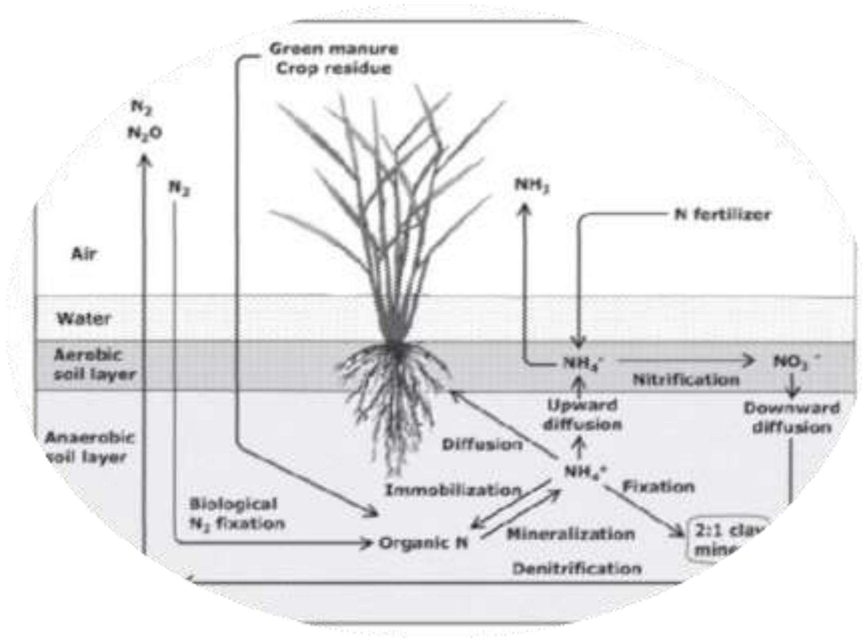
ANNUAL RESEARCH REVIEW WORKSHOP 2024-25

VIII. SOIL SCIENCE DIVISION

(Crop-Soil-Water Management Program Area)



BANGLADESH RICE RESEARCH INSTITUTE

Content

INTRODUCTION

Soil Science Division, a principal component of Crop-Soil-Water Management (CSWM) program area of BRRI, is entrusted with responsibility of conducting research on soil-plant continuum for improving rice yield sustainably. Scientists of this division develop and execute soil research programs. The CSWM program committee, under the guidance of the Director (Research) periodically reviews and evaluates the research findings and set priorities on short-and long-term research objectives.

Soil Science Division conducts research on soil fertility and fertilizer management along with biofertilizer, integrated nutrient management for rice-based cropping systems, long-term monitoring of nutrient management and greenhouse gas emission measurements. Besides, Scientists also conducted research on micronutrients, biochar effect, saline soil management, estimation of global warming potential in different cropping patterns in Bangladesh and climate smart agriculture. Evaluation of new fertilizer materials for rice is an additional task to this division. Masters and PhD students frequently share divisional facilities for their thesis works. During July 2022 to June 2023 following Scientists and staff were involved with divisional activities:

Name	Designation	Man-months
Md Rafiqul Islam Islam, PhD	CSO & Head	12
Umme Aminun Naher, PhD	PSO	12
Muhammad Sazidur Rahman, PhD	PSO	12
ATM Sakhawat Hossain, PhD	PSO	12
Fahmida Rahman, PhD	SSO	12
Md Mozammel Haque, PhD	SSO	12
Masuda Akter, PhD	SSO	12
S M Mofijul Islam, PhD	SSO	12
Md. Mosud Iqbal, PhD[1]	SSO	0
Md. Nazrul Islam, PhD	SSO	12
M Imran Ullah Sarker, MS[2]	SSO	0
Afsana Jahan, MS	SSO	12
Tanjina Islam	SO	12
Mehedi Hasan Khan	SO	12
Nasima Akhter, B.Sc	SA	12
Abu Taleb, Diploma in Agril.	SA	12
Md Azimuddin, MDA in Agril. Busi.	SA	04
Shakyla Begum	LDA	12
Md. Rafiqul Hassan	GA	12
Nazma Akter	LA	12

