conducted at BRRI farm, Gazipur, Twenty-day-old rice seedlings of BRRI dhan90 were transplanted inthe experimental plots, chemical fertilizers and biofertilizer were applied onto the experimental plots. The treatments were, T_1 = NPKSZn (BRRI Recom. Dose), T_2 = N (70%) KSZn (100%) + BRRI organic fertilizer @ 2 t ha^{-1}, T_3 = T_1 + BRRI organic fertilizer @ 2 t ha^{-1}, T_4 =N (70%) KSZn (100%), T_5 = Control. N, P, and K fertilizers were applied in the forms of urea, triple super phosphate, muriate of potash (KCl), respectively. BRRI organic fertilizer (containing beneficial bacteria inoculated with 1:1 ratio of peat grow and empty fruit bunch of oil palm) was broadcast during last land preparation. Each plot size was 4 m × 3 m and the internal distance from plot to plot was one meter. The experiment was arranged in randomized complete block design (RCBD), with 4 replications.

Table 19. Effect of BRRI organic fertilizer on yield and yield attributes of BRRI dhan90

Treatments	Plant ht (cm)	Tiller m^{-2}	Panicle m^{-2}	Grains $Panicle^{-1}$	Yield* (t ha^{-1})
T_1= BRRI Recom. Dose	115	202	194	172	3.00
T_2 = N (70%) KSZn (100%) + BRRI organic fertilizer @ 2 t ha^{-1}	112	201	191	169	3.50
T_3 = T_1 + BRRI organic fertilizer @ 2 t ha^{-1}	117	212	205	187	3.60
T_4 =N (70%) KSZn (100%)	115	201	188	154	3.30
T_5 = Control	110	168	143	140	2.66
$Lsd_{(0.05)}$	1.5	3.9	2.7	3.2	0.24
CV(%)	3.4	9.1	6.4	7.4	0.56

*Poor yield was mainly due to lodging resulted from depression

Result and discussion

It was observed that BRRI organic fertilizer application affected rice growth in terms of plant height, number of tillers, and panicles (**Table 19**). Significantly highest plant height (117 cm), tiller numbers m^{-2} (212), panicle m^{-2} (204), grains $panicle^{-1}$ (187), grain yield (3.6 t ha^{-1}) were observed in NPKSZn (BRRI Recom. Dose) with BRRI organic fertilizer @ 2 t ha^{-1} treatments followed by N (70%) KSZn (100%) with BRRI organic fertilizer (3.5 t ha^{-1}). It was reported that using the BRRI organic fertilizer, to a certain extent, enhanced the rice growth and yield (Radziah *et. at*., 2014). Naher *et. al.,* (2016) found that N and P (50%) with bio-fertilizer increased the number of tillers, panicle length and produced the highest grain yield in rice. However, there was significant difference among the NPKSZn (BRRI Recom. Dose) with BRRI organic fertilizer @ 2 t ha^{-1} treatments and N (70%) KSZn (100%) with BRRI organic fertilizer @ 2 t ha^{-1} treatments in terms of highest plant height, number of tiller m^{-2}, number of panicle m^{-2}, grain $panicle^{-1}$ but not grain yield (**Table 19**).

Conclusion

The highest yield (3.6 t ha^{-1}) was observed in BRRI organic fertilizer combined with BRRI recom. dose (T_3).

Expt.9: Effect of foliar application of chitosan on growth, yield and physio-biochemical characteristics of rice under salinity stress

PI: N Akter **CI:** M M Rana, R Akter, S A Islam, M K A Bhuiyan and M Sh Islam

Introduction

Excess salinity in the soil is one of the major environmental factors that limit plant growth and yield of a wide variety of crops including rice. Salinity-induced ionic and osmotic stresses reduce rate of photosynthesis and consequently cause oxidative stress, which is also responsible for growth reduction (Hasanuzzaman *et al*., 2014). Salinity-induced yield reduction of rice is alarming for the food security of the ever-growing population of the world, especially in Asia. So, it is an urgent task of agronomists to salinity management to ensure food security of rising population, since the expansion of rice-growing areas is limited because of various stresses including salinity (Munns 2002). Chitosan (CS) similar to plant growth regulators, is a partially deacetylated form of chitin, a natural biopolymer from the exoskeleton of crab, shrimp and fungal cell walls, which is biocompatible, biodegradable and a sustainably renewable cheap resource that has many applications, including plant defense, confer resistance against salinity stress. Exogenous chitosan application could mitigate salt stress by increasing antioxidant enzyme and foliar application of chitosan on plant yield have been evaluated.

Objectives: This research aims to elucidate the chitosan's response on growth, chlorophyll content, proline content, Na^+/K^+ ratio and yield of salt-sensitive and salt-tolerant rice cultivars under salinity stress.

Materials and methods: A pot experiment was conducted at rain-out shelter of the Agronomy Division, BRRI, Gazipur in T. Aman, 2022. The pots were set as split-split design with three replications. The main plots represented two salinity levels; i. 0 mM NaCl, ii. 65 mM NaCl (Approximately 6.5 dS m^{-1}). Sub-plots represented two concentrations of chitosan; i. 0 ppm, ii. 250 ppm. Sub-sub-plots represented two varieties of rice; i. BRRI dhan49 (salt sensitive), ii. BRRI dhan73 (salt tolerant). Chitosan was sprayed two times at active tillering and at heading stages. Twenty-five-day-old seedlings were transplanted using two seedlings per hill on 25 July, 2022. The full dose of P-K-S was applied during final soil preparation and N was applied in three splits (1/3rd at 15 DAT, 1/3rd at 30 DAT and 1/3rd at 45 DAT) following BRRI recommended dose. Each pot (10 kg soil) received 1.2 g N, 0.8 g P, 0.50 g, K 0.8 g S and Zn 0.15 g, as Urea, TSP, MOP, Gypsum and $ZnSO_4$, respectively. The plant height (cm) was taken from the base of the plant (at soil level) up to the tip of the panicle. Chlorophyll and proline content was determined according to the method developed by Coombs *et al*., 1985 and Bates *et al*. 1973. Chlorophyll and proline were measured in a UV visible spectrophotometer (Shimadzu, Japan), and sodium and potassium were measured in a PFP7 flame photometer (Jenway). Statistical analyses were performed using CropStat7.2 statistical software of IRRI.

Results and Discussion

Growth parameter

The highest plant height was found in BRRI dhan73 at the maturity stage (**Table 20**). There was a significant variation observed in plant height due to salinity treatments. Salinity reduced the plant height compared to its respective control in all growth duration. Supplementation of 250 ppm CS on salt-stressed rice plants improved the growth significantly in both varieties. Salinity stresses greatly affected the development and viability of tillers at different growth stages. Both rice varieties were significantly influenced by salinity level in terms of tiller production, varietal variation had a significant effect on tillers hill^{-1} over time. The chitosan-treated salt-stressed susceptible rice BRRI dhan49 had a significantly higher tiller number hill $^{-1}$ compared to salt-tolerant BRRI dhan73 (**Figure 8**).

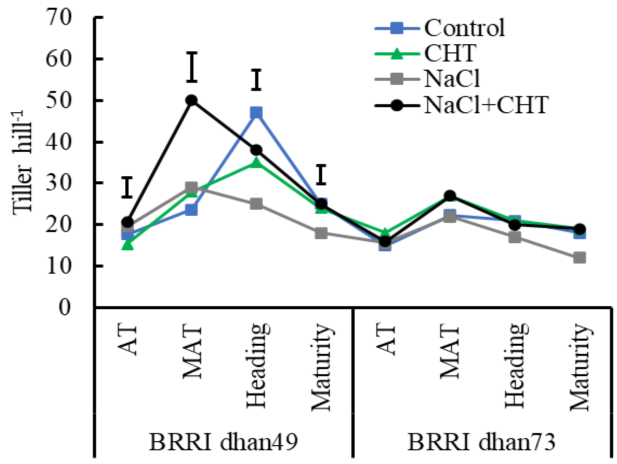


Figure 8. Tillering pattern of tested varieties at different growth stages under salinity stress, Vertical bars represent Lsd $_{(0.05)}$.

Chlorophyll content, proline content and Na^+/K^+ ratio in rice plants

Chlorophyll content indicates the greenness of leaves, which differed significantly due to different salinity levels. The highest chlorophyll content; chlorophyll a (3.23 mg g^{-1} FW) was measured in BRRI dhan73. The content of Chl 'a' was found higher in the tolerant cultivar compared to the sensitive cultivar. Salt stress (65 mM) caused a drastic reduction in Chl 'a' and Chl 'b' contents compared to non-stress conditions in the BRRI dhan49, whereas salt tolerant cultivar BRRI dhan73 showed a slight reduction (**Figure 9A**).

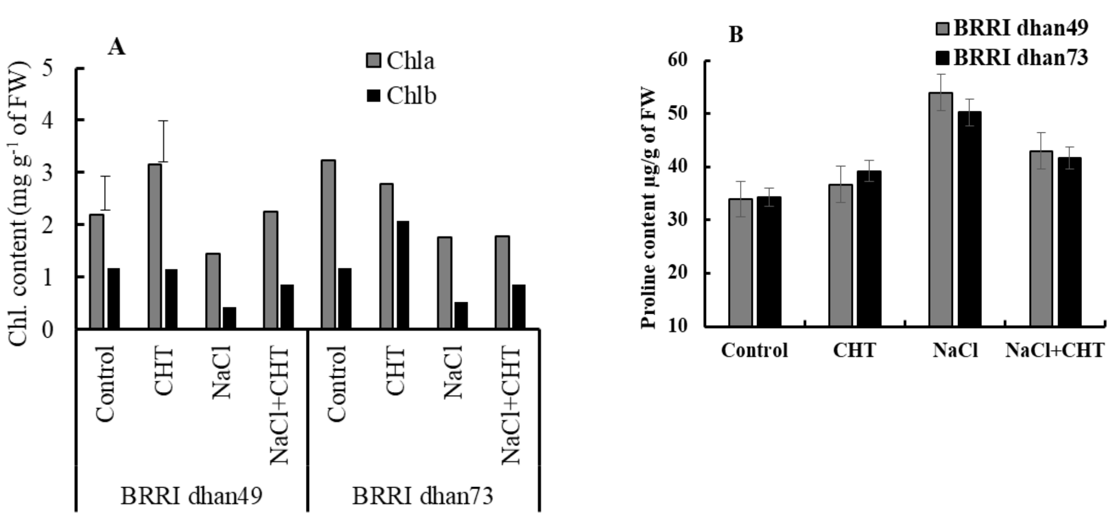


Figure 9. Chlorophyll content and Proline content (A, B) at heading stage of BRRI dhan49 and BRRI dhan73 under salinity stress. Vertical bars represent Lsd $_{(0.05)}$.

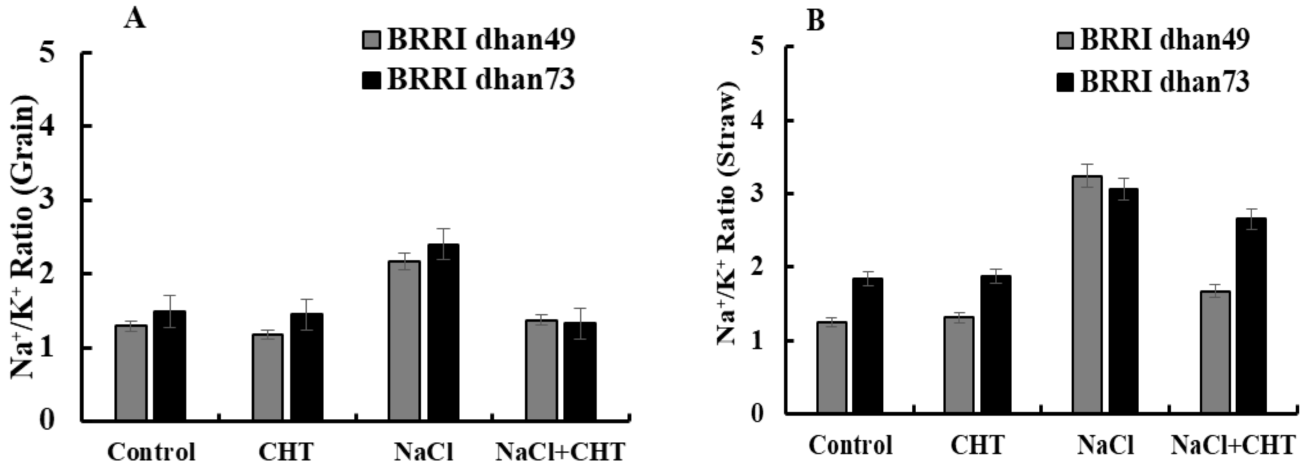


Figure 10. Na^+/K^+ ratio in grain and straw (A, B) at maturity stage in the two rice cultivars under salinity stress. Vertical bars represent Lsd $_{(0.05)}$.

Exogenous application of CHT showed significant alleviation of Chl 'a' and Chl 'b' content in both varieties (**Figure 9A**). In both varieties, significant differences of proline contents were found in both saline and non-saline conditions. The proline content was significantly higher in BRRI dhan49 (54 µmol g^{-1} of FW) in saline conditions. Saline conditions supplemented with 250 ppm of CHT mitigate the upregulation of the proline content of both varieties (**Figure 9B**).

After exposure to 65 mM NaCl, BRRI dhan49 accumulated less Na^+ and maintained higher K^+ levels in straw and grain, compared to BRRI dhan73 (**Figure 10**). Significant increases in Na^+ /K^+ ratio in grain and straw of both varieties were observed in response to salt stress. On the contrary, CHT application showed a significant decrease in grain Na^+ /K^+ ratio in both varieties' response to salt stress (**Figure 10**).

Yield and yield components

In both varieties 65 mM salinity level reduced panicle $hill^{-1}$. Grains $panicle^{-1}$ were significantly influenced by different treatments in BRRI dhan49 compared to BRRI dhan73. In saline conditions, yield reduction was found from both variety and chitosan spray, which could slightly mitigate the saline stress in BRRI dhan73. In BRRI dhan49, grains $panicle^{-1}$ and yield reduced in saline conditions but with 250 ppm chitosan spray grains $panicle^{-1}$ and yield increased in both saline and non-saline conditions (**Table 20**). BRRI dhan49 gave a higher yield compared to BRRI dhan73 for all treatments. In 65 mM salinity level BRRI dhan49 gave 16.3% higher yield with 250 ppm chitosan spray than without spray (**Table 20**).

Table 20. Effect of salinity and Chitosan spray on growth and yield components of BRRI dhan49 and BRRI dhan73 in T. Aman 2022, BRRI, Gazipur

Salinity level	Chitosan spray	Variety	Plant height (cm)	Panicle $hill^{-1}$	Grains $panicle^{-1}$	1000 GW (g)	Yield (g pot^{-1})
0 mM	0 ppm	BRRI dhan49	114	23	131	18.2	55.2
		BRRI dhan73	129	16	167	20.6	54.3
	250 ppm	BRRI dhan49	116	22	141	17.1	52.2
		BRRI dhan73	123	18	166	20.2	55.6
65 mM	0 ppm	BRRI dhan49	106	17	99	18.6	34.4
		BRRI dhan73	119	10	104	21.1	27.0
	250 ppm	BRRI dhan49	113	23	114	18.2	43.4
		BRRI dhan73	127	18	123	19.5	38.2
Lsd$_{(0.05)}$			5.34	3.80	21.8	NS	8.29
CV%			2.5	11.5	9.4	10.2	10.4

Expt.10: **Application of chitosan to improve salt tolerance of rice in the Boro season**

PI: N Akter CI: M M Rana and R Akter

Introduction

Salinity is a serious threat to crop production in the southern region of Bangladesh and it is one of the adverse environmental factors that affect plant growth from seed germination to productivity. Osmotic stress and ion toxicity are effects caused by salinity as a result reduced growth and photosynthesis occur. Chitosan similar to plant growth regulators, is a partially deacetylated form of chitin, a natural biopolymer from the exoskeleton of crab, shrimp and fungal cell walls, which is biocompatible, biodegradable and sustainably renewable cheap resource that has many applications, including plant defense, confer resistance against salinity stress. Exogenous chitosan application could mitigate salt stress by increasing antioxidant enzymes and foliar application of chitosan on plant yield has been evaluated.

Objective: The present study aims to elucidate the chitosan's response on growth, chlorophyll content, proline content, photosynthetic activity, Na^+/K^+ ratio and yield of salt-sensitive and salt-tolerant rice cultivars under salinity stress.

Materials and methods: A pot experiment was conducted at rain-out shelter of Agronomy Division, BRRI, Gazipur in Boro, 2022-23. The pots were set as split-split design with three replications. The main plots represented two salinity levels; i. 0 mM NaCl, ii. 65 mM NaCl (Approximately 6.5 dS m^{-1}). Sub-plots represented two concentrations of chitosan; i. 0 ppm, ii. 250 ppm. Sub-sub-plots represented two variety of rice; i. BRRI dhan28 (salt sensitive), ii. BRRI dhan67 (salt tolerant). Chitosan was sprayed two times at active tillering and at heading stages. Thirty-five-day-old seedlings were transplanted using two seedlings per hill on 18 January, 2023. Full dose of P-K-S was applied during final soil preparation and N was applied in three equal splits ($1/3^{rd}$ at 15 DAT, $1/3^{rd}$ at 30 DAT and $1/3^{rd}$ at 45 DAT) following BRRI recommended dose. Each pot (10 kg soil) received 1.5g N, 1.0 g P, 0.60 g, K 1.0 g S and Zn 0.20 g, as Urea, TSP, MoP, Gypsum and $ZnSO_4$, respectively. Chlorophyll and proline content was determined according to the method developed by Coombs *et al*., 1985 and Bates *et al*. 1973. Relative water content (RWC) was measured according to Barrs and Weatherley (1962). The content of MDA was determined by the thiobarbituric acid reaction as described by Heath and Packer (1968). Chlorophyll content, proline and MDA content were measured in a UV visible spectrophotometer (Shimadzu, Japan). Sodium and potassium were measured in a PFP7 flame photometer (Jenway). Statistical analyses were performed using CropStat7.2 statistical software of IRRI.

Results and Discussion

Chlorophyll content, relative water content and photosynthesis rate in rice plants: Chlorophyll content indicates the greenness of leaves, which differed significantly due to different salinity levels. The highest chlorophyll content; chlorophyll a (3.76 mg g^{-1} FW) was measured in BRRI dhan67. The content of Chl 'a' was found higher in the tolerant cultivar compared to the sensitive cultivar. Salt stress (65 mM) caused a drastic reduction in Chl 'a' and Chl 'b' contents compared to non-stress conditions in the BRRI dhan28, whereas salt tolerant cultivar BRRI dhan67 showed a slight reduction. On the contrary, supplementation of CS showed significant alleviation of Chl 'a' and Chl 'b' content in both varieties (**Figure 11**). There was a significant variation observed for relative water content due to varietal variation. BRRI dhan67 (77%) recorded the highest relative water content compared to BRRI dhan28. Sharp decreases in relative water content (51% in BRRI dhan67 and 55% in BRRI dhan28 at 65 mM salt-stressed condition) were observed in response to salt stress, compared to untreated control (**Figure 11**). CHT could increase relative water content under salt-stressed conditions.

In both varieties, significant differences of photosynthetic rate were found in both saline and non-saline conditions. The photosynthetic rate was significantly higher in BRRI dhan67 (27.1 µmol CO_2 m^{-2} s^{-1}) supplemented with chitosan with non-saline condition and salt stress reduced the photosynthetic rate in BRRI dhan28 and BRRI dhan67 (11.6 and 10.8 µmol CO_2 m^{-2} s^{-1}). Saline condition supplemented with 250 ppm of CS enhanced the upregulation of chlorophyll content and photosynthetic activity of both varieties (**Figure 11**).

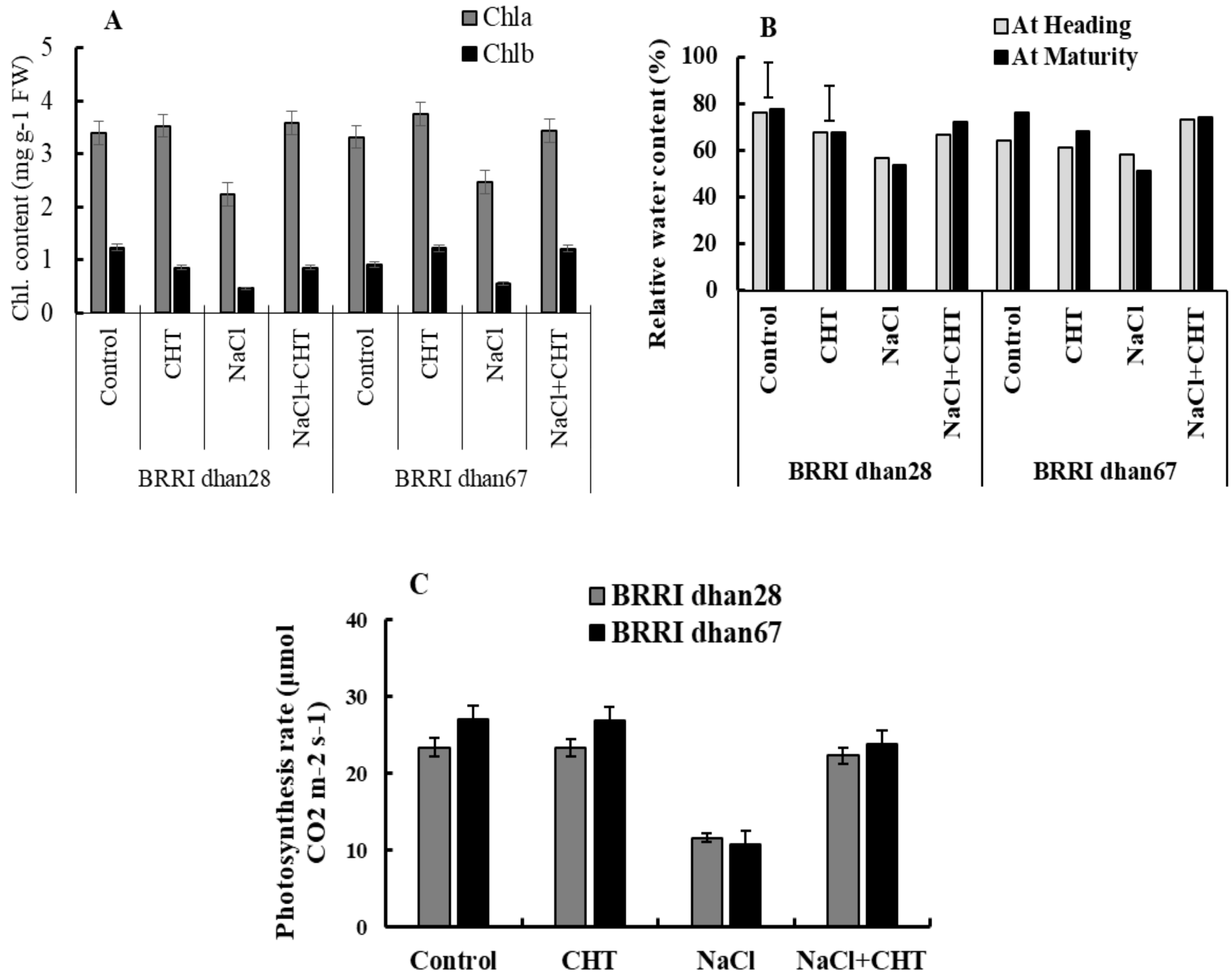


Figure 11. Chlorophyll content, relative water content and photosynthetic rate (A, B, C) of BRRI dhan28 and BRRI dhan67 under salinity stress. Vertical bars represent Lsd$_{(0.05)}$.