[1]Transfer to BRRI RS, [2]Abroad for higher study

Useful Scientific Information

- The calculated economically optimum N dose advanced line BR11894-R-R-R-R-169 was 156 kg N ha^{-1}.
- The calculated economic optimum N dose of PQR ALART material BR11359-4R-181 was 150 kg and for BR11359-4R-279 was 155 kg N ha^{-1},
- The calculated economic optimum N dose of PQR-Path ALART material was 155 kg N ha^{-1}, and for the check varieties BRRI dhan50 and BRRI dhan104 the doses were 150 and 158 kg N ha^{-1}.
- The calculated economic optimum N dose of favorable Boro ALART material BR11318-5R-8 was 165 kg Nha- 1, and for the check variety BRRI dhan92 the dose was 160 kg Nha-1.
- The application of the DPN (Disease Preventive Nutrient) solution with the recommended fertilizers slightly increased the grain yield of BRRI dhan87 and BRRI dhan90.
- The application of SILIFORCE-4 with the recommended fertilizers slightly increased the grain yield of BRRI dhan102.
- Urea deep placement significantly increased rice yield under both AWD and CSW.
- Applying ammonium chloride at different doses did not significantly influence the grain and straw yields of BRRI dhan 87 and BRRI dhan103 in the Gazipur and Rajshahi sites
- The Isabion with 100% STB NPKSZn has some beneficial effect on grain yield (5 to 21%) and MBCR (1.7 to 3.6) over 100% STB NPKSZn only, irrespective of locations and spraying rates.
- Response of rice to applied P under soil P deficit conditions was sharp and the response was much lower in T. Aman (wet season) than in Boro (dry season). Soil test based P application can ensure the better rice yield.
- Exact 40 and 80 kg K ha^{-1} appears to be the optimum application rate for T. Aman and Boro rice in Madhupur Tract soils.
- The selected BRRI Sonagazi farm has wide spatial variation in the most important soil properties like pH-H_2O, OC, total N and available K, hence could be suitable to do research on identifying variable rates of N and K fertilizers instead of their uniform rates.
- Tested line L_1= BR28NILQRL6.1-01 seems to be more nitrogen efficient in terms of short duration breeding lines as it gave statistically higher yield than the check variety CK_1= BRRI dhan88. So, this breeding line may proceed for further trial to develop N use efficient rice variety.
- Long-term omission of N, P and K adversely affected rice yield in Grey Terrace soil of BRRI farm, Gazipur (AEZ 28, Modhupur Tract) in both T. Aman and Boro seasons. Omission of S and Zn have less or no yield reduction in both seasons. Application of IPNS based chemical and organic fertilizers have great positive impact on sustaining rice yield as well as maintaining soil fertility.
- The omission of N in in Boro season from complete fertilizer significantly reduced the grain yield of rice at all BRRI RS farm. Among the major nutrient elements, omission of N appeared as the most yield limiting nutrient followed by P and K omission for rice in Boro season.
- Intensive rice cropping with NPKSZn resulted in highest annual yield of rice compared to other chemical fertilizer applocation. Application of Zn and Cu fertilizer showed positive effect on rice yield. Application of different organic amendment with IPNS based fertilizers has great positive impact on sustaining rice yield as well as soil fertility. So, IPNS based fertilizer management is necessary for sustainable rice production in Bangladesh.
- STB dose and 50% STB + MM fertilizer produced significantly higher grain yield than farmers practice and cumulative yield of triple rice cropping was always higher than double rice cropping pattern.
- The INM combinations using PM and CD with 25-50% reduced doses of chemical fertilizers can produce satisfactory rice yield. It can save chemical fertilizers cost in a significant amount and may minimize the environmental pollution in both soil, water and air with judicial use or less use of chemical fertilizer.
- Integrated nutrient management has great impact on increasing rice yield of fine and aromatic rice in north–western part of Bangladesh. Both the rice varieties BRRI dhan104 and BRRI

dhan107 gave satisfactory yield with application of reduce doses (25-50%) of chemical fertilizer with 1-2 ton cowdung per hectare. Around 25-30% yield increase was observed with INM practices over fertilizer control and similar yield was obtained in comparison with 100% chemical fertilizer in both varieties. The findings may reduce the production cost with saving the excess fertilizer cost. The research work in T. Aman season is going on.