Proline content, MDA content and K^+ /Na^+ ratio:

Salt stress increased the proline and MDA content compared with that of the non-stress condition. Supplementation of CS could significantly reduce the proline and MDA content in all the cultivars. Saline conditions supplemented with 250 ppm of CS had a similar trend of decrease in proline and MDA content in BRRI dhan28 and BRRI dhan67 (**Figure 12**). After exposure to 65 mM NaCl, BRRI dhan67 accumulated less Na^+ and maintained higher K^+ levels in straw and grain, compared to BRRI dhan28 (**Figure 13**). Significant increases in Na^+ /K^+ ratio in grain and straw of both varieties were observed in response to salt stress. On the contrary, chitosan application showed a significant decrease in grain Na^+ /K^+ ratio in both varieties' response to salt stress (**Figure 13**)

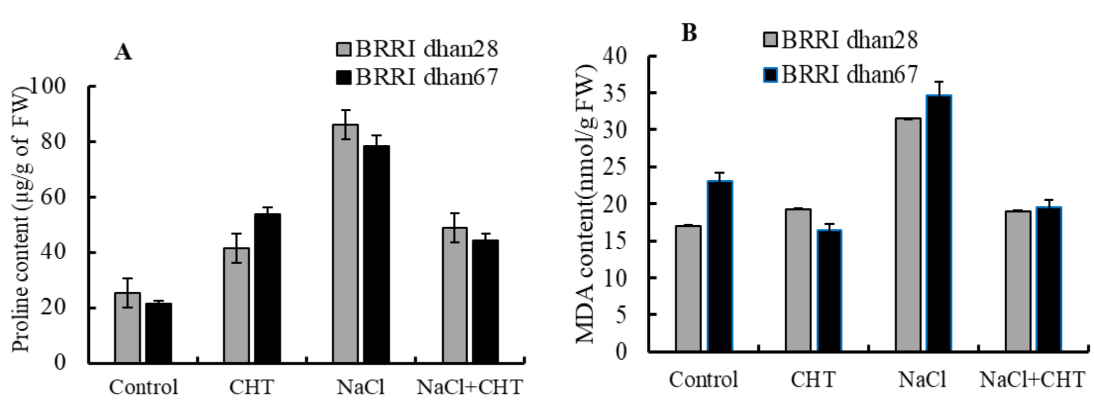


Figure 12. Proline and MDA contents in leaves at the heading stage (A, B) in the two rice cultivars under salinity stress.

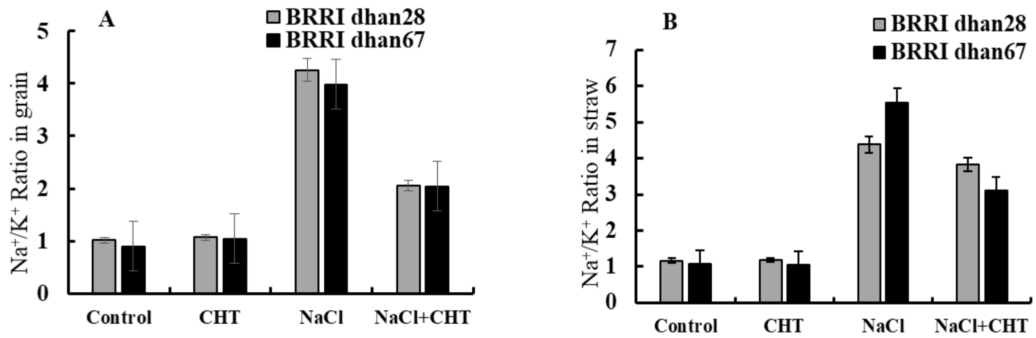


Figure 13. Na^+/K^+ ratio in grain and straw (A, B) at maturity stage in the two rice cultivars under salinity stress. Vertical bars represent $Lsd_{(0.05)}$.

Growth and yield components

Salinity (65 mM NaCl) caused a significant reduction (81.3 cm) in plant height of BRRI dhan28 compared with respective control plants during growth stages. Supplementation of 250 ppm CS on salt-stressed rice plants improved the growth significantly in both varieties. In non-saline conditions, plant height was increased by chitosan application in BRRI dhan67. In both variety 65 mM salinity level reduced panicle hill^{-1} and 1000 GW. Grains panicle^{-1} were significantly influenced by different treatments in BRRI dhan28 compare to BRRI dhan67. In saline condition, yield reduction was found from both variety and chitosan spray could slightly mitigate the saline stress in BRRI dhan28. In BRRI dhan67, grains panicle^{-1} and yield reduced in saline conditions but with 250 ppm chitosan spray grains panicle^{-1} and yield increased in both saline and non-saline condition (**Table 21**). Higher sterility (48%) was found in BRRI dhan28 than BRRI dhan67 for all treatment combinations. In 65 mM salinity level BRRI dhan67 gave 45% higher yield with 250 ppm chitosan spray than without spray (**Table 21**).

Table 21. Effect of salinity and Chitosan spray on growth and yield components of BRRI dhan28 and BRRI dhan67 in Boro 2022-23, BRRI, Gazipur

Salinity level	Chitosan spray	Variety	Plant height (cm)	Tiller hill^{-1}	Panicle hill^{-1}	Grains panicle^{-1}	1000 GW (g)	Yield (g pot^{-1})	Sterility %
0 mM	0 ppm	BRRI dhan28	96	25	24	119	18.19	53.7	17.9
		BRRI dhan67	96	22	21	128	18.73	52.5	9.2
	250 ppm	BRRI dhan28	91	24	20	108	18.35	49.7	16.6
		BRRI dhan67	100	20	19	136	17.79	48.0	8.8
65 mM	0 ppm	BRRI dhan28	81	12	10	70	12.1	7.24	48.8
		BRRI dhan67	83	14	9	80	14.1	11.2	47.5
	250 ppm	BRRI dhan28	90	21	13	81	16.15	11.7	20.6
		BRRI dhan67	99	19	13	93	19.07	27.7	12.3
$Lsd_{(0.05)}$			11.02	5.41	4.73	34.1	3.60	8.41	17.6
CV%			6.7	15.3	16.4	18.7	12.1	14.4	43.7

N.B: Sterility% was higher and grain wt. was lower due to heat stress in 1st week of April.

Conclusion: Salt stress caused a reduction in growth, chlorophyll content, photosynthesis rate and yield of both varieties. In summary, the foliar application of chitosan was an effective way to improve the salt tolerance of rice. Exogenous application of chitosan significantly improved the growth, mitigated the adverse effects of salt stress on rice by decreasing the Na^+/K^+ ratio and 45% higher yield of BRRI dhan67 in response to salt stress. The experiment needs to verify at field condition for further confirmation.

Expt.11: Mitigation of waterlogging stress in T. Aman through the application of plant protectants coupled with balanced fertilization

PI: N. Akter **CI:** R Akter and M M Rana

Introduction

Plants require water for growth but excess water that occurs during submergence or waterlogging is harmful. Waterlogging is defined as a condition of the soil in which excess water limits gas diffusion (Setter and Waters 2003). Waterlogging is one of the focal abiotic stresses, which affects crop growth (Setter and Waters, 2003; Lone *et al.*, 2018). The principal cause of damage to plants grown in waterlogged soil is an inadequate supply of oxygen to the submerged tissues as a result of the slow diffusion of gases in water and rapid consumption of O_2 by soil microorganisms. The main adaptation of lowland rice to soil waterlogging is the formation of aerenchyma, which permits relatively unhindered transport of O_2 from well-aerated shoots to submerged roots (Jackson and Armstrong 1999). Waterlogging remains a significant constraint to cereal production across the globe in areas with high rainfall and/or poor drainage. Improving tolerance of plants to waterlogging is the most economical way of tackling the problem. However, under severe waterlogging combined agronomic and genetic solutions will be more effective. This study focuses on the impact of waterlogging on soil properties, plant growth and crop management practices to mitigate waterlogging. Combined application of fertilizers and plant protectants (Abscisic acid; ABA, H_2O_2, Glutathione and proline) can provide another option for ameliorating detrimental effects of waterlogging in rice, with the fertilizers acting as a nutrient supplier, while the plant protectants assist with recovery from physiological injury (Li *et al.*, 2013).

Objectives

This study aims to determine the effect of combined application of fertilizer and plant protectants on the growth, yield, biochemical studies and nutrient uptake of waterlogging T. Aman rice.

Materials and methods

A pot (Plastic bucket) experiment was conducted at rain-out shelter of Agronomy Division, BRRI, Gazipur in T. Aman, 2022. The pots were set as RCB (factorial) design with three replications. Five crop managements were: CM_1 = Recom. Fertilizer Dose (100%), CM_2 = RDF 100% + 10 µM ABA + waterlogging stress, CM_3 = RDF 100% + 10 µM H_2O_2 + Water stress, CM_4 = RDF 100% + 5 mM GSH + waterlogging stress, CM_5 = RDF 100% + 5 mM Proline +waterlogging stress. BRRI dhan51 (submergence tolerant) and BRRI dhan87 were used as variety. Waterlogging stress were given for 7 days at 25 DAT, 45 DAT, 65 DAT and 85 DAT. Plant protectants were sprayed three times at active tillering, at maximum tillering and at heading stages. Twenty-five-day-old seedlings were transplanted using two seedlings per hill on 31 July, 2022. Full dose of P-K-S was applied during final soil preparation and N was applied in three splits (1/3rd at 15 DAT, 1/3rd at 30 DAT and 1/3rd at 45 DAT) following BRRI recommended dose. Each pot (25 kg soil) received 2.6 g N, 1 g P, 0.7 g K, 1 g S and Zn 0.25 g, as Urea, TSP, MOP, Gypsum and $ZnSO_4$, respectively. The initial soil status of the experimental field was pH = 6.7, N = 0.15%, P = 7.4 ppm, K = 0.19 me/100g, S = 26.7 ppm, and Zn = 3.5 ppm. The plant height (cm) was taken from the base of the plant (at soil level) up to the tip of the panicle (reproductive). Chlorophyll and proline content was determined according to the method developed by Coombs *et al*., 1985 and Bates *et al*. 1973. Chlorophyll content and proline content were measured in a UV-visible spectrophotometer (Shimadzu, Japan). Statistical analyses were performed using CropStat7.2 statistical software of IRRI.

Results and Discussion

Waterlogging effects on growth, biochemical parameters, grain yield and yield components:

There were no significant differences were observed in plant height in both varieties under waterlogging stress (**Table 22**). Waterlogging stresses slightly affected the development of tillers. Varietal variation had significant effect on tillers hill^{-1} at different growth stages over time

(**Figure 14**). The highest tillers hill^{-1} was found in BRRI dhan51 compared to BRRI dhan87 in CM1 and CM2. In **Figure 15A** showed that BRRI dhan51 had the highest chl a and chl b in controlled condition compare to BRRI dhan87, whereas under waterlogging condition statistically similar chlorophyll content was observed in CM2 and CM4 in both varieties. The highest proline content was found in CM3 in both varieties whereas other crop management shows statistically identical result (**Figure 15B**). The number of panicles per plant, grains per panicle, and 1000 GW, were slightly decreased by waterlogging but differed in the rate of decrease in response to Phyto protectants application. Higher yield was observed in BRRI dhan87 in CM2 (RDF+ ABA with water stress) followed by CM1 in BRRI dhan51 (**Table 22**).

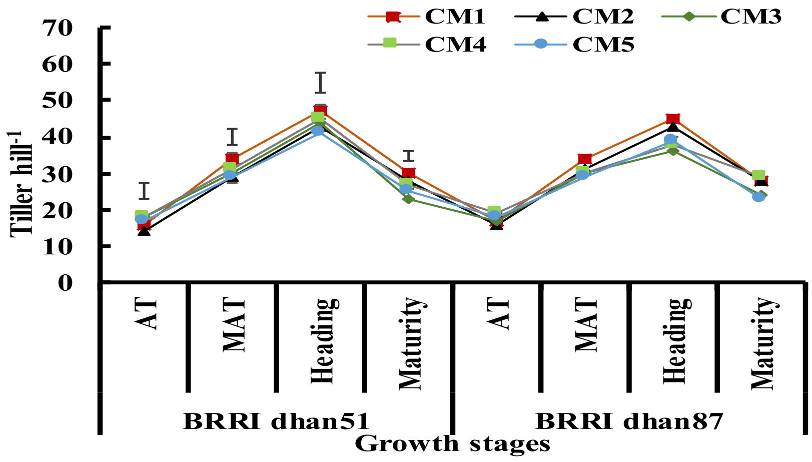


Figure 14. Tillering pattern of tested varieties with different crop management, Vertical bars represent Lsd (0.05).

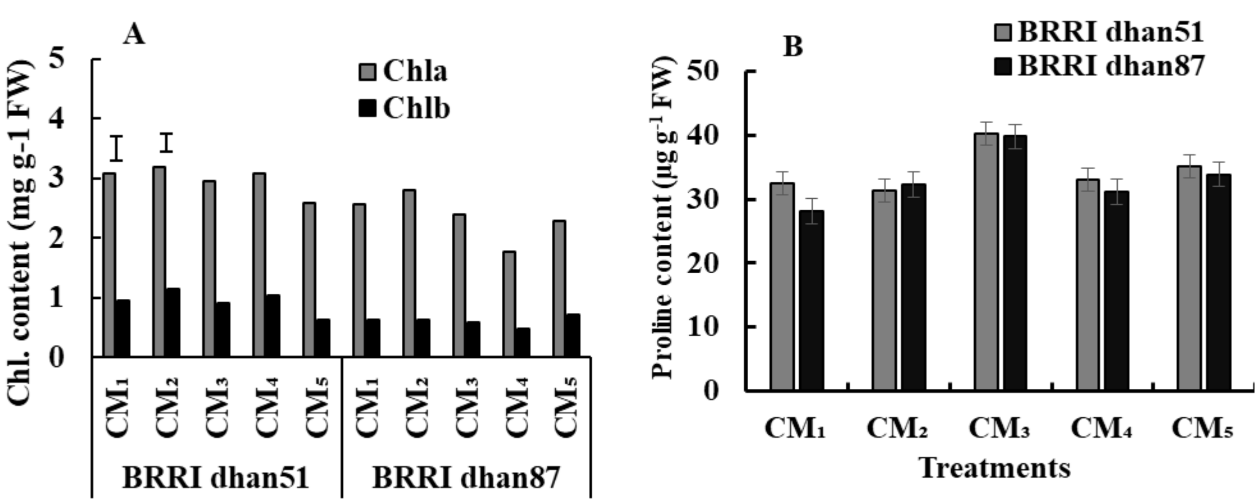


Figure 15. Chlorophyll contents (A) and Proline contents in leaves at the heading stage (B) stage in the two rice cultivars under waterlogging stress. Vertical bars represent Lsd (0.05).

Table 22. Yield and yield components of BRRI dhan51 and BRRI dhan87 as affected by crop management at BRRI farm, Gazipur

Variety	Crop management	Plant ht. (cm)	Panicle $hill^{-1}$	Grains $panicle^{-1}$	Yield (g pot^{-1})
BRRI dhan51	CM_1	117	27	164	75.5
	CM_2	116	25	165	69.6
	CM_3	115	21	148	52.7
	CM_4	118	24	151	69.8
	CM_5	117	23	171	63.2
BRRI dhan87	CM_1	137	25	136	55.8
	CM_2	136	26	146	82.8
	CM_3	131	22	109	49.6
	CM_4	134	24	95	52.1
	CM_5	132	20	91	37.4
LSD $_{(0.05)}$ for V × CM		NS	2.16	36.4	16.17
CV (%)		2.5	5.2	15.3	15.4

CM_1 = Recom. Fertilizer Dose (100%), CM_2 = RDF 100% + 10 µM ABA + water stress, T_3 = RDF 100% + 10 µM H_2O_2 + water stress, T_4 = RDF 100% + 5 mM GSH + water stress, T_5 = RDF 100% + 5 mM Proline +water stress; V_1= BRRI dhan51 and V_2 = BRRI dhan87.

Nutrient uptake

Reduced nitrogen uptake is one of the main effects of waterlogging stress in rice. Nutrient uptake significantly varied among the varieties and treatments. CM1 treatment has higher N, P, K uptake at maturity stage (114, 22.3, 109 kg ha^{-1}) in BRRI dhan87 followed by (109, 17.7, 98.6 kg ha^{-1}) in BRRI dhan51, whereas statistically similar N, P, K uptake was found in both varieties for CM2. There were no consistent differences between BRRI dhan51 and BRRI dhan87 in other management for N, P, K uptake. Irrespective of treatments higher N uptake was found in BRRI dhan87 followed by BRRI dhan51, respectively (**Figure 16**).

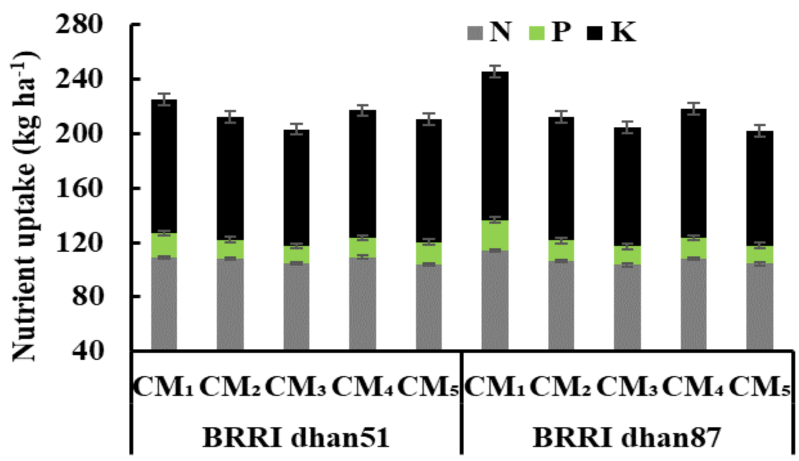


Figure 16. Total nutrient uptake (kg ha^{-1}) of BRRI dhan51 and BRRI dhan87 influenced by different crop management, Vertical bars represent standard error (SE).

Conclusion

Stagnant waterlogging for 7 to 10 days from the active tillering stage onwards, showed markedly reduced tiller, panicle $plant^{-1}$ and grain yield. Recommended fertilizer (100%) with Phyto protectants (ABA) could partially improve the growth, and ameliorates the adverse effects of waterlogging stress on rice. The experiment needs to be repeated for further confirmation.

Expt.12: **Growth stage-based Nitrogen management for yield maximization of Hybrid rice in T. Aman and Boro season**

PI: M K A Bhuiyan, CI: M M Mahbub

Rationale

Hybrid rice has different patterns of N uptake at different growth stages of rice. It was found that the later-flowering spikelet of hybrid varieties have more soluble carbohydrates and sucrose than earlier-flowering superior spikelet at the grain-filling stage (Mohapatra *et al.*, 1993, Tao and

Zhang 2003). Islam and Bhuiya (2007) reported that @160 kg N ha^{-1} in 4 equal splits at basal, MT, PI, and heading stages showed better growth and yield. The number of grains per panicle resulting from late nitrogen application (PI stage) was 12% greater than that obtained from traditional nitrogen application (Wei *et al*., 2016). Islam (2009) reported that the last top dress of urea during the flowering stage produced a higher grain yield of hybrid rice. For irrigated rice in the Sahel (Djaman K 2018) environment it is recommended to apply nitrogen for higher yield by splitting in three (e.g., 40% N applied at 15 DAT, 40% at panicle initiation and the remaining 20% at the booting stage).

Hypothesis

A fourth split of nitrogen application at booting or early flowering stage can improve the grain filling of hybrid varieties which resulted in higher grain yield.

Objectives:

1. To investigate hybrid rice response to different nitrogen levels and timing of application at different growth stages to achieve higher yield and
2. To determine the nitrogen use efficiency of BRRI hybrid rice varieties

Methodology

The experiments were conducted following a split plot design with 3 Reps. (N rate in main plot and time of N application in sub-plot at BRRI farm Gazipur. BRRI hybrid dhan5 (Boro season) and BRRI hybrid dhan6 (T. Aman season) were used as planting materials. The N rates (Kg ha^{-1}) were 0, 50, 100, 150 and 200 for the Boro season and 0, 40, 80, 120, and 160 for the T. Aman season, respectively.

N application timing in T. Aman and Boro seasons were as follows

Time of N application in Aman 2022 and Boro 2022-23	NT1	25% as basal	25% at Active tillering	25% at Mid-tillering stage (MT)	25% before panicle initiation
	NT2	20% as basal	30% during AT	30% at maximum tillering stage	20% during booting stage
	NT3	20% as basal	30% during AT	35% during maximum tillering stage	15% during flowering stage

Initial soil chemical properties at 0–15 cm soil depth in the experimental plot were: soil pH= 6.3, total N(%)= 0.12, exchangeable K (m equi/ gm soil) 0.18, available P (ppm) were 11.6. other doses of fertilizers for P, K, S and Za were applied as TSP, MoP, Gypsum and $ZnSO_4$. All other agronomic practices were applied as and when necessary.

Nitrogen content and Nitrogen uptake by rice plants

After harvest grain and straw samples were taken from respective plots and all samples were oven-dried, weighed, ground, and then subsamples were taken for N determination. N content grains and straw was measured by the standard micro-Kjeldahl procedure. N uptake in grain and straw was calculated by following formulae:

$$\text{Nitrogen uptake by grain (kg ha}^{-1}\text{)} = \frac{\text{\% N in grain} \times \text{grain yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Nitrogen uptake by straw (kg ha}^{-1}\text{)} = \frac{\text{\% N in straw} \times \text{straw yield (kg ha}^{-1}\text{)}}{100}$$

Nitrogen use efficiency

Nitrogen use efficiencies are grouped or classified as agronomic efficiency, physiological efficiency, agro-physiological efficiency, apparent recovery efficiency, and utilization efficiency and are calculated by using the following formulas (Fageria *et al*., 1997; Fageria and Baligar, 2001).

Agronomic efficiency (AE) = Gf - Gu /Na = kg kg^{-1}

where Gf is the grain yield in the fertilized plot (kg), Gu is the grain yield in the unfertilized plot (kg) and Na is the quantity of nutrients applied (kg).

Physiological efficiency (PE) = Yf - Yu / Nf –Nu = kg kg^{-1}
where Yf is the total biological yield (grain plus straw) of the fertilized plot (kg), Yu is the total biological yield in the unfertilized plot (kg), Nf is the nutrient accumulation in the fertilized plot (kg), and Nu is the nutrient accumulation in the unfertilized plot (kg).
Agrophysiological efficiency (APE) = Gf - Gu / Nf – Nu = kg kg^{-1}
where Gf is the grain yield in the fertilized plot (kg), Gu is the grain yield in the unfertilized plot (kg), Nf is the nutrient accumulation by straw and grains in the fertilized plot (kg), and Nu is the nutrient accumulation by straw and grains in the unfertilized plot (kg).
Apparent recovery efficiency (ARE) = Nf - Nu /Na × 100 = %
where Nf is the nutrient accumulation by the total biological yield (straw plus grain) in the fertilized plot (kg), Nu is the nutrient accumulation by the total biological yield (straw plus grain) in the unfertilized plot (kg), and Na is the quantity of nutrient applied (kg).
Utilization efficiency (EU) = PE × ARE = kg kg^{-1}
Partial factor productivity (PFP): It is the average productivity, and measured by grain output divided by quantities of fertilizer. PEP is an important indicator of fertilizer use efficiency was calculated using grain yield and the amount of N applied

Partial factor productivity (PFP) = Grain yield (kg ha^{-1}) /N applied (kg ha^{-1})

Results and discussion

T. Aman season
Table 23 indicated that the interaction effect of GSBNM× N rates on grain yield, straw yield, and HI were not significant. But different N rates significantly affect grain yield, straw yield, and harvest index. It was observed that N applied as 25% basal + 25% at AT+ 25% at MT + 25% at BPI with 120 kg N ha^{-1} produced higher grain yield (6.67 t ha^{-1}). Lower yield (5.56 t ha^{-1}) was observed from N application in 20% basal+ 30% at AT + 35% at Max. Tillering + 15% at FS 15% with 120 kg N ha^{-1}. **Table 24** showed non significant effect of GSBNM on grain yield and N content and uptake in grain and straw.
Nitrogen content in grain and straw was presented in **Table 24.** Grain and straw N (%) was the highest with the treatment received 120 kg N ha^{-1} applied at different growth stages. The highest grain and straw N content (1.54 % & 0.85 %) were observed in 120 kg N ha^{-1} with N applied as 25% basal +25% at active tillering stage + 25% at MT + 25% at BPI. The treatment N_{120} obtained the highest N uptake in grain and straw (102.83 kg ha^{-1}, 46.46 kg ha^{-1}). The lowest N uptake in grain and straw was observed in the control plot, which indicated the soil inherent capacity of N supply to rice plants. Nitrogen uptake in grain and straw with corresponding N rates was highly significant (**Table 25**).
Nitrogen use efficiency (NUE) by crop plants has been defined in six different ways. All six nitrogen use efficiencies were calculated and are presented in **Table 26**. All the N use efficiencies were significantly decreased with increasing N rates in most cases. Across N rates higher agronomic efficiency was 50 and lower was 7 kg grain produced per kg N applied, and physiological efficiency was 137 and 58 kg biological yield (straw plus grain) per unit of N accumulation was calculated. Agro-physiological efficiency was 60 and 34 kg grain produced per kg of N accumulated in the grain and straw across N rates. Apparent recovery efficiency was 110 and 13 and utilization efficiency was 96 and 18 kg grain produced per kg of N utilized across N rates. Partial factor productivity was 136 and 33 across N rates.
Determination of optimum doses of N for BRRI hybrid dhan6
The optimum dose for the tested hybrid rice varieties was determined by regression of the grain yield with the N tares: $Y=a+bN+cN^2$. Where Y is rice yield (kg ha^{-1}), N is nitrogen dose (kg ha^{-1}), a is intercept (estimated yield without N application), and b and c are co-efficient, respectively. Differentiating Y with respect to N of the equation gives the nitrogen dose for the maximum yield. The optimum nitrogen dose for maximum yield was calculated by N=-b/2c.The variation of grain yield of BRRI hybrid dhan6 at different nitrogen rates was determined through

a regression equation (**Figure 17**). Differentiating the quadratic equation of yield response with respect to applied different N doses the optimum N rate appeared as 100 kg, and 109 kg ha^{-1} and 91 kg ha^{-1} for BRRI hybrid dhan6 with corresponding GSBNM practices respectively.

Boro Sesson

Table 27 indicates a significant effect of GSBNM × N rate on the grain yield yield of BRRI hybrid dhan5. Among the N rates 150 kg N ha^{-1} with 20% as basal +30% at AT + 30% at Max. tillering +20% at BS observed the highest grain yield (8.53 t ha^{-1}).

Determination of optimum doses of N for BRRI hybrid dhan5

The optimum dose for the tested BRRI hybrid dhan5 was determined by regression of the grain yield with the N tares: $Y=a+bN+cN^2$. Where Y is rice yield (kg ha^{-1}), N is nitrogen dose (kg ha^{-1}), a is intercept (estimated yield without N application), and b and c are co-efficient, respectively. Differentiating Y with respect to N of the equation gives the nitrogen dose for the maximum yield. The optimum nitrogen dose for maximum yield was calculated by $N=-b/2c$. The variation of grain yield of BRRI hybrid dhan5 at different nitrogen rates was determined through a regression equation (**Figure 18**). Differentiating the quadratic equation of yield response with respect to applied different N doses the optimum N rate appeared as 139 kg, 169 kg ha^{-1}and 155 kg ha^{-1}for BRRI hybrid dhan5 with corresponding GSBNM practices, respectively.

Conclusion: Nitrogen applied as 25% basal + 25% at active tillering stage + 25% at mid tillering stage + 25% at before panicle initiation with 120 kg N ha^{-1} produced the highest grain yield, straw yield, uptake more N in grain and straw. The optimum N rate appeared as 100 kg, and 109 kg ha$^{-1,}$ and 91 kg ha^{-1} for BRRI hybrid dhan6 with corresponding GSBNM practices, respectively. Among them, 100 kg N ha^{-1} was the best for BRRI hybrid dhan6 according to growth stage-based application and scheduling. But in Boro season, for BRRI hybrid dhan5 N application, @150 kg ha^{-1} with 20% as basal + 30% at active tillering stage + 30% at maximum tillering stage + 20% at booting + 15% during flowering produced the highest grain yield.

Table 23. Interaction fffect of growth stage-based N management and N rates on grain yield, straw yield and harvest index of BRRI hybrid dhan6, T. Aman 2022, BRRI farm, Gazipur.

Nitrogen rate (kg ha^{-1})	N management	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	HI
N_0	NT1	3.43	4.34	0.45
N_{40}		5.43	6.94	0.45
N_{80}		5.72	6.17	0.47
N_{120}		6.67	6.05	0.53
N_{160}		5.11	5.97	0.46
N_0	NT2	3.28	4.37	0.43
N_{40}		5.13	5.65	0.47
N_{80}		5.34	5.86	0.47
N_{120}		6.02	5.74	0.51
N_{160}		5.28	6.78	0.46
N_0	NT3	3.37	3.96	0.46
N_{40}		5.48	5.68	0.49
N_{80}		5.60	5.62	0.50
N_{120}		5.84	5.98	0.51
N_{160}		4.50	5.97	0.43
Lsd for GSBNM		ns	0.28	ns
Lsd for N rate		0.38	0.37	0.26
Lsd for N × GSBNM		ns	ns	ns
CV(%)		7.5	6.7	5.7

Table 24. Effect of GSBNM on grain yield, straw yield, N content, and N uptake of BRRI hybrid dhan6

Growth stage-based N management	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	N (%) grain	N (%) straw	N uptake by grain (Kg ha^{-1})	N uptake by straw (Kg ha^{-1})
Basal (25%) + Active tillering stage (25%) + Mid tillering stag (25%) +Before panicle initiation (BPI) (25%) (NT1)	5.27	5.83	1.17	0.57	65.91	30.25
Basal (20%) +Active tillering stage (30%) + maximum tillering stage (30%) + Booting (20%) (NT2)	5.01	5.63	1.18	0.56	61.97	28.36
Basal (20%) + Active tillering stage (30%) + maximum tillering stage 35% + during flowering (15%) (NT3)	4.95	5.34	1.21	0.55	62.99	27.60
$LSD_{(0.05)}$	ns	0.28	ns	ns	ns	ns
CV(%)	7.5	6.7	9.5	2.6	13.4	12.8

Table 25. Interaction effect of growth stage-based N management and N rate on N content in grain, straw and N uptake in BRRI hybrid dhan6

Nitrogen rate (kg ha^{-1})	Growth stage-based N management	N content in grain (%)	N content in straw (%)	N uptake in grain (Kg ha^{-1})	N uptake in straw (Kg ha^{-1})
0	Basal (25%) +Active tillering stage (25%) +Mid tillering stag (25%) +Before panicle initiation (BPI) (25%)(NT1)	0.84	0.40	36.43	17.02
40		1.12	0.47	60.64	24.72
80		1.37	0.62	78.51	32.40
120		1.54	0.85	102.73	46.56
160		1.0	0.51	51.30	30.57
0	Basal (20%) +Active tillering stage (30%) +maximum tillering stage (30%) +Booting (20%) (NT2)	0.79	0.39	35.15	15.68
40		1.18	0.46	60.45	21.63
80		1.40	0.61	74.63	29.85
120		1.50	0.82	83.62	40.18
160		1.06	0.55	56.03	34.49
0	Basal (20%) +Active tillering stage (30%) +maximum tillering stage 35% + during flowering (15%)(NT3)	0.86	0.40	38.09	16.01
40		1.40	0.45	76.91	21.05
80		1.30	0.61	71.69	30.19
120		1.48	0.80	83.16	40.33
160		1.0	0.52	45.09	30.45
Lsd $_{(0.05)}$ for GSBNM		ns	**	ns	**
Lsd $_{(0.05)}$for N rate		0.11	0.14	8.40	3.61
Lsd $_{(0.05)}$ for N × GSBNM		ns	0.25	14.55	ns
CV(%)		9.5	2.6	13.4	12.8

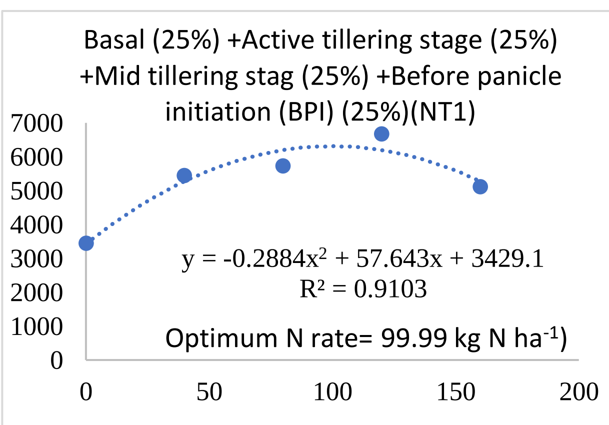
Table 26. Nitrogen use efficiencies of BRRI hybrid dhan6 as affected by growth stage-based N management and N rates

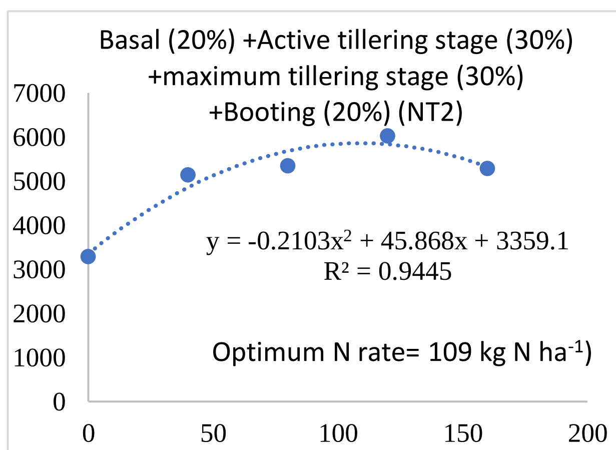
Nitrogen rate (kg ha^{-1})	Growth stage-based N management	AE Kg ka^{-1}	PE Kg ka^{-1}	APE Kg ka^{-1}	ARE (%)	UE Kg ka^{-1}	PFP Kg ka^{-1}
40	Basal (25%) +Active tillering stage (25%) + Mid tillering stag (25%) + Before panicle initiation (BPI) (25%)	50	77	41	80	62	136
80		29	53	34	72	38	71
120		27	121	60	80	96	56
160		11	113	60	18	20	32
40	Basal (20%) +Active tillering stage (30%) +maximum tillering stage (30%) +Booting (20%)	46	73	39	78	56	128
80		26	58	38	67	39	67
120		23	97	50	61	60	50
160		12	114	50	25	29	33
40	Basal (20%) +Active tillering stage (30%) +maximum tillering stage 35% + during flowering (15%)	53	81	46	110	85	137
80		28	60	36	60	36	70
120		21	150	54	58	87	49
160		7	137	54	13	18	28
Average		28	95	47	60	52	71

AE= Agronomic Efficiency ,PE= Physiological Efficiency, APE= Agro-physiological Efficiency, ARE= Apparent Recovery Efficiency, UE= Utilization Efficiency, PFP= Partial factor Productivity

Table 27. Interaction effect of growth stage-based N management and N rate on grain yield of BRRI hybrid dhan5, Boro 2022-23, BRRI, Gazipur

Nitrogen rate (kg ha^{-1})	Growth stage-based N management	Grain yield (t ha^{-1})
0	Basal (25%) +Active tillering stage (25%) +Mid tillering stag (25%) +Before panicle initiation (BPI) (25%)	3.86
50		6.39
100		7.29
150		8.15
200		7.39
0	Basal (20%) +Active tillering stage (30%) +maximum tillering stage (30%) +Booting (20%)	3.57
50		6.82
100		7.86
150		8.53
200		7.84
0	Basal (20%) +Active tillering stage (30%) +maximum tillering stage 35% + during flowering (15%)	3.83
50		7.11
100		7.87
150		7.85
200		7.53
Lsd for GSBNM		ns
Lsd for N rate		0.38
Lsd for N × GSBNM		0.58
CV(%)		5.2





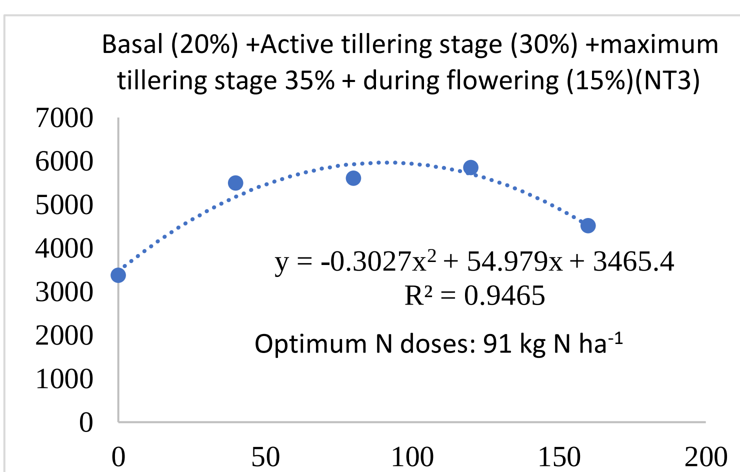


Figure 17. Grain yield responses to growth stage-based N management and N rates and determination of optimum N doses in BRRI hybrid dhan6

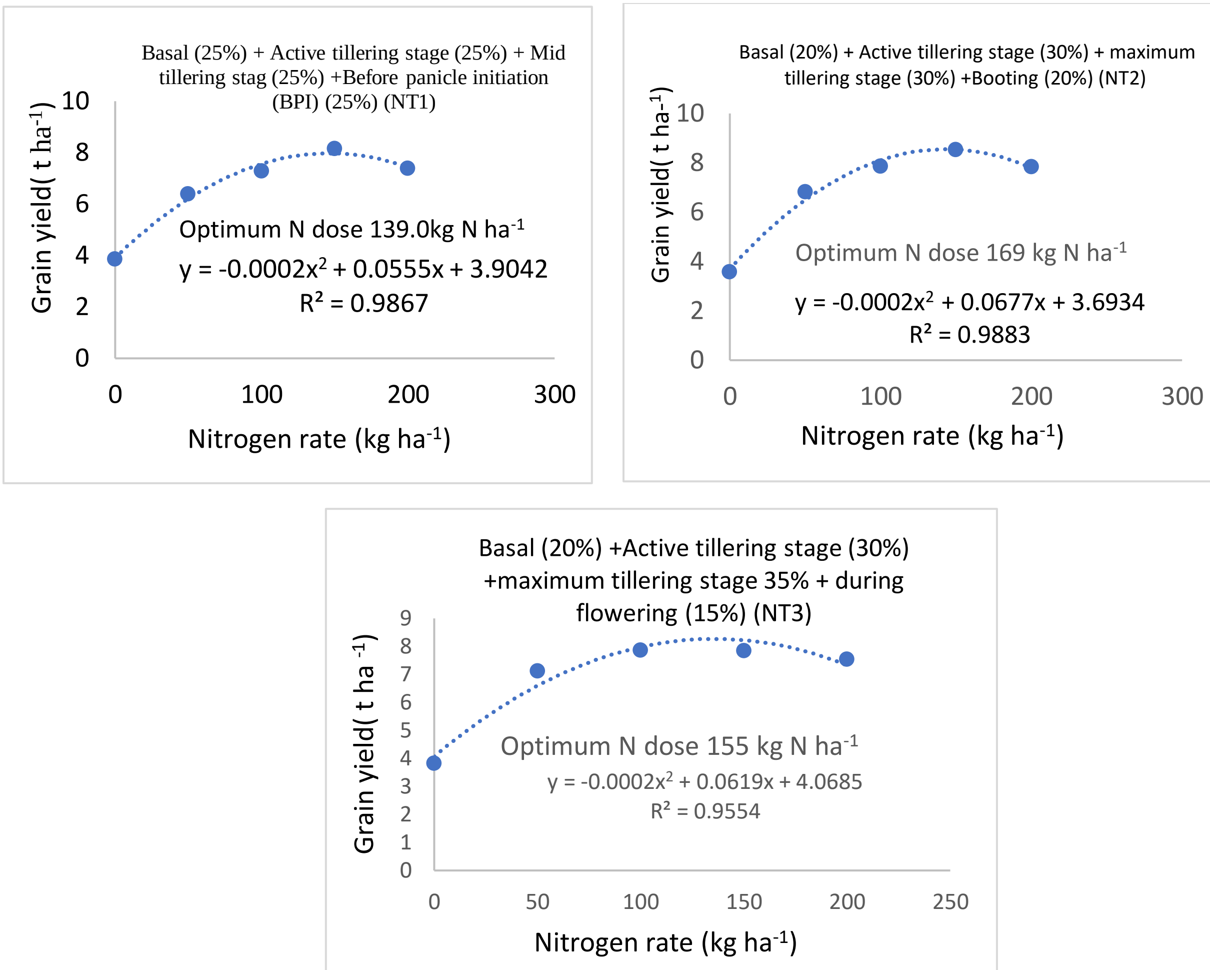


Figure 18. Grain yield responses to growth stage-based N management and N rates and determination of optimum N doses in BRRI hybrid dhan5

MOLECULAR TRAIT MANAGEMENT

Expt.13: Physiological, biochemical and molecular mechanisms of salinity tolerance in rice

PI: M M Rana, CI: S A Islam and N Akter

Introduction

Salinity is the second-leading soil problem in rice-growing countries, and it is thought to be a major global barrier to boosting rice production (Gregorio *et al.*, 1997). Salinity is reported to affect around 100,000 hectares of rice crop land by 2056. It has also been observed that the cultivation of salinity-sensitive rice genotypes can reduce rice yield by 50% (Selamat & Ismail, 2008). In general, the large inhibitory effect of salinity on plant growth can be attributed to: (1) osmotic effects, (2) ionic toxicity, and (3) nutritional imbalance. Possible salt tolerance mechanisms in rice involve ion homeostasis and compartmentalization, ion transport and uptake, biosynthesis and accumulation of osmo-protectants, osmolytes, and compatible solutes, activation of antioxidant enzymes for ROS detoxification, and hormone modulation (Reddy *et al.*, 2017). BRRI has developed six excellent salt tolerant varieties having good yield, but their salt tolerance mechanism is not extensively studied. This study aimed to get insight into the physiological, biochemical and molecular mechanisms by which BRRI developed salt-tolerant varieties respond to the salinity stress.

Materials and methods

This study was conducted from April to June 2023 in a rain-out shelter, Agronomy Division, Bangladesh Rice Research Institute, Gazipur. Six rice varieties (BRRI dhan47, BRRI dhan67, BRRI dhan73, BRRI dhan78, BRRI dhan88, and BRRI dhan99) were tested at seedling stage using pot culture. Two different salinity level viz. 0 and 12 dSm^{-1} were considered as salinity treatment. The trial was set up in a complete randomized design using three replicates with 10 plants per trial unit. Salt was added 14 days after planting to measure the visual symptoms of salt toxicity.

Measurement of K^+ and Na^+ content in shoot

Rice shoots were harvested randomly 14 days of salt imposed and oven-dried at 75°C for 48 hours. Finely powered plant samples (50 mg) were digested with $HNO_3/HClO_4$ solution (7.5:2.5) using a digester until the solution becomes clear. The digested solution was shaken gently and filtered through 0.2-µm filters (Whatman, England), and the solid fraction was discarded. The digest was diluted to 25 ml in volumetric flask. Three biological replicates were used. The content of Na^+ and K^+ in the extract was quantified by flame photometer (PFP7, Jenway, Staffordshire, ST15 OSA, UK) using a standard curve.

RNA isolation, cDNA synthesis and quantitative real-time PCR (qRT-PCR) analysis

Total RNA from rice shoot tissue (100 mg) was extracted using the Trizol method, and the cDNA was synthesized from 1 µg of the total RNA with ReverTra Ace® qPCR RT Master Mix with gDNA Remover (Toyobo, Japan) according to the manufacturer's instructions. The qPCR analysis was performed using SsoFast Eva Green Supermix (Bio-Rad) and CFX96 real time PCR system/C1000TM Thermal Cycler (Bio-Rad). The expression level of the *18S rRNA* gene (Accession no. AK059783) was used as an internal control (reference gene). Relative expression of the target genes was calculated using the comparative Ct method.

Results and Discussion

Data on seedling growth and salinity injury of the tested rice genotypes were recorded (**Figure 19 & 20**). The results showed that BRRI dhan47 and BRRI dhan99 are tolerant [1]; BRRI dhan67 and BRRI dhan73 are moderately tolerant; and BRRI dhan78 is susceptible at 12 dSm^{-1}. The ratio of Na: K varied significantly at 0 and 12 dSm^{-1} among the tested rice cultivars (**Figure 21**). The lower amount of Na: K was measured from rice cultivars BRRI dhan47 and BRRI dhan99 followed by BRRI dhan73 > BRRI dhan67 > BRRI dhan78 > BRRI dhan88 at 12 dSm^{-1} salinity level.

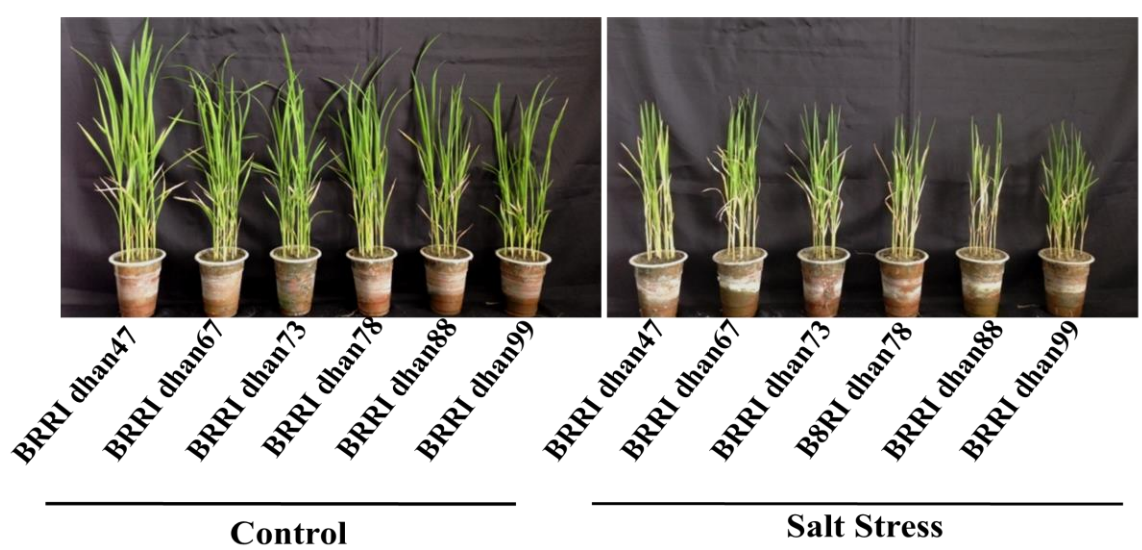


Figure 19. Phenotypic comparison of rice seedlings grown in 0 and 12 dSm^{-1} NaCl for two weeks

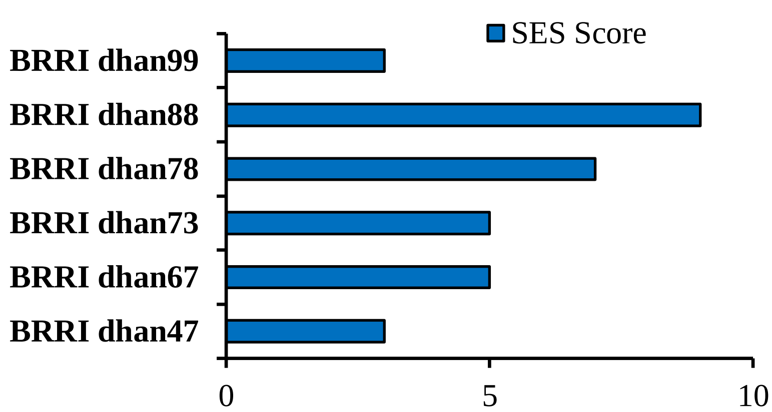


Figure 20. SES* score of rice seedlings grown in 12 dSm^{-1} salt stress for 10 days

*SES score 1, 3, 5, 7, 9 indicate highly tolerant, tolerant, moderately tolerant, susceptible and highly susceptible, respectively.