- Application of soil test based K as chemical fertilizer or integrated use of chemical K plus rice straw or rice husk ash have remarkable effect on increasing grain yield of both varieties in old Himalayan Piedmont soil of AEZ 1. On an average 30% yield increase observed in application of K fertilizer over K control in for both rice varieties in Boro season.
- AWD irrigation reduces about 38-42% of total CH_4 flux and 35-39% of GWP than continuous standing water (CSW) at different location in Bangladesh.
- In T. Aman season, rainfed condition reduced 12-18% GWP than other irrigation system. In Boro season, reduce about 15% of GWP by AWD irrigation system than continuous standing water (CSW) system. In T. Aman, rain fed water management one of the key technique for reducing total CH_4 emission, and GWP and GHG intensity without sacrificing rice yield. In Boro season, AWD is the important irrigation system for reducing GHG, GWP but not significant different of grain yield than CSW irrigation system.
- At BRRI Gazipur application of Bio-coated urea (BCU) increased N use efficiency, improved rice yield (10 to 40%) and saved 40%.
- Study results proved BRRI organic fertilizer (0.5 t ha^{-1} to 1 t ha^{-1}) has the potential to supplement 30% N and 100% P requirement for HYV rice without sacrificing yield.
- Matiranga soils are acidic and pH ranged from 4.7 to 6.1. Soil organic matter is low to medium (1.2% to 2.5%) and having 0.07% to 2.5% total N. In the Matiranga, top 15 phylum/genera identified were *Alphaproteobacteria, Gammaproteobacteria, Acidobacteriae, Bacteroidia, Vicinamibacteria, Verrucomicrobiia, Actinobacteria, Acidimicrobiia, Myxococcia, Polyangiia, Bathyarchaeia, Anaerolineae, Parcubacteria, Desulfuromonadia, Gemmatimonadia.* Rice cropping system diversified relative abundance of bacteria.

SUB-SUB PROGRAM I: SOIL FERTILITY AND PLANT NUTRITION

Project 1: Fertility Assessment of Rice Soils and Nutrient Use Efficiency in Rice

Expt. 1. Determining N requirement of cold tolerant ALART materials

A.T.M. Sakhawat Hossain and Md. Rafiqul Islam

Introduction

Nitrogen (N) is the most yield limiting and widely applied nutrient in Bangladeshi rice field in all rice growing season, and rice crop exhibits stronger response to applied N than other nutrients. Nitrogen management is essential in growing rice and N fertilization can largely improve rice productivity and profitability (Angus et al., 1994; De-Xi et al., 2007). Rice crop generally requires 16-18 kg N for each ton of grain yield under optimum condition. The N requirement of rice varies with the rice genotypes (Jing et al., 2008; Hirzel et al., 2011). Biomass production of irrigated rice is mainly driven by the supply of N (Thein, 2004). Even the demand of the rice plant for other macro-nutrients are also depends on N supply. On the other hand, inappropriate N fertilization adversely affects the crop growth and yield. So, it is necessary to determine the optimum N requirement of promising or advanced rice genotypes before releasing as a new variety. Keeping the above points in mind, a study was undertaken to find out the optimum N doses by evolving N response curves for one cold tolerant rice genotype and two check varieties of Boro season.