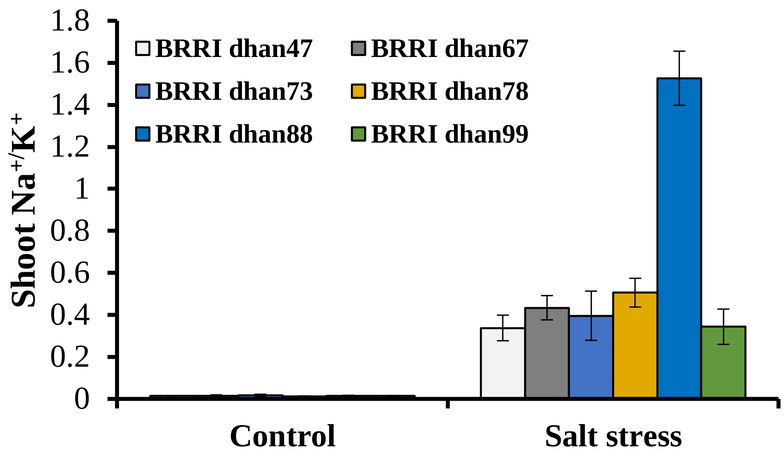


Figure 21. Shoot Na^{+}/K^{+} of the tested rice varieties grown with or without salt stress

Without NaCl stress, no significant difference in proline content was observed among the genotypes. Under salt stress condition, BRRI dhan67 and BRRI dhan99 had significantly higher proline content followed by BRRI dhan47, BRRI dhan73, BRRI dhan78, and BRRI dhan88 (**Figure 22**). The relative expression levels of ***OsHKT1;1, OsSalT*** and ***OsNHX1*** transcripts were analyzed in rice shoot grown with or without salt stress. In BRRI dhan88, the relative expression levels of ***OsHKT1;1, OsSalT*** and ***OsNHX1*** were not increased under salt stress, relative to the control condition (**Figure 23**). Under salt stress condition, BRRI dhan47, BRRI dhan67, BRRI dhan73, BRRI dhan78 and BRRI dhan99 had significantly higher relative expression levels of high-affinity K^+ transporter 4 (*OsHKT1;1*) than the control condition. The relative expression level of *OsSalT* was more than 2-fold in BRRI dhan78 under salt stress. In BRRI dhan73 and BRRI dhan99, the relative expression levels of Na^+/H^+ exchangers (*OsNHX1*) were under salt stress, relative to the control condition. The high-affinity K^+ transporter 4 (*OsHKT1;1*) gene has been found to regulate accumulation of higher K^+ and lower Na^+ in shoots under salt stress (Garciadeblás *et al.*, 2003). Therefore, salinity tolerance in BRRI dhan47, BRRI dhan67, BRRI dhan78 associate with the function of *OsHKT1;1* in maintenance of K^+/Na^+ homeostasis in the tissue. Salinity tolerance in BRRI dhan73 and BRRI dhan99 might associate with the function of *OsHKT1;1 and* Na^+/H^+ exchangers (*OsNHX1*).

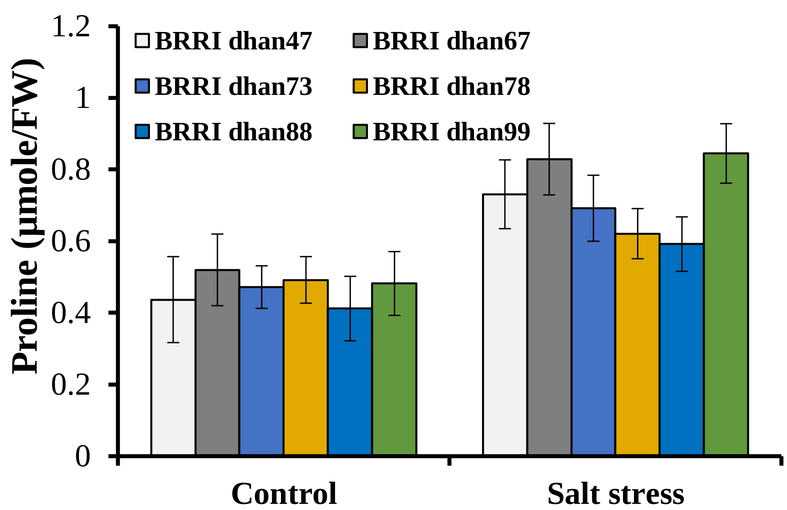


Figure 22. Proline content of the tested genotypes grown with or without salt stress

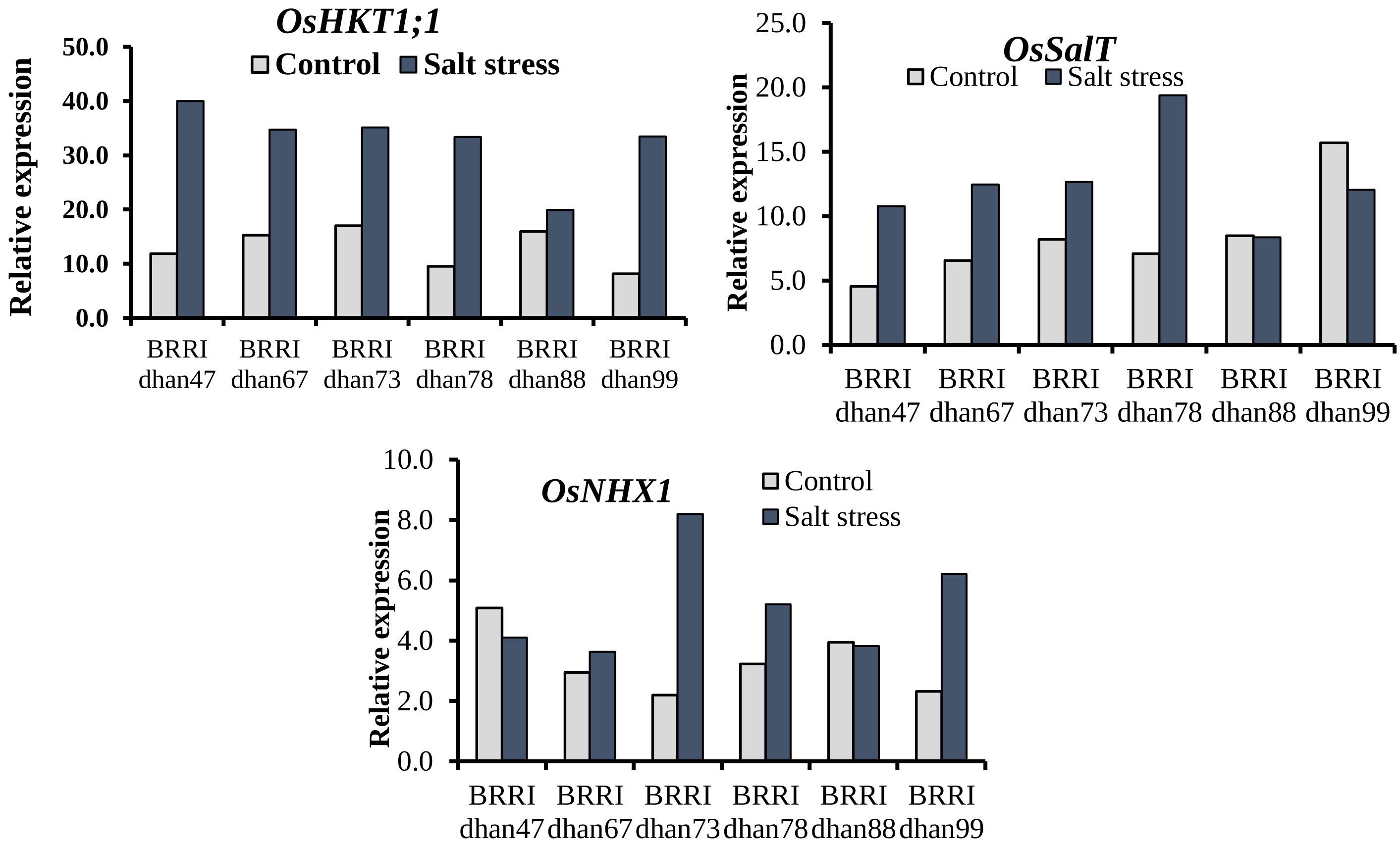


Figure 23. Relative expression levels of *OsHKT1;1*, *OsSalT* and *OsNHX1* transcripts in rice shoot grown with or without salt stress

Conclusion

Salinity tolerance in BRRI dhan47, BRRI dhan67 and BRRI dhan78 associate with the function of *OsHKT1;1* in maintenance of K^+/Na^+ homeostasis in the tissue. Salinity tolerance in BRRI dhan73 and BRRI dhan99 might associate with both the function of high-affinity K^+ transporter 4 (*OsHKT1;1*) *and* Na^+/H^+ exchangers (*OsNHX1*).

GOOD AGRICULTURAL PRACTICES

Expt.14: Yield maximization of Boro rice through good agricultural practice (GAP)

PI: MKA Bhuiyan, CI: MM Mahbub and M Sh Islam

Rationale

Good agricultural practices (GAPs) in rice production comprised a package of technologies, including improved variety, nursery preparation and intensive care, transplanting, weeding and pest management, nutrient management, water management and timely and proper harvesting (MOAI Myanmar, 2013) which make safe and healthy food while taking into account economic, social and environmental sustainability. Reducing the rice yield gap may be partly achieved through practicing good agricultural practices (GAP) in many countries. The purpose of this work is to spread the basic concepts of Good Agricultural Practices (GAP) in order to: guide the production systems towards sustainable agriculture and ecologically safe, obtain harmless products of higher quality, contribute to food security.

Objectives

1. To observe the yield performance by practicing GAPS
2. To compare the economics of GAPs and BRRI-recommended practices

Materials and Methods

There are many components of GAPs. Among them, a few components were evaluated on three varieties. The varieties were BRRI hybrid dhan5, BRRI dhan100, and BRRI dhan96. Good agricultural practice (GAP) and conventional recommended management (CRM) were considered. Management of GAPs were a. Balance fertilizer application (N,P,K,S, Zn) (soil test based) b. Alternate wetting and drying (AWD) c. BRRI weeder fb 1 HW at 45 DAT d. Integrated insect and disease management and e. Maintaining planting depth 2-3cm. Conventional BRRI recommended management (CRM) were: a. BRRI recommended fertilizer and cultural practices b. Normal irrigation practice, c. Herbicide fb 1HW d. Insect and disease management by applying pesticides. The experiment followed a factorial RCB design with three replications during the Boro season of 2022-23 at BRRI farm Gazipur.

Results and discussion

Table 28 showed that the interaction effect of varieties × management differed significantly on grain yield, straw yield, and harvest index. Individual effects of varieties also differed significantly on grain yield but management had no significant effect on grain yield, straw yield and HI. But GAPs management gave higher yield in BRRI dhan100 and BRRI dhan96. Because in GAPs practice fertilizers were applied as plant demand. So, the growth and development of plants were better which contributed to producing more grain panicle^{-1} and panicles m^{-2}. The highest grain yield was observed in BRRI dhan100×GAPs (8.02 t ha^{-1}) followed by BRRI hybrid dhan5 with GAPs. According to the results, it revealed that GAPs produced higher grain yield compared to conventional BRRI recommended practices in different varieties, which are safe, environment-friendly and cost-effective.

Partial budgeting of GAP against CRM with different BRRI varieties

The estimated net change in profit due to the adoption of GAPs techniques over CRP worked out using partial budgeting technique was found significantly higher. The net change in the profit obtained by the GAPs techniques was observed to be 808 Tk./ ha for BRRI hybrid dhan5, 23383 tk. /ha for BRRI dhan100 and 11608 Tk./ha for BRRI dham96 (**Table 29, 30 and 31**). Hence, it can be concluded that the adoption of GAPs practices in rice cultivation is economically viable.

Table 28. Yield and yield characters of BRRI varieties as affected by two management practices at BRRI farm Gazipur during Boro 2022-2023.

Variety (V)	Management (M)	GY (t ha^{-1})	SY (t ha^{-1})	HI
BRRI hybrid dhan5	GAP	7.63	7.85	0.49
	CRM	7.61	8.69	0.47
BRRI dhan100	GAP	8.02	7.71	0.51
	CRM	7.30	7.92	0.48
BRRI dhan96	GAP	6.95	7.64	0.48
	CRM	6.56	7.52	0.47
LSD $_{(0.05)}$ for V		0.45	ns	ns
LSD $_{(0.05)}$ for M		ns	ns	ns
LSD $_{(0.05)}$ for V × M		0.51	ns	ns
CV (%)		4.0	7.5	3.2

GAP=Good agricultural practices; CRM= Conventional BRRI recommended management

Table 29. Partial budgeting of GAP against CRM with BRRI hybrid dhan5

Added income due to change	**Added cost due to change**
BRRI hybrid dhan5 (Paddy)= 20 kg @ Tk.30/kg = Tk.600.00	Weeding= Tk.2100
Straw 840 kg @ 2.5 Tk/ kg = Tk. (-)2100 Tk.	Perching = Tk. 600
Reduced cost due to change	Reduce income due to cost= None
Fertilizer = Tk. 4208	
Irrigation = Tk. 800	
Sub total = 600-(2100)+4208+800) = Tk. 3508	Sub-total= Tk. 2700.00
Net change= (3508-2700) Tk. = 808 Tk.	

Table 30. Partial budgeting of GAP against CRM with BRRI dhan100

Added income due to change	**Added cost due to change**
BRRI dhan100 (Paddy)= 720 kg @ 30Tk/kg = Tk.21600.00	Weeding= Tk. 2100
The straw 210 kg @2.5Tk/ kg = Tk. 525	Perching = Tk.600
Reduced cost due to change	Reduce income due to cost= None
Fertilizer = Tk. 4208	
Irrigation = Tk. 800	
Sub-total = (21600-(525)+4208+800)= 26083 Tk.	Sub-total= Tk. 2700.00
Net change= (26083-2700) Tk. = Tk. 2338	

Table 31: Partial budgeting of GAP against CRM with BRRI dhan96

Added income due to change	**Added cost due to change**
BRRI dhan89 (Paddy)= 300kg @ 30Tk/kg = Tk. 9000.00	Weeding= Tk. 2100
Straw 120kg @2.5tk/ kg = Tk. 300	Perching = Tk. 600
Reduced cost due to change	Reduce income due to cost= None
Fertilizer = Tk. 4208	
Irrigation = Tk. 800	
Subtotal = (9000+300+4208+800) = Tk. 14308	Sub-total = Tk. 2700.00
Net change= (14308-2700) Tk. = Tk. 11608	

YIELD MAXIMIZATION

Expt. 15: Effect of agronomic factors for maximizing yield of BRRI dhan70 through developing sustainable production management protocol

P I: M A B S Sarker and **C I:** R A S A Islam, M M Rana

Rationale: The popularity and demand of Long Slender Premium Quality Fine Rice varieties are increasing day by day in country as well in abroad for their especial quality. BRRI already has developed some high yielding Long slender Premium Quality Fine Rice varieties for T. Aman season. There is a scope to increase productivity of land by introducing this variety with good management protocol and earn huge foreign currency by exporting this rice in the international market. BRRI dhan70 is similar quality like *Katarivog* and which is now becoming popular at Dinajpur region. But yield of these varieties is very low due to lack of proper production management protocol, disease especially BLB and blast infestation in T. Aman season. Lodging is one of the common problems which reduced the yield. To realize the potential yield and benefit of BRRI dhan70 is therefore, to be achieved through proper intervention of agronomic management for these varieties. Disease infestation also may keep minimum level by adopting the proper agronomic management. Grain quality may also improve through the Agronomic Management. So, it is needed to develop variety wise production management protocol for maximizing yield. This research aimed to find out the specific production management protocol for various ecosystems of this especial type of varieties. The objectives of the experiment were**:**

1. To study contributions of agronomic factors to maximize yield of BRRI dhan70 and
2. To find out and recommend the best production management protocol for sustainable higher yield of BRRI dhan70 in T. Aman season.

Methods and materials: Factor A: Two time of crop establishment (T): T_1 = 1 July Seeding and T_2 = 15 July Seeding. Factor B: Two age of seedling (A): A_1 = 15 day and A_2 = 30 day. Factor C: Two Population density or spacing (S): S_1 = 25 x 25 cm (16 hill m^{-2}) and S_2 = 20 x 20 cm (25 hill m^{-2}). Factor D: Two fertilizer management (F): F_1 = BRRI recommended, F_2 = Soil test based. The experiment was laid down in Factorial RCB design with three replications. BRRI recommended other intercultural managements like weed, irrigation, insects, diseases were followed as and when necessary.

Results and discussion: The result showed that there was significant grain yield difference in different agronomic management factor-based treatments (**Figure 24**).The highest grain yields were obtained from the agronomic based treatment combination of $F_2S_1A_1T_2$ (5.89 t ha^{-1}) followed by $F_2S_1A_2T_1$ (5.16 t ha^{-1}). The lowest grain yield was observed from $F_2S_2A_1T_1$ (1.52 t ha^{-1}). It was one year experiment result. For confirmation the result, the experiment needs to be repeated.

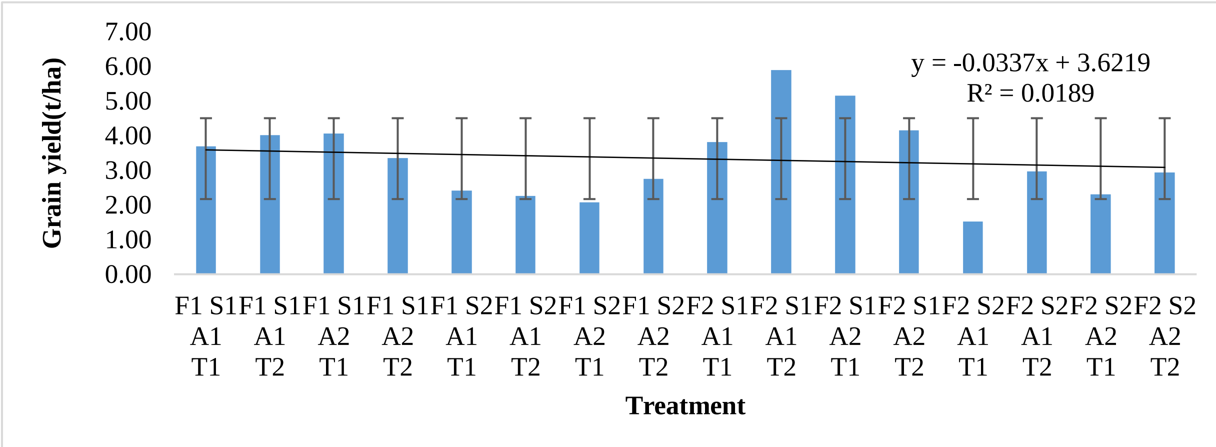


Figure 24: Effect of different agronomic factors on grain yield of BRRI dhan70 through developing sustainable production management protocol.

(T_1=1 July & T_2=15 July seeding; A_1= 15 day & A_2=30 day old seedling; S_1=25×25 cm & S_2=20×20 cm spacing, F_1=BRRI recommened & F_2=STB dose)

Expt. 16: Maximizing yield of BRRI developed T. Aman varieties through influencing some Agronomic Critical Factors

P I: M A B S Sarker, **CI:** R Akter and M M Rana

Rationale: To realize the potential yield of rice and it's benefit, Agronomic Critical factors or practices i.e. plant spacing, intermittent drying and wetting of field, young seedling, frequent weeding and addition of compost have importance. The increased yields also depend on other factors: careful and timely transplanting of seedling; preparation and management of the soil; control over irrigation water; quality of the soil itself and varieties appropriate for the specific growing areas. The new sets of technique may change the traditional management practices to bring out the unexploited potentiality of rice production in Bangladesh. So, much research and evaluation still need to be done on these Agronomic critical factors for growing higher rice production.

This study of the individual factor together with their possible combinations under a given environmental site like BRRI, Gazipur has been examined with the following objectives:

1. To study the effect of Agronomic most critical factors for yield maximization of BRRI developed varieties.
2. To find out and recommended the most appropriate Agronomic critical factors packages for yield maximization of BRRI developed varieties.

Materials and Methods: Different Agronomic critical factors based five managements were considered as Factor A: M_1 = BRRI Recommended practices, Agronomic Critical factors based proposed four treatments were M_2, M_3, M_4 and M_5. Factor B was three varieties: V_1= BRRI dhan71as short duration, V_2= BRRI dhan87 as medium duration and V_3= BRRI dhan52 as long duration. The detail treatment description is as bellow:

Critical factors	M_1	M_2	M_3	M_4	M_5
Transplanting time	V_1=BRRI dhan71 August 15 V_2=BRRI dhan87 August 10 V_3=BRRI dhan52 July 30	V_1=BRRI dhan71 July 30 V_2=BRRI dhan87 July 25 V_3=BRRI dhan52 July 14	V_1=BRRI dhan71 August 05 V_2=BRRI dhan87 July 30 V_3=BRRI dhan52 July 20	V_1=BRRI dhan71 August 10 V_2=BRRI dhan87 August 05 V_3=BRRI dhan52 July 24	V_1=BRRI dhan71 August 20 V_2=BRRI dhan87 August 15 V_3=BRRI dhan52 August 04
Seedling age (Day)	30	15	20	25	35

Spacing (cm x cm)	20 x 20	25 x 25	25 x 20	25 x 15	25 x 10
Seedling/hill	2-3	2	2	2	3-4
Upper soil Stirring	0	20 DAT & 35 DAT	20 DAT & 35 DAT	20 DAT & 35 DAT	20 DAT & 35 DAT

Other recommended intercultural operations were followed as when was necessary. The experiment was laid down in Factorial Randomized Complete Block design with three replication.

Results and discussion: The result showed that there was significant effect of different agronomic management factors on the yield and yield components of short duration, medium duration and long duration variety (**Table 32**). It was found that all tested varieties gave higher grain yield in the agronomic management combination M_4. Higher yield was achieved due to higher contribution of yield components especially higher panicle m^{-2} and grain panicle^{-1} production.

So for obtaining higher grain yield;

a. The seeding of short duration T. Aman variety like BRRI dhan71 should be done on 2nd week of July and transplanting on 1st week of August with 20-25 days old seedling. Following Spacing should be 25 x 15 cm and STB fertilizer management would be followed and additionally 1% MoP solution should be sprayed on 25 and 40 DAT. Additional 1 t ha^{-1} vermi-compost should be applied just before transplanting.

b. The seeding medium duration T.Aman variety like BRRI dhan87 should be done in 1st week of July and transplanting within 3rd week of August with 25 days old seedling. Spacing should be 25 x 15 cm and STB fertilizer management would be followed and additionally 1% MoP solution should be sprayed on 30 and 45 DAT. Additional 1 t ha^{-1} vermi-compost should be applied just before transplanting.

c. The seeding of long duration T.Aman variety like BRRI dhan52 should be needed done within 4th week of June and transplanting within 3rd week of July with 20 -25 days old seedling. Spacing should be 25 x 15 cm and STB fertilizer management should be followed and additionally 1% MoP solution should be sprayed on 30 and 45 DAT. Additional 1 t ha^{-1} vermi-compost should be applied just before transplanting.

Table 32. Effect of agronomic critical factors on plant height, panicle m^{-2}, grains panicle^{-1} and sterility% of Boro varieties at BRRI farm, Gazipur during Boro 2022-23

Management (M)	Variety (V)	Plant height (cm)	Panicle Number (M^{-2})	Fill grain (Panicle^{-1})	Grain yield (t ha^{-1})	Sterility (%)
M_1	BRRI dhan71	121	190	100	5.41	34
	BRRI dhan87	119	210	126	4.98	24
	BRRI dhan52	129	213	119	4.72	45
M_2	BRRI dhan71	133	193	130	5.07	27
	BRRI dhan87	133	212	104	4.86	37
	BRRI dhan52	132	221	103	5.76	41
M_3	BRRI dhan71	128	235	112	4.31	28
	BRRI dhan87	123	228	102	4.34	38
	BRRI dhan52	129	213	107	4.82	46
M_4	BRRI dhan71	128	237	128	6.72	21
	BRRI dhan87	118	233	125	6.55	38
	BRRI dhan52	100	237	113	6.28	38
M_5	BRRI dhan71	120	260	115	6.11	20
	BRRI dhan87	127	310	120	5.61	33
	BRRI dhan52	134	243	109	6.44	42
LSD $_{(0.05)}$ for V × M		25.997	55.235	25.882	1.154	14.315
LSD $_{(0.05)}$ for V		11.626	24.701	11.574	0.516	6.401
LSD $_{(0.05)}$ for M		15.009	31.889	14.942	0.666	8.264
CV (%) (Management*Variety)		12.4	14.6	13.8	12.6	24.9

Expt. 17: Effect of agronomic factors for maximizing yield of BRRI dhan94 through developing sustainable production management protocol

PI: M A B S Sarker; CI: M M Rana, R Akter and N Akter

Rationale: Each and every rice variety has it's sensitivity to management for growth, yield and coping of environmental hazards of various locations. Especially, medium duration T. Aman variety perceived medium period in natural condition at field during vegetative and reproductive stages. Throughout this time, agronomic management may be required to cope with these factors. So, it is important to find out variety wise specific production management protocol for various ecosystems. BRRI dhan94 is a newly developed high yielder (>5.0 t ha^{-1}) medium duration T. Aman variety. For obtaining it's high yield potentiality, it is necessary to find out the sustainable production management protocol for BRRI dhan94. This study was taken with the following objectives:

1) To study contributions of some agronomic factors to high yield of BRRI dhan94 in T. Aman season**,**
2) To find out the best production management protocol for sustainable higher yield of BRRI dhan94.

Materials and Methods: Factor A: Time of crop establishment (T) was two, T_1 = 1 July Seeding and T_2 = 15 July Seeding. Factor B: Age of seedling (A) was two, A_1 = 15 day and A_2 = 30 day. Factor C: Spacing (S) was two, S_1 = 25 × 25 cm (16 hill m^{-2}) and S_2 = 20 × 20 cm (25 hill m^{-2}). Factor D: Fertilizer Management (F) was two, F_1 = BRRI recommended fertilizer Management, F_2 **=** Soil test based high yield goal with additional one ton vermi-compost per hectare. The experiment was laid down in Factorial RCB design with three replications. BRRI recommended other intercultural managements like weed, irrigation, insects, diseases were followed as necessary.

Results and discussion: The result showed that there was significant effect of different Agronomic factors on the yield and yield components (**Table 33 and Figure 25**). The highest grain yield was achieved from the treatment $F_2A_2S_2T_2$ (6.53 t ha^{-1}) followed by F_1 A_2 S_1 T_2 (5.81 t ha^{-1}) (**Figure 25**). Significantly higher yield was observed resulted from higher yield components. For obtaining the highest grain yield, BRRI dhan94 should be seeded on 15 July and transplanting with 30 days old seedling, maintaining 20 × 20 cm spacing. Soil test-based fertilizer effective compared to BRRI Recom. Dose.

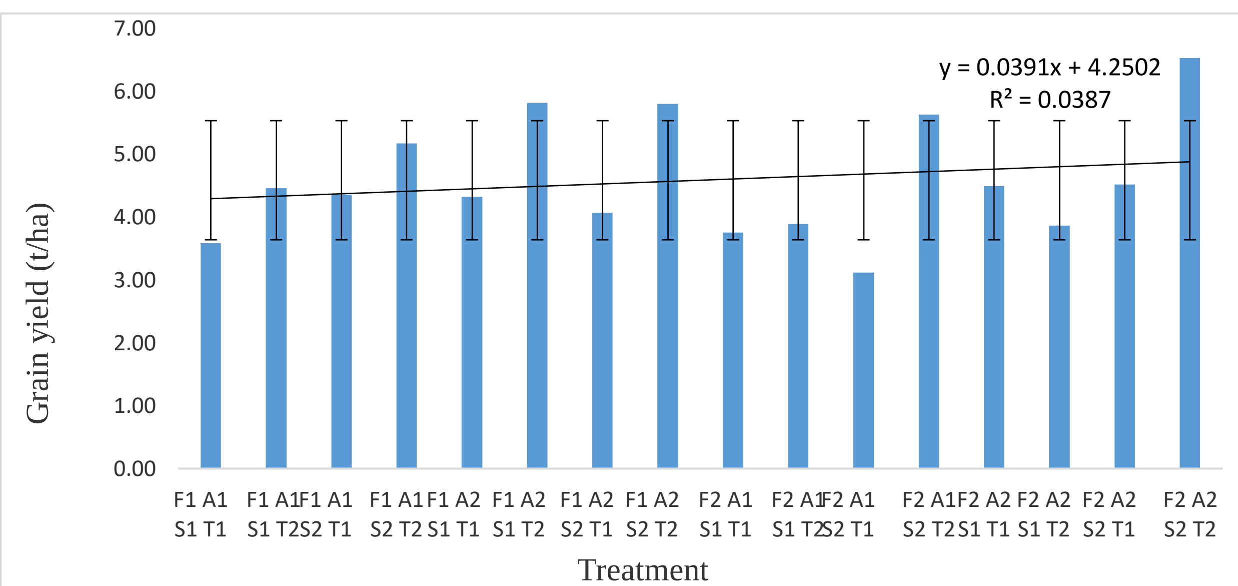


Figure 25: Effect of different agronomic factor on the yield maximization of BRRI dhan94 through developing sustainable production management protocol

(T_1=1 July & T_2=15 July seeding; A_1= 15 day & A_2=30 day old seedling; S_1=25×25 cm & S_2=20×20 cm spacing, F_1=BRRI recommened & F_2=STB dose

Table 33. Effect of different agronomic factors on plant height and yield components of BRRI dhan94 in T.Aman, 2022, BRRI farm, Gazipur

Treatment	Plant height	Panicle m^{-2}	Grain $panicle^{-1}$	Sterility
	(t ha^{-1})	(no.)	(no.)	(%)
F1 A1 S1 T1	113	184	165	15
F1 A1 S1 T2	113	163	159	15
F1 A1 S2 T1	114	216	159	21
F1 A1 S2 T2	116	216	163	17
F1 A2 S1 T1	117	160	160	21
F1 A2 S1 T2	111	169	131	18
F1 A2 S2 T1	113	238	151	21
F1 A2 S2 T2	109	184	122	16
F2 A1 S1 T1	117	169	177	20
F2 A1 S1 T2	118	157	145	19
F2 A1 S2 T1	115	229	177	18
F2 A1 S2 T2	113	229	127	22
F2 A2 S1 T1	114	184	167	18
F2 A2 S1 T2	110	121	135	20
F2 A2 S2 T1	113	187	171	16
F2 A2 S2 T2	109	233	155	17
$LSD_{(0.05)}$ for (FER*AGE*SPA*TIM)	6.067	43.828	39.175	10.66
$LSD_{(0.05)}$ for (FER*AGE)	3.03	21.91	19.58	5.33
$LSD_{(0.05)}$ for (FER*SPA)	3.03	21.91	19.58	5.33
$LSD_{(0.05)}$ for (FER*TIM)	3.03	21.91	19.58	5.33
$LSD_{(0.05)}$ for (AGE*SPA)	3.03	21.91	19.58	17.18
CV (%)	3.2	13.8	15.3	35.9

(T_1=1 July & T_2=15 July seeding; A_1= 15 day & A_2=30 day old seedling; S_1=25×25 cm & S_2=20×20 cm spacing, F_1=BRRI recommened & F_2=STB dose

Expt. 18: Maximizing yield of BRRI developed Boro varieties through influencing some Agronomic Critical Factors

PI: M A B S Sarker; C I: M M Rana, R Akter and N Akter

The study of the individual four best performing management factors together with their possible combinations under a given environmental site like BRRI, Gazipur during Boro season 2022-23 has been examined with the following objectives

1. To study the effect of Agronomic most critical factors-based treatment for yield maximization of BRRI developed different growth duration-based varieties.
2. To find out and recommended the most appropriate Agronomic critical factors packages for yield maximization of those varieties.

Materials and Methods: Different Agronomic critical factors based four managements were considered as Factor A: such as M_1 = BRRI Recommended practices, Agronomic Critical factors based proposed five treatments were: M_2, M_3 M_4 M_5 and M_6. Varieties were considered as Factor B, such as: V_1= Short duration (BRRI dhan88), V_2= Long duration (BRRI dhan89) and V_3= Check variety (BRRI dhan29). Other recommended agronomic management were followed as and when necessary. Factorial Randomized Complete Block design was followed with three replications.

Results and discussion: The highest grain yield was observed by long duration varieties BRRI dhan29 and BRRI dhan89 in agronomic factor based proposed M_2, M_3 and M_4 management treatments followed by M_1. BRRI dhan88 gave lower yield than long duration varieties in all management treatments. BRRI dhan88 gave similar yield in all management treatment. It was observed that with in the same variety, there was no significant difference in plant height at all tested management treatments (**Table 34**) but significant difference was observed in all yield components like panicle number m^{-2}, grain $panicle^{-1}$ production and sterility% (**Table 34**). Higher yield was observed resulted from higher panicle number m^{-2} and fill grain per panicle and less sterility%.

It may be recommended from the results (**Table 34**) that seed should be sown on last week of December, younger seedling (15 to 25-day old) should transplant following wider spacing (25 x 25 cm) within 3rd week of December. Upper soil stirring would be done on 20 & 35 DAT. STB fertilizer management would be followed and additionally 1% MoP solution should be sprayed on 30 and 45 DAT. Long duration varieties produced identical higher yield in all management treatments.

Table 34. Effect of agronomic critical factors on plant height, panicle no., fill grain and sterility of Boro varieties at BRRI farm, Gazipur, Boro 2022-23

Management (M)	Variety (V)	Plant height (cm)	Panicle m^{-2}	Grains Pan^{-1}	Grain yield (t ha^{-1})	Sterility (%)
M_1	BRRI dhan88	91	304	111	6.35	27
	BRRI dhan89	102	238	174	6.96	15
	BRRI dhan29	98	270	166	7.36	21
M_2	BRRI dhan88	88	310	173	6.24	22
	BRRI dhan89	104	269	172	7.80	12
	BRRI dhan29	98	265	157	7.79	30
M_3	BRRI dhan88	92	300	173	6.35	19
	BRRI dhan89	106	247	178	7.75	23
	BRRI dhan29	98	239	178	7.54	28
M_4	BRRI dhan88	94	269	143	6.25	31
	BRRI dhan89	103	233	185	7.90	20
	BRRI dhan29	97	235	195	8.14	26
LSD $_{(0.05)}$ for V × M		5.55	29.74	31.02	0.78	10.90
LSD $_{(0.05)}$ for V		2.77	14.87	15.51	0.39	5.45
LSD $_{(0.05)}$ for M		3.20	17.17	17.91	0.45	6.29
CV (%)		3.4	6.6	11.0	6.4	28.3

(Note: The field performance of M_2, M_3 and M_4 treatment was very good in up to booting stage, after that 50 to 60% lodging was occurred at heading and hard dough stage).

Expt. 19: Effect of some agronomic factors for maximizing yield of long duration variety BRRI dhan92 through developing sustainable production management protocol in Boro season

PI: M A B S Sarker, CI: R Akter and M M Rana

Rationale: Each rice variety has it's own management sensitivity for growth, yield and environmental hazard at different location. Especially, long duration Boro variety perceived long period in natural condition at field during vegetative and reproductive stages. Throughout this time, agronomic management play a dynamic role for better crop growth and yield. So, it is important to find out variety wise specific production management protocol at different locations for maximizing yield. BRRI dhan92 is a newly developed high yielding Boro variety. For exploiting high yield potentiality of the variety, it is necessary to find out the sustainable production management protocol for BRRI dhan92.

Objectives:

1. To study some agronomic factors for high yield contribution of long duration BRRI variety (BRRI dhan92) in Boro season and
2. To find out the best production management protocol for sustainable higher yield of the long duration variety.

Materials and Methods: Factor A was three Age of seedling (A): A_1 = 15 day A_2 = 35 day and A_3 = 55 day. Factor B was Three Population density or spacing (S): S_1 = 30 x 30 cm (11.1 hill m^{-2}), S_2 = 25 x 25 cm (16 hill m^{-2}) and S_3 = 20 x 20 cm (25 hill m^{-2}). Factor C was two Fertilizer

Management (F): F_1 = AEZ based high yield goal targeted BRRI fertilizer recommendation and F_2 = Soil test based high yield goal targeted fertilizer recommendation along with one t ha^{-1} vermi-compost and 1% MoP solution need to spray at 30 and 45 DAT. Other recommended agronomic management were followed as and when necessary. Factorial Randomized Complete Block design with three replications was followed.

Results and discussion: The result showed that, there was significant effect of different treatment on yield and yield contributing factors (**Table 35**). The highest grain yield was obtained from the treatment $F_2S_1A_1$ (8.53 t ha^{-1}) followed by $F_1S_1A_1$ (8.24 t ha^{-1}). The lowest grain yield was observed from $F_2S_3A_3$ (6.15 t ha^{-1}) than F1S1A3 (6.25 t ha^{-1}). The obtained higher yield was contributed by higher panicle $m^{-2}$and grain $panicle^{-1}$ and lower sterility %. The results indicated that for obtaining higher yield, STB fertilizer along with 1 t ha^{-1} vermi-compost need to apply along with 1% MoP solution spray at 30 and 45 DAT. 15-day old seedling maintaining wider spacing should be transplanted. Lodging was occurred 30-40% during heading to ripening stage. As a result actual crop performance was hampered. To confirm the findings it is needed to repeat the experiment next year.

Table 35. Effect of some agronomic factors on yield and yield component of different growth duration varieties, BRRI farm, Gazipur, Boro 2022-23

Treatment	Panicle m^{-2}	Grain $panicle^{-1}$	Grain yield (t ha^{-1})	Sterility (%)
F1 S1 A1	298	140	8.24	21
F1 S1 A2	250	131	7.19	26
F1 S1 A3	195	125	6.25	24
F1 S2 A1	290	138	7.60	20
F1 S2 A2	244	113	6.49	32
F1 S2 A3	242	144	7.23	23
F1 S3 A1	352	100	7.34	25
F1 S3 A2	306	100	7.23	28
F1 S3 A3	327	103	6.35	27
F2 S1 A1	298	142	8.53	23
F2 S1 A2	220	114	6.53	28
F2 S1 A3	228	138	6.56	24
F2 S2 A1	293	115	7.51	24
F2 S2 A2	237	113	6.90	24
F2 S2 A3	296	114	6.89	33
F2 S3 A1	355	119	7.23	34
F2 S3 A2	325	113	7.06	29
F2 S3 A3	237	112	6.12	24
LSD$_{(0.05)}$ **(** FER*SPA*AGE**)**	76.076	24.62	0.820	17.02
LSD$_{(0.05)}$ **(**FER*SPA**)**	42.768	14.211	0.473	9.829
LSD$_{(0.05)}$ **(** FER*AGE **)**	42.768	14.212	0.474	9.829
LSD$_{(0.05)}$ **(** SPA*AGE **)**	52.380	17.406	0.580	12.038
CV (%)	16.1	12.8	7.0	18.6

A_1 = 15 day A_2 = 35 day and A_3 = 55 day; S_1 = 30 x 30 cm, S_2 = 25 x 25 cm and S_3 = 20 x 20 cm; F_1 = AEZ based high yield goal targeted BRRI fertilizer recommendation, F_2 = Soil test based high yield goal targeted fertilizer recommendation

SOIL HEALTH MANAGEMET

Expt.20: Characterization of salt-tolerant PGPR isolated from coastal saline soil in Bangladesh

PI: R Shultana, CI: U A Nahar & M M Rana

Introduction

About 53% of the coastal areas in Bangladesh are affected by salinity (Rasel *et al*., 2013; Shatil *et al*., 2021). Salt-tolerant rice varieties often fail to produce a satisfactory yield in actual saline soil due to the lack of proper soil management. Physical removal of salts or chemical amendments is not only expensive but also has an adverse ecological impact and it is not possible to cover large areas for soil renovation purposes (Shultana *et al*., 2020). Indigenous PGPR strains available in saline soil could be an alternative for saline soil management (Pan *et al*., 2019). To date, available research findings are inadequate on the simultaneous application of region-specific salt-tolerant PGPR with different salt-responsive rice varieties under saline soil conditions. Therefore, the experiment was conducted to screen out potential salt-tolerant bacterial strains isolated from coastal saline soil.

Materials and Methods

The experiment was conducted at the soil microbiology laboratory, Agronomy division during the season of T. Aman, 2022. The soil was collected from the Satkhira district under the Upazilla of Ashashuni (N-22^{0}31.585´; E-089^{0}12.381´) and Shayamnagar (N-22^{0}22.519´; E-089^{0}06.319´). Initially, twenty bacteria were isolated from the collected soil. The strains of different shapes, sizes, and colors were identified and separated. The distinct strains were preserved in slant agar media and kept at 4^{0}C. The strains were tested at various NaCl concentrations (0, 0.5, 1, 1.5 and 2M). Five bacterial strains were screened out through a preliminary test on salinity tolerance and plant growth-promoting characters. The five selected bacterial strains were further allowed to test for various salinity tolerance characters which include bacterial growth in saline media, Floc yield production, Exopolysaccharide production and uptake of sodium. Besides, plant growth-promoting characters include nitrogen fixation, phosphate solubilization and indole acetic acid production. The generated data were analyzed following Analysis of Variance (ANOVA) using R-4.1.1 software. The treatment means were compared by Least Significant difference (LSD) at a probability level of 0.05.

Results and discussion

The salt-tolerant traits of the selected bacterial strains:

Bacterial growth under saline media: The growth of all bacterial strains gradually fell with the increase in salinity concentrations. The considerable populations of Sat-2 (6.90), Sat-4 (6.65) and Sat-6 (6.45) were measured at 1.5M of NaCl concentrations (**Figure 26**).

Floc yield production: The floc yield of the tested bacterial strains was increased gradually with the increase of NaCl concentrations showing a maximum value at 1.5M of NaCl concentrations. The bacterial strain Sat-2 (16.90g/L) was ranked first following Sat-4 and Sat-6 (**Figure 27**).

Exopolysaccharide production: The exopolysaccharide production of the tested bacterial strains gradually increased with the increase of NaCl concentrations showing the highest peak at 1M of NaCl concentrations. The strain Sat-6 followed by Sat-2 produced the highest exopolysaccharide at 1M of NaCl concentrations (**Figure 28**).

Uptake of sodium: The uptake of sodium of the tested bacterial strains was positively linked with the salinity concentrations. The highest uptake of sodium was measured by the strain Sat-4 followed by Sat-2 at 1.5M of NaCl concentrations (**Figure 29**).

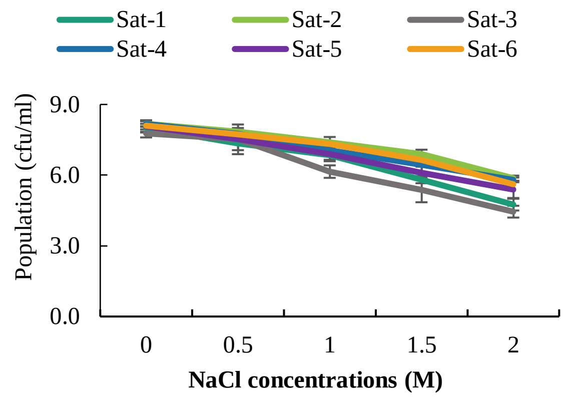


Figure 26: The effect of NaCl concentrations on bacterial growth under TSB medium

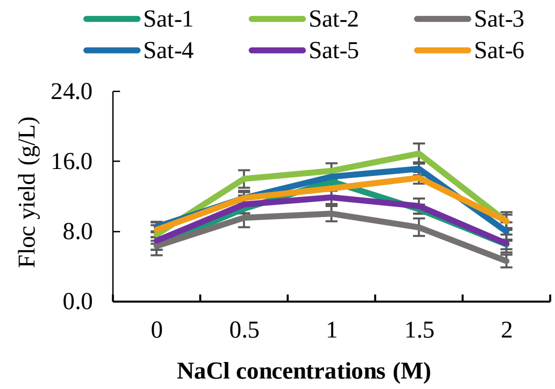


Figure 27: The effect of NaCl concentrations on bacterial floc yield production under TSB medium

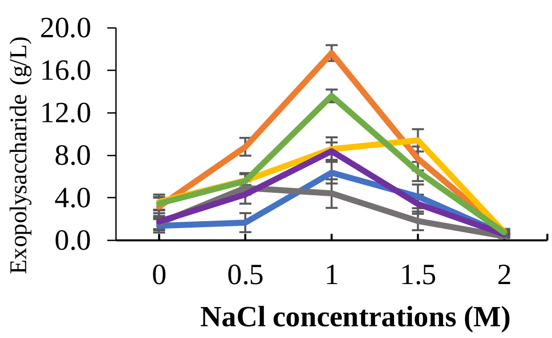


Figure 28. The effect of NaCl concentrations on bacterial exopolysaccharide production under TSB medium

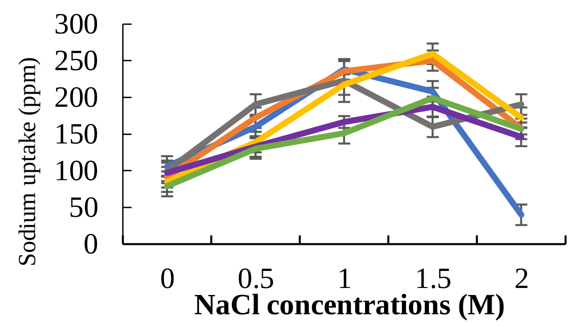


Figure 29. The effect of NaCl concentrations on bacterial sodium uptake under TSB medium

Plant growth-promoting traits:

Among the six bacterial strains, Sat-4, Sat-5 and Sat-6 were enabled to fix atmospheric nitrogen. On the other hand, Sat-1, Sat-2 and Sat-4 showed phosphate solubilization ability. Further, Sat-2 was the highest IAA producer (69 ppm) (**Table 36**)

Table 36. Plant growth-promoting traits of the selected bacterial strains

Bacteria	N_2 fixation	P solubilization	IAA (ppm)
Sat-1	-	+	22
Sat-2	-	++	69
Sat-3	-	-	2
Sat-4	+++	+	28
Sat-5	++	++	27
Sat-6	+	-	13

Note: '+' positive; '-' Negative

Discussion

The reported bacterial strains can survive in salt-stressed environments since they can produce floc yield or aggregate as a response to salinity which increased with the higher concentration of NaCl. Moreover, bacterial flocculation or aggregate formation positively correlated with EPS production. Similarly, Hong *et al.* (2017) identified B. *iodinum* RS16 as a higher floc yield producer at 1.5 M of NaCl concentration which further protects the host plant against various stresses. The above-mentioned attributes for salinity tolerance of the reported strains have a direct effect on sodium (Na) uptake from the saline media at 1.5M of NaCl concentrations. The sodium (Na^+) binding capacity of bacterial EPS was earlier stated by Arora *et al*., (2010) who reported that bacteria can bind the Na^+ ion under salinity stress through the excretion of EPS, which consequently reduces its toxicity in the soil.