Materials and Methods

Field trial was conducted at BRRI farm, Gazipur in Boro 2024-25 season to determine the N requirement of cold tolerant rice advanced line. One cold tolerant advanced line V_1= BR11894-R-R-R-R-169 was compared with two check varieties V_2= BRRI dhan28 and V_3= BRRI dhan67 in Boro. Six N rates (kg ha^{-1}): N_0, N_{40}, N_{80}, N_{120}, N_{160} and N_{200} were applied for the experiment following split-plot design with 3 replications, where N rates were assigned in main-plot and rice genotypes in sub-plot.

All treatments had received blanket doses of chemical fertilizers P-K-S-Zn @ 15-70-12-1 $kgha^{-1}$, respectively. All fertilizers except urea were applied as basal at final land preparation. U rea was applied into three equal splits in with one third as basal, 1st top dressing at 20 DAT and the rest one on 5 days before panicle initiation (PI) stage. Thirty-five days old seedlings of each rice genotypes were transplanted. Irrigation, weeding and other cultural management practices were done equally as per needed. At maturity the crop was harvested manually in the area of 5 m^2 at 15 cm above ground level, however, 16 hills from each plot were harvested at the ground level for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. The tiller and panicle number per meter square were recorded. Each ALART line/variety was regressed in a quadratic model of the grain yield vs. Nitrogen rates to find out optimum N rates for the respective rice genotype.

Results and Discussion

Grain yield and N requirements

Grain yield of most genotypes increased with the increasing of N rates up to 160 kg ha^{-1} and then decreased. The cold tolerant line BR11894-R-R-R-R-169 produced similar grain yield than the check variety BRRI dhan67. The calculated economic optimum dose of N for advanced line BR11894-R-R-R-R-169 was 156 kg N ha^{-1} **(Fig. 1).**