Conclusion

The salt-tolerance and plant growth-promoting traits revealed that Sat-2, Sat-4, Sat-5 and Sat-6 are potential salt-tolerant PGPR strains that could be considered for further plant inoculation study.

Expt.21: Study on salt-tolerant PGPR inoculation on the growth of rice seedlings under salt-stress condition

PI: R Shultana, CI: U A Nahar & M M Rana

Introduction

In the current agricultural systems, the development of an eco-friendly approach to enhance plant growth under abiotic stresses has received more attention (Viscardi *et al*, 2016). Taking into consideration this scenario, attention should be given to enhancing the yield of salt-affected rice cultivation areas by taking advantage of the salt-tolerant plant growth-promoting rhizobacteria (PGPR). A clear understanding of PGPR mechanisms could help towards efficient utilization of beneficial microorganisms for the enhancement of plant growth under saline soil conditions (Pan *et al*., 2019). To date, insufficient research findings are available on the combined application of region-specific salt-tolerant PGPR with different salt-responsive rice varieties under saline conditions. Several salt-resistant rice varieties already have been commercialized in Bangladesh but in many cases, the field performance of these varieties in actual saline areas has failed to reach a satisfactory level. Therefore, along with the cultivation of salt-tolerant rice plants, the adoption of different salt-tolerant PGPR as an organic source of fertilizer could be a promising alternative for rice cultivation in the saline ecosystem. Hence, the experiment will be conducted to observe the effect of different PGPR inoculations on the growth of rice seedlings at various salinity concentrations.

Materials and methods

The experiment was conducted at the rainout shelter, Agronomy division during the season of Boro, 2022-23. The treatments were comprised as six bacterial inoculum (no inoculum, UPMRB9, Sat-2, Sat-4, Sat-5, Sat-6) and three salinity levels (0, 6, 8 dSm^{-1}). The plants were cultured in a hydroponic system following the protocol of Yoshida *et al* (1976). Sodium chloride (NaCl) was added at the rate of 3 and 4 g/L to the nutrient solution to reach the desired electrical conductivity (EC) of 6 and 8 dSm^{-1}, respectively (Gregorio, 1997). The trays were filled up with 7L of culture solution to ensure optimal nutrient uptake by the roots. A portable pH meter was used to measure the pH of the saline nutrient solution and pH 5 was adjusted to each day by incorporating KOH and HCL. The pails were arranged in a Randomized Complete Block Design following three replications. The data on plant height, number of tillers, shoot length, root length, shoot dry weight, root dry weight and the ratio of sodium and potassium were measured. All the data generated were analyzed following Analysis of Variance (ANOVA) using R-4.1.3 software. The treatment means were compared by Least Significant difference (LSD) at a probability level of 0.05.

Results and discussion

The shoot dry weight of rice plants inoculated with five bacterial strains was not varied significantly under non-saline conditions. However, the values significantly differed under salt-stress conditions. At 6 $dSm^{-1}$of salinity, significantly the highest shoot dry matter was produced by UPMRB9 inoculated plants (26.62 g) followed by Sat-2 (24.75 g) and Sat-4 (23.24 g). Further, at 8 $dSm^{-1}$of salinity, UPMRB9 was the highest contributor (14.28 g) followed by Sat-2 (11.16 g) (**Figure 30**). On the other hand, a significant variation in root dry weight was measured regardless of salinity concentration. The bacterial strain UPMRB9 was the major contributor to the highest dry matter production (11.93 g) followed by Sat-2 (11.07 g) under non-stress conditions. The consistent contribution of these two strains was also measured under the salt-stress condition which was 8.44 g and 7.62 g at 6 dSm^{-1} and 7.30 g and 6.09 g at 8 dSm^{-1} respectively (**Figure 30**). The uptake of sodium by the rice plants varied with the inoculation of different bacterial strains under various salinity levels. The uninoculated plants at 8 $dSm^{-1}$of salinity consumed the highest sodium (%). Among the five bacterial strains, Sat-4 significantly contributed to lowering the uptake of Na^{+} in BRRI dhan99 at 6 dSm^{-1} of salinity (**Figure 31**). The highest shoot and root dry matter production of the rice plants inoculated with the bacterial strains, UPMRB9 and Sat-2 is because these two strains are capable of reducing the salt-stress effect of rice seedlings since the strains can produce the highest exopolysaccharides thus, they can bind sodium ion in solution consequently sodium becomes less available to plants. Besides, the strains showed their ability to produce higher indole acetic acid production, nitrogen fixation and phosphate solubilization which stabilizes normal plant growth even in salt-stress conditions. Likewise, Shultana *et al.*, (2020) demonstrated the highest growth of rice plants inoculated with UPMRB9.

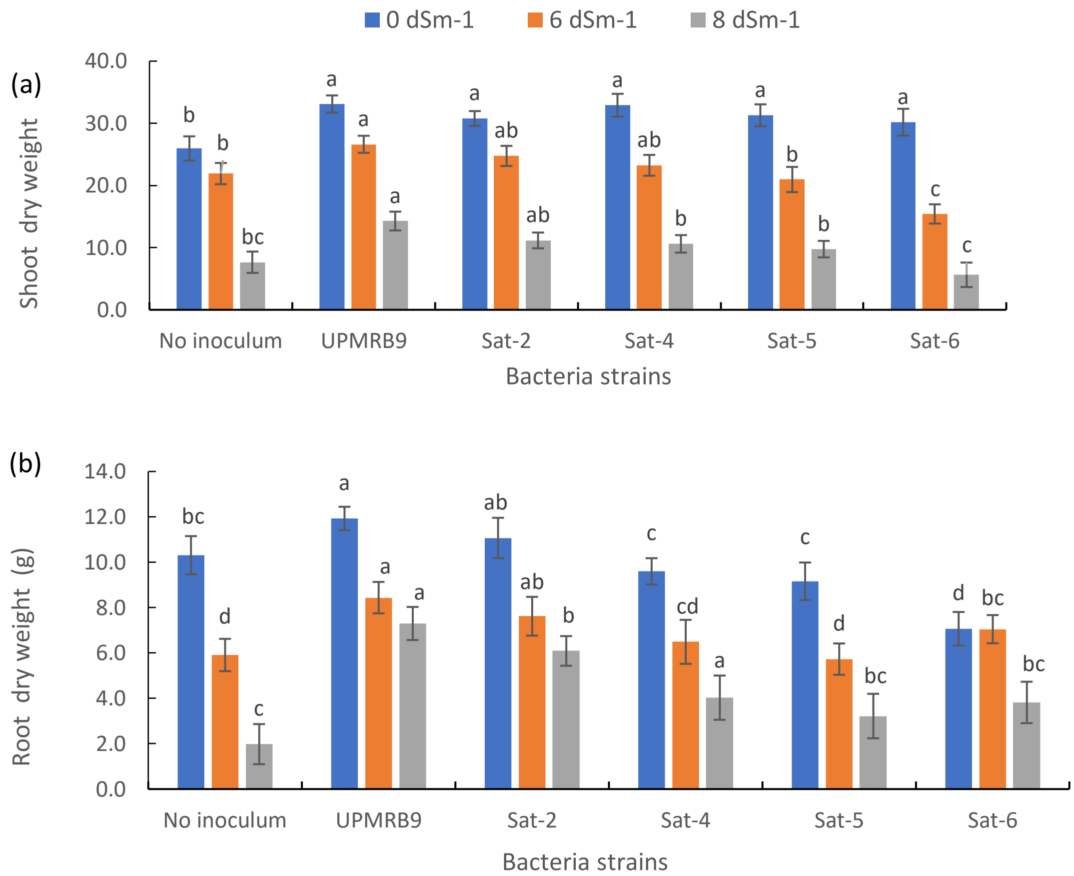


Figure 30. Effect of bacterial inoculation on the shoot dry weight (a) and root dry weight (b) of rice seedlings under the salt-stress condition (The Means having the same letter within the bacterial strains do not differ significantly using the LSD test at p>0.05)

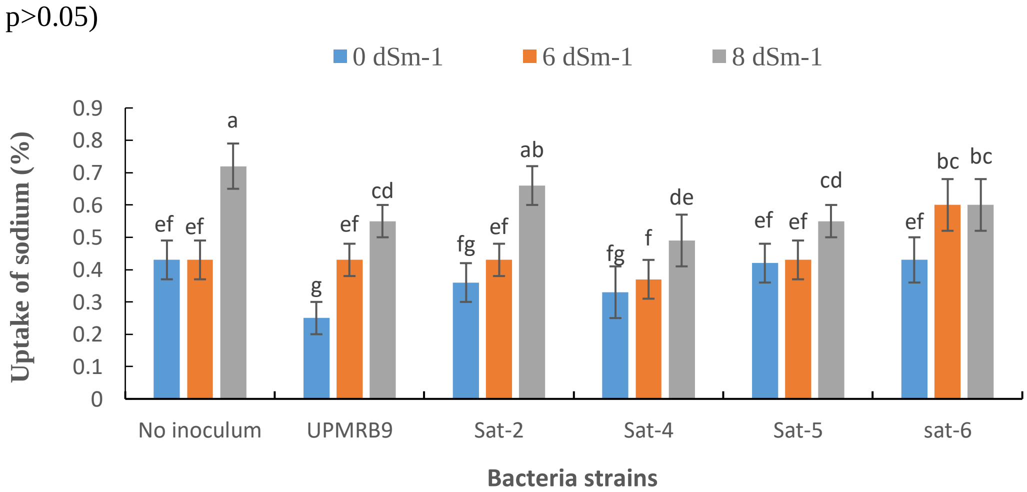


Figure 31. Effect of bacterial inoculation on the uptake of sodium (%) in rice seedlings under varying salinity levels (The means having the same letter within the bacterial strains do not differ significantly using the LSD test at p>0.05).

Conclusion

Among the four tested bacterial strains Sat-2 and Sat-4 are comparable with the check bacterial strain UPMRB9. Hence, this bacterial strain could be considered as a salt-tolerant strain which can significantly contribute to reducing the salinity stress of rice at the seedling stage. However, further confirmation is needed before the final recommendation.

Expt.22: Improvement of soil health in four crops pattern through agronomic management

PI: M Sh Islam, CI: N Akter, R Akter and R sultana

Rationale

Nutrient management is very important when cropping intensity is high. Agronomic management including fertilizer management should be different for intensive cultivation. When 3 to 4 crops are grown in rice-based cropping system, nutrient management is crucial issue. It is difficult to maintain soil health when intensive crop cultivation is going on. Considering the above facts, a long-term study was under taken at BRRI farm Gazipur to improve the soil health and to increase the cropping intensity and productivity.

Materials and methods

A long-term study was under taken from 2017-18 to 2022-23 at east byde (Agronomy research field) of BRRI farm, Gazipur with the four crops cropping pattern: T. Aus (BRRI dhan48)-T. Aman (BRRI dhan87)-Potato (BARI Alu41)-mungbean (BARI Mung-6). Agronomic management was: 1. Incorporation of mungbean stubble with soil before T. Aus 2. Incorporation of compost @ 2.0 t ha^{-1} (dry wt. basis) with soil before potato sowing and 3. Recommended dose of chemical fertilizers was applied for all crops as per schedule.

Results and discussion

The crop yield of T. Aus 2022, T. Aman 2022 and Potato are presented in **Table 37**. The results indicated that the yield of BRRI dhan48 (T. Aus) and BRRI dhan87 (T. Aman) are satisfactory. The potato yield was lower (21.5 t ha^{-1}) compared to previous year (2021-22). It was mainly due to a poor irrigation system, the soil was not properly level. It was not possible to harvest mungbean because of poor germination and uneven flowering. However, the mungbean plant was incorporated with soil at flowering stage. The rice equivalent yield (REY) was 29.28 t ha^{-1} (21.5 t ha^{-1} potato = 19.35 t ha^{-1} rice, Rice = Tk 20 kg^{-1}, Potato = Tk 18 kg^{-1}), which is still low. In 4 crops system, the REY should be more than 35 t ha^{-1} to make it profitable and viable. The results of soil analysis showed that there was an increasing trend in soil pH, P, K, S & Zn with few exceptions (**Table 38**) when compared with the previous year. There was very little change in soil OM and total N%. However, despite of cultivation of 4 crops in same land, are not harmful in terms of soil fertility the proper agronomic management is given. In T. Aus, T. Aman-Potato-Mungbean cropping pattern showed higher number of total bacterial population (3.05×10^6 cfu/g dry soil over the Boro-fallow-T. Aman cropping pattern (**Figure 32**).

Table 37. Yield of different crops in 4 crops systems BRRI farm, Gazipur, 2022-23

Crops	Field duration	Variety	Yield (t ha^{-1})	Remarks
T. Aus	11 May to 06 August 2022	BRRI dhan48	4.68	-
T. Aman	10 August to 6 Nov 2022	BRRI dhan87	5.25	-
Potato	20 Nov 19 to 19 Feb 2023	BARI Alu41	21.50	REY=19.35 t ha^{-1}
Mungbean	1 March 2023 (Sowing)	BARI mung6	-	Poor germination

(1 kg rice=Tk. 20, 1kg potato= Tk. 18)

Table 38. Comparison of initial soil status of experimental plots in 4 crops system, 2021-22 & 2022-23, BRRI Gazipur

Crop	pH		OM		Total N		P (ppm)		K (meq/100 g)		S (ppm)		Zn (ppm)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2021-22	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T. Aus	7.41	7.58	2.15	2.18	0.13	0.14	8.9	14.35	0.14	0.19	11.8	13.2	1.63	1.97
T. Aman	7.25	7.64	2.03	2.09	0.12	0.13	9.6	15.32	0.15	0.21	9.7	13.0	1.51	1.61
Potato	7.22	7.57	2.22	2.07	0.14	0.13	11.9	14.09	0.20	0.21	6.7	12.8	1.19	1.39
Mungbean	7.02	7.31	2.12	2.13	0.13	0.13	15.3	13.36	0.21	0.20	13.3	12.7	1.16	2.20

(a) (b)

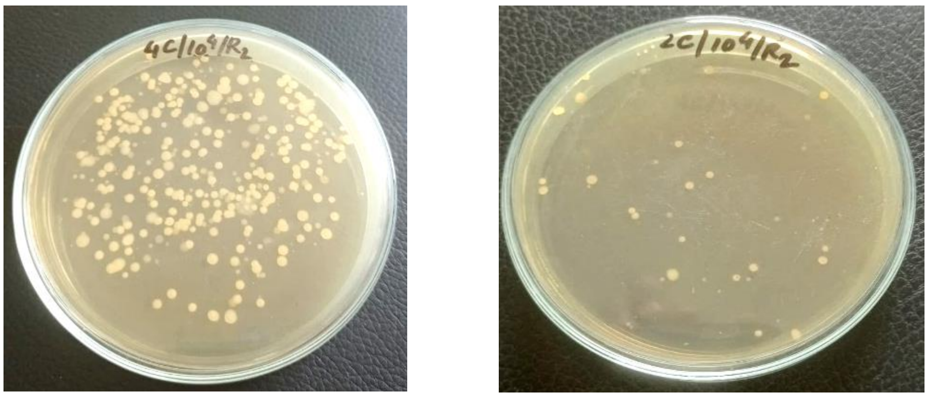


Figure 32. Total bacterial population counted in soil collected from (a) four crops and (b) 2 crops cropping pattern

Conclusion

Despite of cultivation of 4 crops in same land, are not harmful in terms of soil fertility if proper agronomic management is given. In T. Aus, T. Aman-Potato-Mungbean cropping pattern showed higher number of total bacterial population (3.05×10^{6} ^{c}fu/g dry soil over the Boro-fallow-T. Aman cropping pattern.

WEED MANAGEMENT

Expt.23: Effect of herbicide on Azolla infestation in rice field

PI: M M Mahbub, CI: M K A Bhuiyan, S Zahan, M K H Tarek

Introduction

Azolla is a fern from Salviniaceae family, which have ability to fix nitrogen and helps to increae the soil fertility. When Azolla was incorporated into the soil, it added 70 kg N ha^{-1} (Pallavolu *et al*., 2002). On the other hand, *Azolla* has a remarkable ability to multiply that form mats on the water's surface can be 30 cm thick, and during hot weather, can double in size within 4 or 5 days. As a result, farmers have to face some problems like, block irrigation cannels (DiTomaso, 2013), excess growth over younger seedlings and create problems during intercultural operation and fertilizer or pesticide applications. Sometimes, it is difficult to control Azolla by hand pulling due to labour shortage. DiTomaso, 2013 have used the herbicides; Penoxsulam, Bispyribac sodium, Glyphosate, Diquat for control Azolla from rice field.

Objective: To reduce the abundance of Azolla from rice fields

Materials and Methods

The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) farm, Rangpur, during T. Aman, 2022 and Boro, 2022-23 to find out the effect of herbicide on weed infestation of rice. The treatments were; T_1: Remove water from the plot (Farmers' practice), T_2: Granite 240 SC (Penoxsulam)@ 93 ml ha^{-1}, T_3: Nomini gold 10 SC (Bispyribac sodium) @ 150 ml ha^{-1}, T_4: Nazat 72 SL (2,4-D Amine)@ 2L ha^{-1} , T_5: Incorporation of Azolla after full mat formation in the field); and vi) T_6: Control. The treatments were distributed in RCB design with three replications. Twenty-eight days-old seedlings of BRRI dhan87 and Thirty-five day old seedlings of BRRI dhan89 were transplanted at 20 × 20 cm spacing. All fertilizers except urea were applied during final land preparation. Irrigation, weeding, disease and insect control were done as and when necessary. Yield data were recorded during harvesting. Statistical analysis was done by CropStat program.

Results and discussion

The highest grain yield 5.29 t ha^{-1} found in T_5 treatment during T. Aman season and consequently panicle m^{-2} and grains panicle^{-1} also found highest in this treatment (**Table 39**). During Boro season the highest grain yield 6.62 t ha^{-1} found in T_5 treatment and panicle m^{-2} and grains panicle^{-1} found highest in this treatment (**Table 40**). The highest Azolla dry wt. found in control treatment at 7 DAS (Days after spray), 14 DAS and 21 DAS both in Aman and Boro season. Penoxulam treated plot showed that at 7 DAS Azolla was decreased but after 7 DAS it was increased gradually both Aman and Boro season. 2,4-D Amine treated plot showed that at 7 DAS Azolla was reduced compare to control but after that it gradually decreased. 2,4-D Amine is a slow acting herbicide which effect also slow in Azolla. Other weed dry wt. found highest at T_1 and T_6 treatment. Penoxulam and 2,4- D Amine perform better to control Azolla which is similar to the findings of DiTomaso *et al*., 2013.

Table 39. Effect of herbicide on Azolla infestation in rice field, T. Aman, 2022, BRRI farm, Rangpur

Treat.	Panicle m^{-2}	Grains/ panicl^{-1}	1000 grain wt. (g)	Grain yield (t ha^{-1})	Weed dry wt. (g m^{-2})	Azolla dry wt. 7 DAS (g m^{-2})	Azolla dry wt. 14DAS (g m^{-2})	Azolla dry wt. 21 DAS (g m^{-2})
T_1	219	103	24.56	5.02	11.66	20. 05	13.24	7.93
T_2	223	101	24.86	5.03	2.70	4.07	7.33	9.13
T_3	202	100	24.23	4.55	1.30	7.86	8.73	12.73
T_4	238	105	24.66	5.23	2.13	3.96	5.93	9.76
T_5	240	106	24.97	5.29	6.26	7.20	10.24	15.31
T_6	168	100	24.16	3.57	10.80	24.13	30.73	34.93
$LSD_{(0.05)}$	19.45	16.82	1.75	0.66	5.06	4.29	4.59	3.66
CV (%)	5.9	9.2	3.9	7.6	16.1	14.1	15.4	17.3

T_1: Remove water from the plot (Farmers' practice), T_2: Granite 240 SC (Penoxsulam) @ 93 ml/ha, T_3: Nomini gold 10 SC (Bispyribac sodium) @ 150 ml/ha, T_4: Nazat 72 SL (2, 4-D Amine) @ 2L ha^{-1} , T_5: Incorporation of Azolla after full mat formation in the field and T_6: Control.

Table 40. Effect of herbicide on Azolla infestation in rice field, Boro, 2022-23, BRRI farm, Rangpur

Treat.	Panicle m^{-2}	Grains panicl^{-1}	1000 grain wt. (g)	Grain yield (t ha^{-1})	Weed dry wt. (g m^{-2})	Azolla dry wt. 7 DAS spray (gm^{-2})	Azolla dry wt. 14 DAS (g m^{-2})	Azolla dry wt. 21 DAS (g m^{-2})
T_1	238	108	24.09	5.61	9.67	18.73	14.30	8.30
T_2	254	112	24.23	6.05	2.01	4.23	7.95	10.24
T_3	266	115	24.66	6.53	2.26	6.96	10.63	15.52
T_4	244	116	24.01	5.80	3.16	4.66	6.41	7.24
T_5	271	117	24.18	6.62	3.03	9.16	12.35	15.67
T_6	176	110	24.36	3.60	9.50	20.65	27.46	31.53
$LSD_{0.05}$	21.16	12.27	1.28	0.53	3.26	3.65	9.24	8.49
CV (%)	7.1	6.5	2.8	11.3	14.4	17.3	14.5	16.5

T_1: Remove water from the plot (Farmers' practice), T_2: Granite 240 SC (Penoxsulam) @ 93 ml ha^{-1}, T_3: Nomini gold 10 SC (Bispyribac sodium) @ 150 ml ha^{-1}, T_4: Nazat 72 SL (2,4-D Amine) @ 2L ha^{-1} , T_5: Incorporation of Azolla after full mat formation in the field and T_6: Control.

Expt. 24: Reduce weed seed in weed Seed Bank of soil in long-term fallow management and herbicide uses in Rice- rice Cropping System

PI: MKA Bhuiyan, CI: MM Mahbub and R Sultana

Introduction

The weed seed bank in the soil is the major source of weeds in rice fields. The size of the weed seed bank in rice fields is highly variable depending on the climate, soil moisture content, cropping pattern used, depth of sampling, history of the areas and management practices used by farmers (Kamoshita *et al*., 2010). Therefore, information on the ecological aspects of weeds occurring in rice, including their potential seed production, is crucial for weed management. Weed management in rice fields focuses on methods suitable to decrease the weed population in the soil seed bank.

Objectives

1. To assess the total number of weed seeds reserve, species available, and dominant weed species present to compare the floristic diversity of soil weed seed bank and

2.To reduce weed seed reservoir through fallow management in different soil depths.

Materials and methods

Two-factor treatments were considered to evaluate the study. Weed management before soil sampling considered factor A (Weed management in the field),

W_1: Kill weed seedlings by tillage or herbicide (Stale seedbed technique/tillage before the flowering of weeds), W_2: Tillage after flowering of weeds, W_3: Weed management by herbicide fb 1HW, W_4:Weed management by HW and W_5: Control (No weeding)

After imposed weed management treatment before transplanting soil sample were collected before land preparation (Factor B). A soil auger was used to take soil samples to a depth up to 15 cm from three depths i.e. 0-5 cm, 05-10 cm and 10-15 cm.

Soil samples were taken by using PVC probe of 2.5 cm diameter for each method from each replication. The soil cores of same depth were bulked and mixed to make composite soil samples. These composite soil samples were divided into three working sub-samples having 600 gm weight of each sample for soil weed seed bank study in pot. Samples of each plot were placed in an individual plastic pot (31 cm diameter × 07 cm depth) in the rain out shelter. The soils were sprinkled with water as needed in order to keep them moist. Weed seedlings that emerged were identified, counted, and removed at 30 days intervals throughout the four months (August, September, October and November in T. Aman, 2022) emergence period. After the removal of each batch of seedlings, soils were thoroughly mixed in order to expose the weed seeds to the upper level of the soil, and re-wetted to permit further emergence. This process was repeated four times. Seedling emergence counts were converted to numbers per m^2 by calculating volume to area. The dominant weed species was determined by the calculation of Importance Value (I.V.) which was expressed as:

$$\text{IV (\%)} = 100 \times \frac{\text{No.of each species in a community}}{\text{Total no.of all species in a community}}$$

Floristic diversity/weed seed diversity was calculated by using Shannon and Weiner's diversity index (Magurran, 1988; Kobayashi *et al*., 2003) based on natural logarithms. Higher values of H' indicate greater floristic diversity (Shannon and Weaver, 1949). The Shannon index was computed by the following formula: $H = -\sum pi\ ln\ pi$; Where ln is the natural logarithm pi = ni /N, ni is the number of sampled individuals of species i N is the total number of sampled individuals.

The texture of the collected soil is clay loam and the bulk density was 1.35 g cm^{-3}.

Results and discussion

Weed seed bank density

Soil depth-wise weed seed bank density

Table 41 (a, b, c, d) indicates weed density m^{-2} in different soil depths in different weed management in the month of August, September, October, and November during the T. Aman 2022 season. Un-weeded plots and soil samples taken from tillage after the flowering of weed seeds showed a higher number of weeds irrespective of soil depths. A soil depth of 0-5 and 5-10 cm showed a higher number of weed seeds. An increase in soil depth decreases the weed seed bank. The upper layer of soil 0-10 cm showed the maximum number of weed seeds. Weed management treatment with herbicide and stale seed bank techniques showed lower weed seed banks in different soil depths. Control plots also showed a higher no. of weed seeds in the soil. The month of October and November counted a lower number of weed seeds compared to the month of August and November. Similar behavior was observed for weed numbers in different months in different soil depths. The significant reduction in weed seed in the seed bank in herbicide and stale seedbed techniques indicates the effective control of weeds in the field.

Relative importance (RI) value of seed species

Species seed bank relative importance was differed significantly by different weed control methods. The RI value data (**Table 42 a, b, c, d**) indicate that *Cyperus difformis, Scirpus maritimus, Echinochloa crus-galli, Frimbristylis miliaceae* and *cynodon dactylon* showed comparatively higher dominance/importance value in soil seed bank at all three upper, middle and lower soil depths. These weed species also showed dominance in case of seedling emergence method at the depth of 0-5 cm follower by 5-10 cm.

Diversity index of weeds species

The Shannon index for diversity of the weed seed bank was ranged from 0.48 to 1.35, depending on the soil sampling depths in different weed management treatments (**Table 43**). In different weed management methods, Shannon's index of weed seeds diversity was high in middle depth in the month of September having 1.35 value which indicates more number of species found at this depth and it was followed by upper depth having a 1.30 index value whereas, minimum index value 0.48 was recorded at lower depth which indicates that under deeper layer of soil, the seeds of different weed species may be decomposed with time which has lesser longevity of seeds. It was minimum in the lowest depth (0.48) in the month of August, while it was higher at 0.90 and 0.78 at the upper and middle depth. Shannon's index of diversity value of weed species under three soil depths in different weed management treatments determined over different months indicated in the month of September and October showed maximum weed diversity.

Table 41(a). Effect of different weed management treatments on depth wise weed seed count per m^2 of soil during T. aman 2022 in the month of August

Weed management treatment	W1			W2			W3			W4			W5		
	Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}		
	soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)		
Weed species	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15
Cyperus difformis	700	728	455	1222	1186	1011	776	871	678	982	988	787	1323	1432	1123
Scirpus marimimus	549	540	564	1234	987	765	543	332	432	652	435	343	987	567	423
Echinochloa crus-galli	409	113	343	232	342	666	454	455	409	454	345	233	876	675	549
Frimbristylis miliaceae	177	287	234	343	229	115	135	115	0	432	344	322	365	269	187
Ludwigia octovalvis	98	95	135	343	-	-	-	88	-	-	21	83	434	234	121
Cynodon dactylon	14	42	211	333	274	65	-	-	-	21	10	0	0	229	0
Monochoria vaginalis	220	309	209	274	822	-	87	23	32	233	111	154	122	111	90
Marsilea minuta	320	231	12	10	-	43	-	-	-	-	-	-	-	-	-
Total weed	2487	2345	2163	3991	3840	2665	1995	1884	1551	2774	2254	1922	4107	3517	2493

W_1= Kill weed seedlings by tillage or herbicide (Stale seed bed technique/tillage before flowering of weeds, W_2=Tillage after flowering of weeds, W_3= Weed management by herbicide fb 1HW , W_4= Weed management by HW, $W_{5=}$ No weeding

Table 41(b). Effect of different weed management treatments on depth wise weed seed count per m^2 of soil during T. aman 2022 in the month of September

Weed management treatment	W1			W2			W3			W4			W5		
	Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}		
	soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)		
Weed species	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15
Cyperus difformis	1032	987	454	1266	1123	1038	833	676	601	723	757	695	1359	1275	567
Scirpus marimimus	343	234	322	531	872	765	565	439	323	353	578	455	655	567	233
Echinochloa crus-galli	234	176	111	365	243	211	209	322	211	277	403	413	456	344	278
Frimbristylis miliaceae	167	165	19	167	176	166	154	376	245	354	267	142	459	244	345
Cynodon dactylon	-	-	122	10	177	133	177	48	23	162	11	59	233	569	211
Monochoria vaginalis	120	78	54	31	43	21	12	23	11	234	43	12	211	54	208
Ludwigia octovalvis	12	-	-	-	22	-	-	28	24	143	56	54	12	77	140
Total weed	1908	1640	1082	2370	2656	2334	1950	1912	1438	2246	2115	1830	3385	3130	1982

Table 41(c). Effect of different weed management treatments on depth wise weed seed count per m^2 of soil during T aman 2022 in the month of October

Weed management treatment	W1			W2			W3			W4			W5		
	Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}		
	soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)		
Weed species	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15
Cyperus difformis	654	543	456	765	733	454	343	345	345	678	567	345	767	678	688
Scirpus marimimus	345	256	233	546	455	234	233	267	52	323	250	143	567	467	543
Echinochloa crus-galli	143	244	165	543	356	243	254	143	31	233	108	232	657	455	212
Frimbristylis miliaceae	345	88	21	244	211	321	211	43	45	23	21	0	345	78	67
Cynodon dactylon	21	23	11	23	22	43	33	22	55	12	11	21	145	34	43
Monochoria vaginalis	23	12	2	27	21	23	24	21	34	3	23	42	56	55	66
Sphenochlea zeylanica	16	23	11	12	5	24	12	0	43	23	22	31	122	156	23
Ludwigia octovalvis	12	9	2	4	4	13	2	21	23	20	21	16	22	12	10
Total weed	1559	1198	901	2164	1807	1355	1112	862	628	1315	1023	830	2681	1935	1652

Table 41(d). Effect of different weed management treatments on depth wise weed seed count per m^2 of soil during T. aman 2022 in the month of November

Weed management treatment	W1			W2			W3			W4			W5		
	Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}		
	soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)		
Weed species	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15
Cyperus difformis	356	312	211	456	411	115	322	234	208	289	267	255	874	678	765
Scirpus marimimus	234	167	109	189	156	156	230	219	176	406	245	256	675	654	465
Echinochloa crus-galli	232	177	89	165	134	188	97	34	43	345	234	187	345	233	211
Frimbristylis miliaceae	43	21	12	165	105	10	75	78	56	176	122	34	134	98	44
Cynodon dactylon	87	23	22	87	56	42	177	9	6	45	42	221	88	32	0
Monochoria vaginalis	22	9	7	77	78	0	0	7	7	23	16	25	87	45	32
Sphenochlea zeylanica	30	20	8	28	0	29	0	8	5	79	26	38	46	33	20
Ludwigia octovalvis	21	6	9	21	22	19	0	5	6	39	34	11	48	23	21
Total weed	1025	735	467	1188	962	559	901	594	507	1402	986	1027	2297	1796	1558

Table 42(a). Species relative importance value (IR) under three soil depths in different weed management treatments determined in the month of August , T. Aman 2022 (a)

Weed management treatment	W1			W2			W3			W4			W5		
	Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}		
	soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)		
Weed species	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15
Cyperus difformis	28	31	21	31	31	38	39	46	44	35	44	41	32	41	45
Scirpus marimimus	22	23	26	31	26	29	27	18	28	24	19	18	24	16	17
Echinochloa crus-galli	16	5	16	6	9	25	23	24	26	16	15	12	21	19	22
Frimbristylis miliaceae	7	12	11	9	6	4	7	6	0	16	15	17	9	8	8
Ludwigia octovalvis	4	4	6	9	-	-	-	5	-	-	1	4	11	7	5
Cynodon dactylon	1	2	10	8	7	2	-	-	-	1	0	0	0	7	0
Monochoria vaginalis	9	13	10	7	21	-	4	1	2	8	5	8	3	3	4
Marsilea minuta	13	10	1	0	-	2	-	-	-	-	-	-	-	-	-

Table 42(b). Species relative importance value under three soil depths in different weed management treatments determined in the month of September, T. Aman 2022 (b)

Weed management treatment	W1			W2			W3			W4			W5		
	Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}		
	soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)		
Weed species	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15
Cyperus difformis	54	60	42	53	42	44	43	35	42	32	36	38	40	41	29
Scirpus marimimus	18	14	30	22	33	33	29	23	22	16	27	25	19	18	12
Echinochloa crus-galli	12	11	10	15	9	9	11	17	15	12	19	23	13	11	14
Frimbristylis miliaceae	9	10	2	7	7	7	8	20	17	16	13	8	14	8	17
Cynodon dactylon	0	0	11	0	7	6	9	3	2	7	1	3	7	18	11
Monochoria vaginalis	6	5	5	1	2	1	1	1	1	10	2	1	6	2	10
Ludwigia octovalvis	1	0	0	0	1	0	0	1	2	6	3	3	0	2	7

Table 42(c). Species relative importance value under three soil depths in different weed management treatments determined in the month of October, T. aman 2022

Weed management treatment	W1			W2			W3			W4			W5		
	Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}		
	soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)		
Weed species	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15
Cyperus difformis	42	45	51	35	41	34	31	40	55	52	55	42	29	35	42
Scirpus marimimus	63	47	41	44	46	31	43	80	12	50	57	42	57	82	128
Echinochloa crus-galli	9	20	18	25	20	18	23	17	5	18	11	28	25	24	13
Frimbristylis miliaceae	22	7	2	11	12	24	19	5	7	2	2	0	13	4	4
Cynodon dactylon	1	2	1	1	1	3	3	3	9	1	1	3	5	2	3
Monochoria vaginalis	1	1	0	1	1	2	2	2	5	0	2	5	2	3	4
Sphenochlea zeylanica	1	2	1	1	0	2	1	0	7	2	2	4	5	8	1
Ludwigia octovalvis	1	1	0	0	0	1	0	2	4	2	2	2	1	1	1

Table 42(d). Species relative importance value under three soil depths in different weed management treatments determined in the month of November, Aman 2022

Weed management treatment	W1			W2			W3			W4			W5		
	Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}			Weed no m^{-2}		
	soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)			soil depth (cm)		
Weed species	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15
Cyperus difformis	35	42	45	38	43	21	36	39	41	21	27	25	38	38	49
Scirpus marimimus	23	23	23	16	16	28	26	37	35	29	25	25	29	36	30
Echinochloa crus-galli	23	24	19	14	14	34	11	6	8	25	24	18	15	13	14
Frimbristylis miliaceae	4	3	3	14	11	2	8	13	11	13	12	3	6	5	3
Cynodon dactylon	8	3	5	7	6	8	20	2	1	3	4	22	4	2	0
Monochoria vaginalis	2	1	1	6	8	0	0	1	1	2	2	2	4	3	2
Sphenochlea zeylanica	3	3	2	2	0	5	0	1	1	6	3	4	2	2	1
Ludwigia octovalvis	2	1	2	2	2	3	0	1	1	3	3	1	2	1	1

Table 43. Shannon's index of diversity value of weed species under three soil depths in different weed management treatments determined over different months, Boro 2022

August	Soil depth (cm)			Sept.	Soil depth (cm)			Octo.	Soil depth (cm)			Nov.	Soil depth (cm)		
WM	**0-5**	**5-10**	**10-15**	**WM**	**0-5**	**5-10**	**10-15**	**WM**	**0-5**	**5-10**	**10-15**	**WM**	**0-5**	**5-10**	**10-15**
W1	0.87	0.85	0.55	W1	1.14	1.20	0.70	W1	1.12	1.10	0.90	W1	1.18	1.11	0.78
W2	0.90	0.78	0.60	W2	1.14	1.35	0.72	W2	1.15	1.16	0.93	W2	1.23	0.90	0.70
W3	0.79	0.70	0.50	W3	1.12	0.86	0.67	W3	0.95	0.94	0.77	W3	0.90	0.80	0.70
W4	0.68	0.66	0.48	W4	1.10	1.20	0.67	W4	0.95	0.80	0.75	W4	0.80	0.75	0.75
W5	0.88	1.23	0.69	W5	1.36	1.30	1.10	W5	1.27	1.38	0.80	W5	0.98	0.88	0.77

WM= Weed management
W_1= Kill weed seedlings by tillage or herbicide (Stale seed bed technique/tillage before flowering of weeds, W_2=Tillage after flowering of weeds, W_3= Weed management by herbicide fb 1HW , W_4= Weed management by HW, $W_{5=}$ No weeding

Conclusion:

From the findings, it may be concluded that the floristic diversity of the soil weed seed bank was higher in the depth of 0-5 and 5-10 cm depth in the month of September and October. The cyperaceous family had the highest species richness under different weed management techniques followed by broadleaf and grassy weeds. Manual weeding and herbicide treatment may cause slight weed seed reduction in deeper layers. Tillage after flowering of weeds and control plots showed higher weed seed in weed seed banks of 0-5 and 5-10 cm layer, but weed seed number at 10-15 cm layer remained lower.

Expt. 25: Residue analysis of herbicide, insecticide and fungicide in soil, water and rice under irrigated ecosystem

PI: N Akter CI: M N Bari, M K A Bhuiyan, M A I Khan, S A Islam and M Sh Islam

Introduction:

Rice consumption has increased in accordance with population growth, the use of pesticides, including pre-and post-emergence herbicides, insecticides, and fungicides, consequently improving its production during the various stages of cultivation (Pareja *et al.,* 2011). In Bangladesh, the use of pesticides in agricultural products has a significant impact on increasing yield products and improving product quality to meet the growing food demand (Abdollahzadeh *et al.,* 2015). Bensulfuron methyl + acetachlor is a new herbicide combination reported to provide effective control of broad-leaved weeds, sedges and grasses in rice when applied at 3-6 DAT. It has been found effective for complex weed flora in rice without any phytotoxic symptoms in the crop (Sunil *et al.,* 2010). The use of pesticides in irrigated rice has intensified in recent years due to the higher incidence of foliar diseases and insect pests and the residues of these pesticides (herbicide, fungicide and insecticide) may contaminate and accumulate in rice (Furlong, 2000). Due to widely used of pesticides has risen over in agricultural practice, it has become food safety issue. The study of pesticides residues in rice is very important to protect consumer's health. So far, little is known about which proportion of the pesticide originally applied in the field could be found in various types of rice and rice straw, which necessitates residue analysis.

Objectives

To analyze the maximum residue level (MRL) of pesticides in soil, water, rice grain and straw.

Materials and methods

The experiment was conducted at BRRI farm, Gazipur in Boro, 2021-22 and 2022-23. The experiment was followed by RCB design with three replications. Thirty-five days old seedlings were transplanted on 8 January 2023 having 20 × 20 cm spacing with two seedlings per hill. BRRI dhan96 were used as a variety. The treatments were: T_1 = Control (Untreated), T_2 = Bensulfuron methyl + Acetachlore (Recommended dose @ 750 g ha^{-1}) T_3 = Bensulfuron methyl + Acetachlore (Double the recommended dose), T_4 = Thiamethoxam + Chlorantraniliprole (Recommended dose Recommended dose @75 g ha^{-1}), T_5 = Thiamethoxam + Chlorantraniliprole (Double the recommended dose), T_6 = Tricyclazole 75%WP (Recommended dose @400 g ha^{-1}), T_7 = Tricyclazole 75%WP (Double the recommended dose). Fertilizers were applied (N-P-K-S-Zn @ 120-18-75-40-4 kg ha^{-1}) for all treated plot. All fertilizers were applied as basal during final land preparation except nitrogenous fertilizer. Nitrogen was applied as top dress in three equal splits at 15, 30 and 50 DAT (days after transplanting). Herbicide was sprayed one time after rice transplanting and other pesticides were sprayed 30 DAT and at heading stage. Representative 0.5 kg paddy soil and 250 mL water samples were collected randomly in each plot at 0 (2 h post-treatment), 5, 10, 20, 30, 40, 80 days and pre-harvest interval (PHI) of 7 days after herbicides application. The representative 0.5 kg rice samples were randomly collected at pre-harvest interval (PHI) of 7 days. All the collected paddy soil, water, and rice samples were stored at −20 °C, respectively.

Collection and preparation of standard solutions

Certified pesticide standards (>90%) of bensulfuron methyl + acetachlore, thiamethoxam, Chlorantraniliprole, tricyclazole, solvents and reagents including acetonitrile and formic acid of LC-MS- grade were obtained from Sigma Aldrich. Magnesium sulphate and anhydrous sodium chloride, Primary secondary amine (PSA) and graphitized carbon black (GCB) were purchased from Sigma Aldrich. Merck Millipore system was used to collect ultra-pure water. Nylon filters (0.2 µm) from Sigma Aldrich were used to filter the sample extracts.

Preparation of standard solutions

Stock solutions (1000 µg mL^{-1}) of the five pesticide (herbicide, pesticide and fungicide) compounds were prepared individually by dissolving the technical-grade material in acetonitrile (v/v) separately. These were labeled and stored in a freezer at –20°C. From the stock solution, intermediate stock and working standard solutions were prepared as mixes.

Sample preparation

The rice grain, rice straw and soil samples were collected from fields. Rice grains were homogenized into fine powder using grinder. Rice straws were milled into coarse powders using a grinder and were used after passing through 0.1 mm metal sieves.

Instrumentation

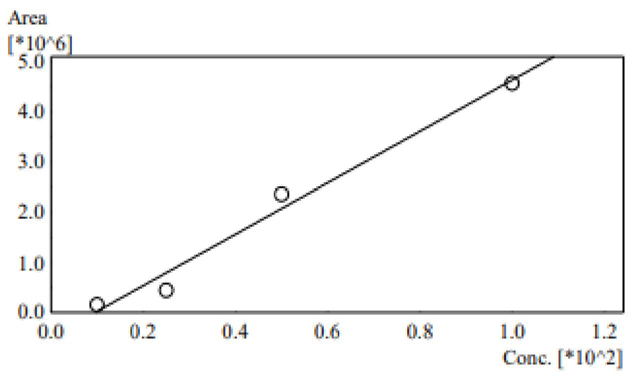
The chromatographic separation was carried out in a LC-MS-MS 8050 system using C18, 5 µm (4.8 × 250 mm) column with a mobile phase of acetonitrile: water acidified with 0.5% formic acid (50:50, v/v) at 0.5 mL min^{-1} flow rate. With these conditions, all the five analytes were detected in 10.0 min. Confirmation was done utilizing Acquity (LC-MS-MS 8050, Shimadzu, Japan). Tandem Quadrupole mass Detector (TQD) with Electrospray ionization (ESI) interface. All the five analytes were ionized in positive polarity.

Extraction and clean up

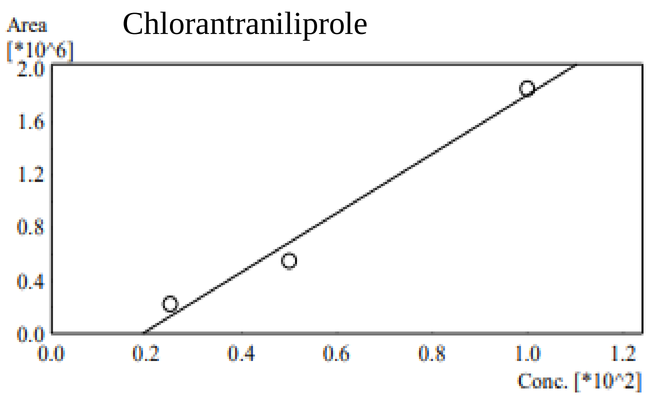
The QuEChERS method (Anastassiades *et al*., 2003) with following modifications was employed for extraction and clean-up process. Homogenized rice whole grain powder (10 g) and soil was weighed out into a 50-mL centrifuge tube. After adding 20 ml of acetonitrile, the centrifuge tube was capped and vortex shaken for 1 min. To this, 4 g anhydrous magnesium sulphate and 1 g of sodium chloride was added and again vortex shaken for 1 min to mix the sample thoroughly. The samples were centrifuged for 10 min at 8000 rpm. From this, 9 mL of supernatant was passed through 4 g of anhydrous sodium sulphate to remove moisture and out of this, 6 mL of extract was transferred into centrifuge tube containing 100 mg PSA and 600 mg anhydrous magnesium sulphate. The samples were mixed thoroughly by vortexing for 1 min and centrifuged for 10 min at 4000 rpm. Finally, 4 mL of acetonitrile layer was transferred into a clean glass test tube. The final volume was reconstituted to 1 ml using acetonitrile and transferred into a 1.5 mL glass auto sampler vial for LC/MS-MS analysis after filtering through a 0.2 µm filter membrane. For straw sample analysis, additionally 10 mg GCB powder was taken into a 50 mL centrifuge tube.

Results and Discussion

The performance of the developed method was validated with linearity, limit of detection (LOD), and limit of quantitation (LOQ). In order to obtain realistic and accurate results, linearity was evaluated by using the matrix-matched standard calibrations method to eliminate matrix effects (**Figure 33**). Excellent linearities were acquired with all the determination coefficients (R_2) higher than 0.98 to 0.99 in the range of 0.005-0.5 mg/L with three to five calibration points for bensulfuron-methyl and 0.025-1 mg/L for thiamethoxam, 56hlorantraniliprole and tricyclazole, respectively (**Figure 34)**. Quantification was calculated using the calibration curve constructed by linear regressing of pesticide concentrations against peak areas.



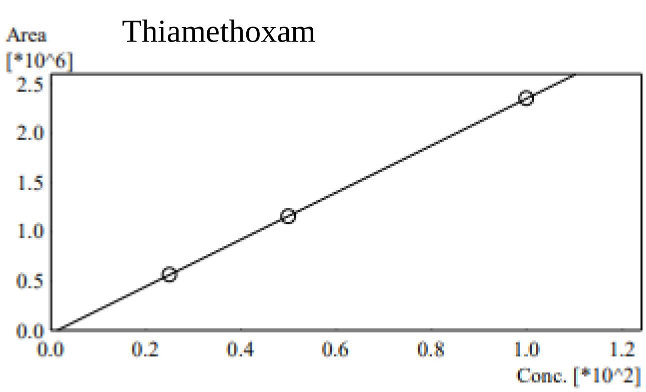
#	Conc.(Ratio)	MeanArea	Area
3	10	155326	155326
4	25	444385	444385
5	50	2361470	2361470
6	100	4568058	4568058



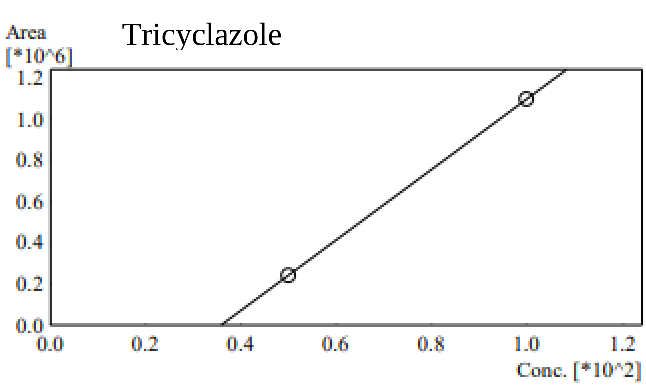
#	Conc.(Ratio)	MeanArea	Area
4	25	224577	224577
5	50	550762	550762
6	100	1854224	1854224

Figure 33. The calibration curve of the four pesticides

Result showed that the retention time of bensulfuron-methyl, thiamethoxam, 57hlorantraniliprole and tricyclazole were 2.14-2.25, 1.85, 2.22 and 2.14 min, individually. Among the 30 samples from different matrix (clean rice, straw and soil), pesticide residues were found only in 10 grain and straw samples from double dose of pesticides treated plot. No residues were found in soil matrix (**Table 44**). The residues of pesticides were found to be below MRL fixed by FSSAI for pesticides in rice (FSSAI, 2018). The experiment needs to be repeated for further confirmation.



#	Conc.(Ratio)	MeanArea	Area
4	25	564836	564836
5	50	1158298	1158298
6	100	2354085	2354085



#	Conc.(Ratio)	MeanArea	Area
5	50	241656	241656
6	100	1096475	1096475

Figure 34. Linearity of rice whole grain and rice straw matrix match pesticide standards.

Table 44. The retention time and concentrations (ppb) of four pesticides in soil, rice grain and rice straw

Treatments	Rice grain		Straw		Soil	
	Retention time (min)	Concentration (ppb)	Retention time (min)	Concentration (ppb)	Retention time (min)	Concentration (ppb)
T_1=Control (Untreated)	-	Not detected	-	Not detected	-	Not detected
T_2=Bensulfuron methyl (Recommended dose @ 750 g/ha)	2.25	Not detected	2.146	Not detected	2.141	Not detected
T_3=Bensulfuron methyl (Double the recommended dose)	2.25	0.827	2.146	0.825	2.141	Not detected
T_4=Thiamethoxam + Chlorantraniliprole (Recommended dose Recommended dose @75 g ha^{-1})	1.853	Not detected	1.842	Not detected	1.829	Not detected
T_5=Thiamethoxam + Chlorantraniliprole (Double the recommended dose)	1.853 2.225	0.96 1.198	1.842 2.223	0.98 1.155	1.829 2.221	Not detected
T_6= Tricyclazole 75%WP (Recom. Dose @400 g ha^{-1})	2.103	Not detected	2.149	Not detected	2.147	Not detected
T_7=Tricyclazole 75%WP (Double the recommended dose)	2.103	0.983	2.149	1.002	2.147	Not detected

Expt. 26: Degradation pattern of herbicide in rice field soil under irrigated ecosystem

PI: S A Islam CI: A Sultana H B Shozib, M M Islam, M K A Bhuiyan and N Akter

Introduction

Herbicides use is increasing in Bangladesh and throughout the world due to increasing labour cost, quick weed control in rice and non-rice areas etc. Consumption of herbicides to the crop production is the highest followed by the fungicides, insecticides, and others. As herbicides are chemical in nature, some group shown phytotoxicity to crop plants, and residue have health hazards when persist in soil and grain. The new molecules of herbicide require lower dose and found no phytotoxic effect to crop. In Bangladesh, Bensulfuron methyl + acetachlor and pendimethalin are the most popular anew molecule of herbicide. So, the study of degradation pattern of herbicide in rice field and residue in rice grain is very important to ensure the health safety issues.

Objectives

To analyze the degradation of residue level of herbicide in soil and rice grain sample.

Materials and methods

The experiment was conducted at BRRI farm, Gazipur in T. Aman, 2022. The experiment was followed by RCB design with three replications. Thirty-five days old seedlings of BRRI dhan87 were transplanted on 28 July, 2022 having 20 × 20 cm spacing with two seedlings per hill. The treatments were: T_1 = Control (Untreated), T_2 = Bensulfuron methyl + Acetachlore; T_3 = Ethoxy sulfuron ethyl and T_4 = Pendimethalin. Fertilizers were applied (N-P-K-S @ 90-16-68 35 kg ha^{-1}) for all treated plot. All fertilizers were applied as basal during final land preparation except nitrogenous fertilizer. Nitrogen was applied as top dress in three equal splits at 15, 30 and 50 DAT (days after transplanting). Herbicide was sprayed one time after rice transplanting and other pesticides were sprayed 30 DAT and at heading stage. Representative 100 g paddy soil composite sample were collected randomly in each plot at 3, 10, 20, 30, 40 days. All the collected paddy soil and rice samples were stored at −20 °C, respectively.

Preparation of standard curve

Analytical standards (Purity by HPLC ≥ 98.0 %) of bensulfuron methyl, acetachlore, ethoxy sulfuron ethyl and pendimethalin and all required chemicals were from Sigma Aldrich, Germany were used in this experiment. Merck Millipore system was used to collect ultra-pure water. Nylon filters (0.2 μm) from Sigma Aldrich were used to filter the sample extracts. Stock solutions (1000 μg mL^{-1}) of the four herbicide compounds were prepared individually separately. These were labeled and stored in a freezer at –20°C. From the stock solution, intermediate stock and working standard solutions were prepared.

Instrumentation

The chromatographic separation was carried out in a LC-MS-MS 8050 system using C18, 5 μm (4.8 × 250 mm) column with a mobile phase of acetonitrile: water acidified with 0.5% formic acid (50:50, v/v) at 0.5 mL min^{-1} flow rate. With these conditions, all the herbicide slandered and samples were run for 40 min. Confirmation was done utilizing Acquity (LC-MS-MS 8050, Shimadzu, Japan). Tandem Quadrupole mass Detector (TQD) with Electrospray ionization (ESI) interface. All the five analytes were ionized in positive polarity.

Extraction

The QuEChERS method (Bożena Łozowicka *et al.*, 2017) were followed with some optimization for extraction from soil and grain. Five grams of homogenized soil sample/rice grain and 10 mL of cold purified water in a 50 mL centrifuge tube to hydrate the samples. Ten milliliters of 1% formic acid in acetonitrile were added and the sample was vortexed for 7 min. A salt mixture, 4 g $MgSO_4$, 1 g NaCl, 1 g trisodium citrate dihydrate ($Na_3C_6H_5O_7$•$2H_2O$) was added and immediately shaken to prevent crystalline agglomerates. Separation of the supernatant by centrifuge for 5 min at 4500 rpm. Three milliliters of extract were transferred into a flask and cold dried by nitrogen evaporation and resuspend with 1.5 ml methanol and filtrate for further analysis by LCMS-MS. Linearities were acquired with all the determination coefficients (R_2) higher than 0.99 in the range of 0.005-0.5 mg/L with three to five calibration points of all herbicide were given in Figure 35. Quantification was calculated using the calibration curve constructed by linear regressing of pesticide concentrations against peak areas (**Figure 35**).

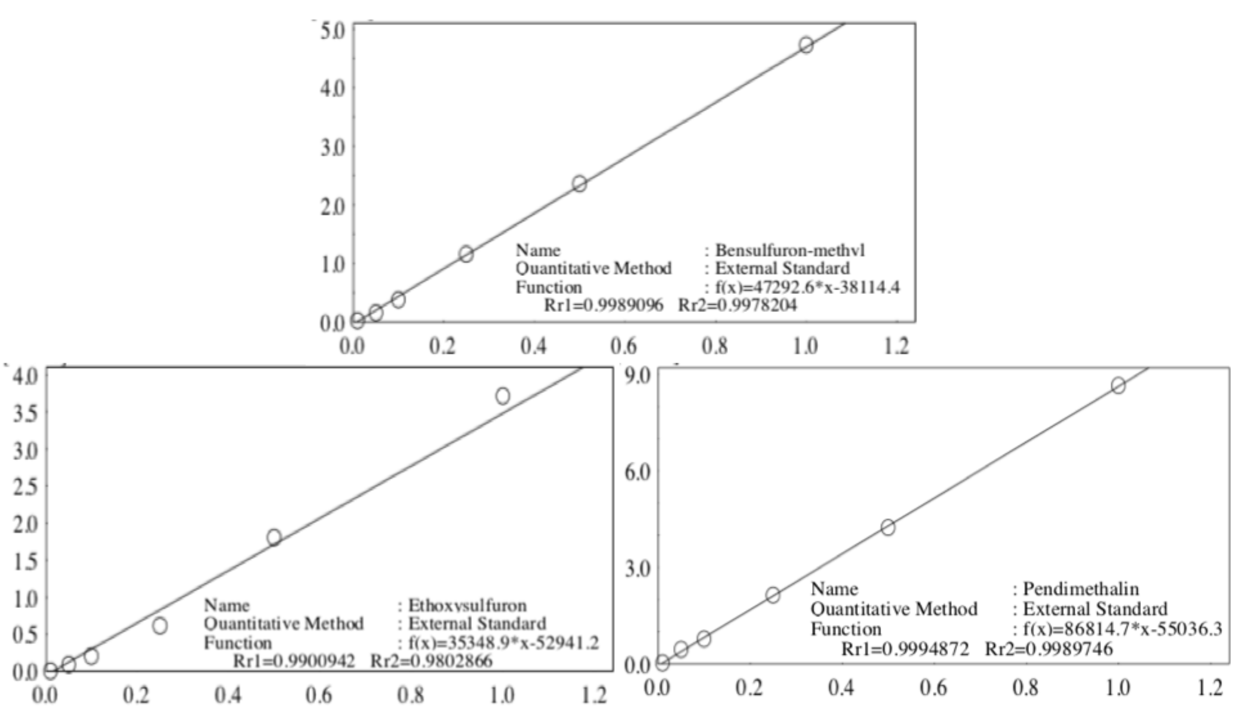


Figure 35. The slandered calibration curve of the three herbicide

Results

The retention time of bensulfuron methyl, ethoxy sulfuron ethyl and pendimethalin were 2.23, 2.43 and 35.55 min, individually. Among the soil samples bensulfuron methyl, ethoxy sulfuron ethyl have been detected up to 30 DAT and pendimethalin have been detected up to 20 DAT (**Table 45**). Acetachlore was not detected in any sample might be due to volatile in nature and need to standardized the protocol for GCMS MS. No residues were found in soil and rice grain matrix after harvesting of rice sample from field. The residues of pesticides were found to be below MRL fixed by FSSAI for pesticides in rice (FSSAI, 2018). Sondhia (2014) also reported that all these tested herbicide are categorized is unlikely to cause any harmful effects with LD50 value > 5000 mg/kg. The experiment needs to be repeated for further confirmation.

Table 45. The retention time and concentrations (ppb) of four pesticides in soil and rice grain

Treatment	Herbicide	Oral LD_{50}	Soil sample at 03 DAT	Soil sample at 10 DAT	Soil sample at 20 DAT	Soil sample at 30 DAT
T1	Control (No herbicide)	-	ND	ND	ND	ND
T2	Bensulfuron methyl	>5000 ppm	20.01 ppb	9.05 ppb	3.02 ppb	ND
T3	Ethoxy sulfuron ethyl	3270 ppm	8.35 ppb	3.89 ppb	1.52 ppb	ND
T4	Pendimethalin	4050 ppm	25.08 ppb	12.98 ppb	5.68 ppb	1.89 ppb

Conclusion

Herbicide residue of Bensulfuron methyl, Ethoxy sulfuron ethyl and Pendimethalin degrade in soil and became ND (Not detectable) within 30 days and no herbicide residue were detected in rice grain sample after harvesting in T. Aman season.

Expt.27: Evaluation of candidate herbicide for weed control efficiency in T. Aman 2022 and Boro 2022-23 season

PI: MKAB, CI: MM Mahbub and Sh. Islam

Introduction: Weed infestation is one of the major threats to crop growth and yield. In Bangladesh, conventionally weeds are controlled in rice fields by hand weeding, which is labor intensive. On the other hand, the herbicide is easy to apply, efficient to control weeds, and cost-effective compared to hand weeding. So, the use of herbicides for controlling weeds in rice fields is gaining popularity day by day. New molecules and new combinations of herbicides are imported by different companies, which need evaluation at the field level for a recommendation. During reporting year (T. Aman 2022 and Boro 2022-23), fifty-one herbicides of twenty different groups were evaluated.

Objective: To evaluate the weed control efficiency of candidate herbicides in transplanted rice.

Materials and Methods: Field trials were conducted at the Bangladesh Rice Research Institute, Gazipur from T. Aman 2022, and Boro 2022-23, seasons. All treatments were laid out in a randomized complete block design with three replications. Thirty-day-old seedlings of BRRI dhan87 in T. Aman and BRRI dhan28 for Boro seasons were transplanted at a spacing of 20 × 20 cm with 2-3 seedlings $hill^{-1}$. Fertilizer was applied following BRRI recommended dose. Twenty different groups of 51 brand herbicides were evaluated during T. Aman 2022 and Boro 2022-23 seasons. The weed control efficiency of all tested herbicides was compared with the control (un-weeded) treatment. Pre-emergence herbicides were applied at 4 DAT and post-emergence herbicides at 1-2 leaf stage of weed. Late post-emergence herbicides were applied in 3-4 leaf stages. Weed sampling was done at 40 DAT for T. Aman and 45 DAT for Boro season. Weed control efficiency was calculated on a weed dry weight basis.

Results and Discussion: Most of the herbicides performed more than 80% weed control efficiency in different weed populations observed in the field (**Table 46**). Only *Cynodon dactylon* cannot be controlled >80% by some herbicides in most cases. Among twenty groups of herbicides, most of the groups were post-emergence and early post-emergence. Among the herbicides, four herbicides did not control weed effectively and their weed control efficiency was less than 80%. Some herbicides were found phytotoxic which were treated as not satisfactory for weed control. In **Table 46**, some new groups of herbicides and their weed control efficiency have been described. **Table 46** shows that post-emergence herbicide coming dominant and most of the herbicide contains combination chemicals which indicate to be more effective. Four herbicides eg. Pyrazosulfuron ethyl 10% + Bispyribac 20% WP, Triasulfuron, Metsulfuran methyl 10% +Chlorimuron ethyl 10%, Bispyribac sodium 40% SC, etc. did not control weed effectively, where the weed control efficiency of this herbicide was less than 80%. Other groups of herbicides were more than 80% weed control efficiency.

Table 46. Herbicide chemical name, dose and weed control efficiency of different herbicide evaluated during T. Aman 2022 and Boro 2022-2023 at BRRI farm Gazipur

Chemical name	Dose ha^{-1}	Season	Weed Control Efficiency (%)					Remarks
			Cynodon dactylon	*Echinochloa crus-galli*	*Monochoria vaginalis*	*Scirpus maritimus*	*Cyperus difformis*	
Bispyribac sodium 18%+ Bensulfuron metlyl 12%	150 g	Aman	82.50	81.50	85.00	82.88	80.80	Postemergence satisfactory
		Boro	75.50	80.00	84.85	76.65	81.08	
Quizalofop p ethyl 15% +ethoxysulfuron 15%	50 g	Aman	80.50	83.0	85.40	82.78	84.75	Post emergence Satisfactory
		Boro	78.10	80.85	82.44	82.30	81.70	
Atrazine + Mesotrione	600 ml	Aman	78.82	80.50	80.45	80.20	80.50	Late post-emergence (3-4 leaves stage); very sensitive, over dose may destroy rice plant.
		Boro	80.54	82.00	83.50	81.90	82.84	
Pretilachlor 15 %+ Oxyfluorfen 12 %+ Oxadiazon 7 %	1.0 L	Aman	78.70	84.00	86.00	82.50	81.55	Post-emergence Satisfactory
		Boro	70.80	83.50	80.60	82.80	81.70	
Pretilachlor + Pyrazosulfuran Ethyl	800 g	Aman	82.70	81.80	82.10	80.28	80.80	Post-emergence. Satisfactory
		Boro	85.00	83.40	85.55	81.80	77.25	
Bispyribac sodium 40% SC	150 ml	Aman	81.50	80.50	82.50	45.75	80.55	Early Post-emergence Satisfactory
		Boro	81.60	80.07	80.80	82.70	82.50	
Pyrazosulfuron ethyl 10% + Bispyribac 20% WP	150 g	Aman	70.60	72.95	72.00	75.75	70.00	Post emergence not Satisfactory
		Boro	77.50	71.60	74.00	77.70	78.96	

TECHNOLOGY TRANSFER

Expt.28: Cost effective weed management in transplanted rice of Haor area

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Weeds are recognized as major biological constraints that hinder the attainment of optimal rice productivity in Bangladesh. In Bangladesh, the traditional methods of weed control by smallholders include hand weeding by hoe and hand pulling. Usually, two or three hand weeding is done for growing a rice crop. However, especially at the time of peak period of labor demand, weeding often is done late, which causes drastic yield loss in rice. Farm families typically are unable to do all their own weeding and need to hire labor. Farmers indicate that finding available labor on time and financing labor is a problem. On an average, in Bangladesh about 40-50% yield was reduced in farmers' field due to poor weed management. Rice production became expensive due to high labor cost.

Research in Bangladesh demonstrated that herbicide applications would produce similar rice yields to three carefully timed hand weeding with a significant reduction in labor requirements and total costs. Pre-emergence herbicides are 38-46% cheaper than one hand weeding. Economic analysis of rice production in Bangladesh revealed that the weed management cost by hand weeding is 5 times higher than herbicide application and 3 times higher than weeder application. Large scale adaptive trail in the farmers' field could be a potential option to popularize mechanical and chemical weed control technology among the farmers' of Bangladesh and to reduce the rice production cost.

Materials and Methods

The trial was conducted at the Tahirpur, Sunamgaj during Boro, 2022-23, seasons to evaluate the method of weed suppression and to find out an appropriate way to reduce weed infestation in farmers field. The trial was carried out with three treatments viz. T_1= Weed management by pre/post emergence herbicide + 1 HW (if needed), T_2= Weed management by BRRI Weeder just after 1st & 2nd top dress of urea and T_3= Weed management by farmers' practice. Twenty-five days old seedlings of BRRI dhan52 were transplanted at 20 × 20 cm spacing with 2 seedlings hill^{-1} at Aman season and thirty-five-day old seedlings of BRRI dhan67, BRRI dhan88 and BRRI dhan89 were transplanted at Boro season. Fertilizer was applied by following BRRI recommended dose Aman: N:P:K:S= 77:12:52:12 kg ha^{-1} and Boro: N:P:K:S:Zn= 120:18:74:20:4 kg ha^{-1}. Pre-emergence (Bensulfuran methyl + acetachlor) herbicide was sprayed at 5 days after transplanting at Sunamganj and post-emergence (Penoxulam) herbicide was sprayed at 8 days after transplanting at Sonagazi with the help of a knapsack sprayer. Weeding was done by BRRI weeder during 1st and 2nd top dress of urea.

Results and discussion

Application of pre or post emergence herbicide and BRRI Weeder both produced the higher grain yield than Farmers' practice at Sonagazi, Feni and Tahirpur, Sunamganj. Because both treatments were applied at suitable time in all locations. Due to late hand weeding, weed infestation was higher in farmer's plots and yield was also reduced than BRRI treatments (**Table 47**).

The highest weed biomass was found for Shama, Halde mutha and Helencha in Farmers practice treatment at Tahirpur, Sunamganj. So weed infestation was highest in these plots. Application of herbicide and BRRI Weeder at proper time reduce the weed infestation effectively (**Table 48**).

Pre emergence herbicide was used at Chicksha, Sunamganj which price was 100/- Tk (per packet) and Post emergence herbicide (300/- Tk per bottle) was used at Moddho Tahirpur, Sunamganj. Three labour required per bigha for both the locations of Sunamganj for herbicide spray. BRRI weeder treatment required 3 labour at Chicksha and 4 labour at Moddho Tahirpur, Sunamganj. Farmers were used 5 and 7 labour for weeding respectively at Chicksha and Moddho Tahirpur (**Table 49**). Considering the cost of three methods herbicide application is most profitable.

Farmer's reactions:

Farmers of Feni and Sunamganj were very much happy to observe the performance of herbicide because they never used this herbicide before and farmers of Sunamganj was used herbicide but not at appropriate time. So they had to use hand weeding several times in their field. All farmers said that herbicide application was more convenient than hand weeding because high labour price and difficulties during application of BRRI weeder. They are interested to apply herbicides to manage weed in next rice crop.

Table 47. Varietal performance at farmer's field in different weed control method at Tahirpur, Sunamganj during Boro, 2022-23

Treatments	Grain yield (t ha^{-1})		
	BRRI dhan67	**BRRI dhan88**	**BRRI dhan89**
Weed management by pre/post emergence herbicide	7.90	6.35	6.95
Weed management by BRRI Weeder just after 1st & 2nd top dress of urea	7.95	6.21	7.03
Weed management by farmers' practice	7.67	6.05	6.60

***There was no irrigation system near the field of BRRI dhan88 and BRRI dhan89. So, yield was decreased due to lack of irrigation during vegetative and reproductive phase.

Table 48. Weed Biomass (dry weight (g) m^{-2}) of different weed control methods at Tahirpur, Sunamgang

Treatments	BRRI dhan88			BRRI dhan67			
	Shama	Halde mutha	Helencha	Shama	Halde mutha	Helencha	Biskatali
Weed management by pre/post emergence herbicide	1.98 g	1.05g	0.62g	1.35g	0.19g	0.65g	0g
Weed management by BRRI Weeder just after 1st & 2nd top dress of urea	1.39g	1.68g	1.02g	1.90g	1.65g	0.43g	0g
Weed management by farmers' practice	5.02g	1.14g	2.07g	4.10g	1.32g	1.08g	0.57g

Table 49. Weeding cost of farmers field (All the operational cost eg. transplanting to harvesting were nearly same) at different area during, 2022-23 at Tahirpur

Treatments	Weeding cost (tk ha^{-1})
Weed management by pre/post emergence herbicide	13000/-
Weed management by BRRI Weeder just after 1st & 2nd top dress of urea	22500/-
Weed management by farmers' practice	24500/-

*Labour cost of Sunamganj was 500/- per day