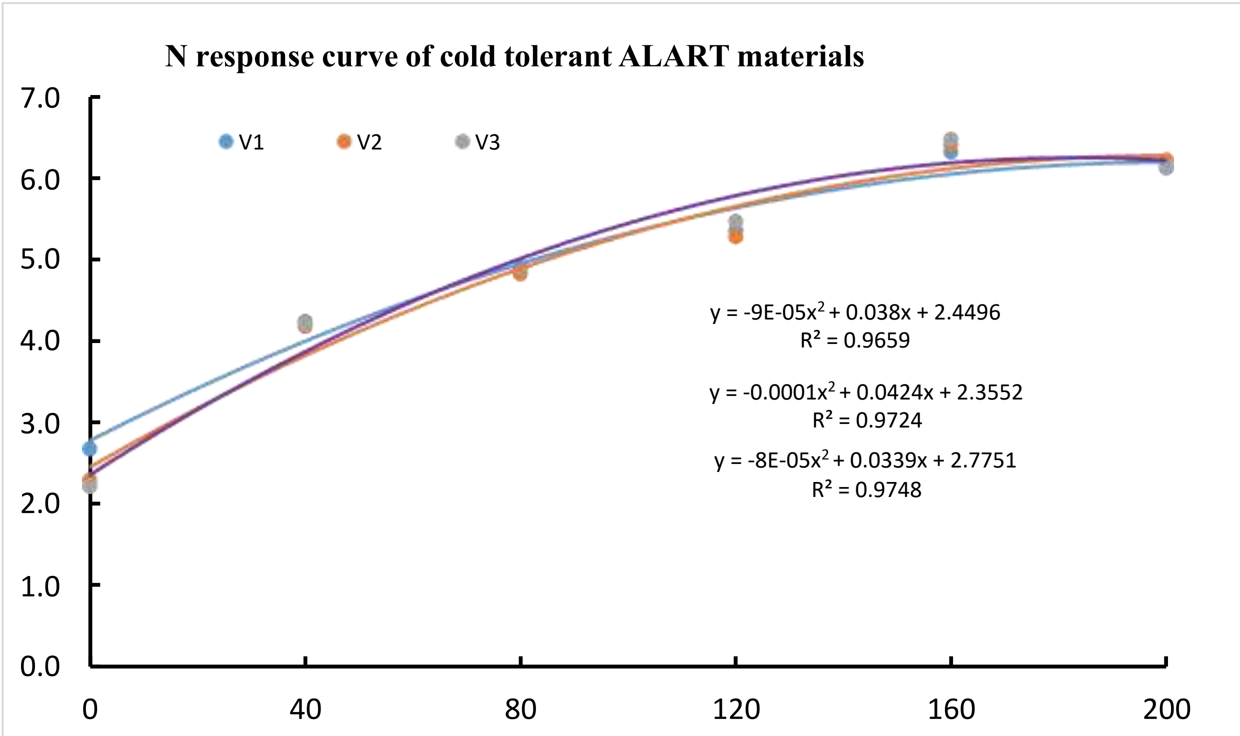


Fig. 1. Nitrogen response curve of cold tolerance ALART materials in Boro 2024-25, BRRI, Gazipur

Conclusion

The calculated economic optimum dose of N for advanced line BR11894-R-R-R-R-169 was 156 kg N ha^{-1}

Expt. 2. Determining N requirement of premium quality (PQR) Boro ALART materials

A.T.M. Sakhawat Hossain and Md. Rafiqul Islam

Introduction

Nitrogen (N) is the most yield limiting and widely applied nutrient in Bangladeshi rice field in all rice growing season, and rice crop exhibits stronger response to applied N than other nutrients. Nitrogen management is essential in growing rice and N fertilization can largely improve rice productivity and profitability (Angus et al., 1994; De-Xi et al., 2007). Rice crop generally requires 16-18 kg N for each ton of grain yield under optimum condition. The N requirement of rice varies with the rice genotypes (Jing et al., 2008; Hirzel et al., 2011). Biomass production of irrigated rice is mainly driven by the supply of N (Thein, 2004). Even the demand of the rice plant for other macro-nutrients are also depends on N supply. On the other hand, inappropriate N fertilization adversely affects the crop growth and yield. So, it is necessary to determine the optimum N requirement of promising or advanced rice genotypes before releasing as a new variety. Keeping the above points in mind, a study was undertaken to find out the optimum N doses by evolving N response curves for one cold tolerant rice genotype and two check varieties of Boro season.

Materials and Methods

Field trial was conducted at BRRI farm, Gazipur in Boro 2024-25 season to determine the N requirement of PQR Boro advanced lines. Two PQR advanced line V_1= BR11359-4R-181 and V_2= BR11359-4R-279 were compared with two check varieties V_3 = BRRI dhan104 and V_4= BRRI dhan107 in Boro. Six N rates (kg ha^{-1}): N_0, N_{40}, N_{80}, N_{120}, N_{160} and N_{200} were applied for the experiment following split-plot design with 3 replications, where N rates were assigned in main-plot and rice genotypes in sub-plot.

All treatments had received a blanket doses of chemical fertilizers P-K-S-Zn @ 14-70-12-1 $kgha^{-1}$, respectively. All fertilizers except urea were applied as basal at final land preparation. Urea was applied into three equal splits in with one third as basal, 1st top dressing at 20 DAT and the rest one on 5 days before panicle initiation (PI) stage. Thirty-five days old seedlings of each rice genotypes were transplanted. Irrigation, weeding and other cultural management practices were done equally as per needed. At maturity the crop was harvested manually in the area of 5 m^2 at 15 cm above ground level, however, 16 hills from each plot were harvested at the ground level for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. The tiller and panicle number per meter square were recorded. Each ALART line/variety was regressed in a quadratic model of the grain yield vs. Nitrogen rates to find out optimum N rates for the respective rice genotype.

Results and Discussion

Grain yield and N requirements

Grain yield of most genotypes increased with the increasing of N rates up to 160 $kgha^{-1}$ and then decreased. The calculated economic optimum N dose of PQR ALART material BR11359-4R-181 was 150 kg and for BR11359-4R-279 was 155 kg N ha^{-1}, respectively **(Fig. 2).**

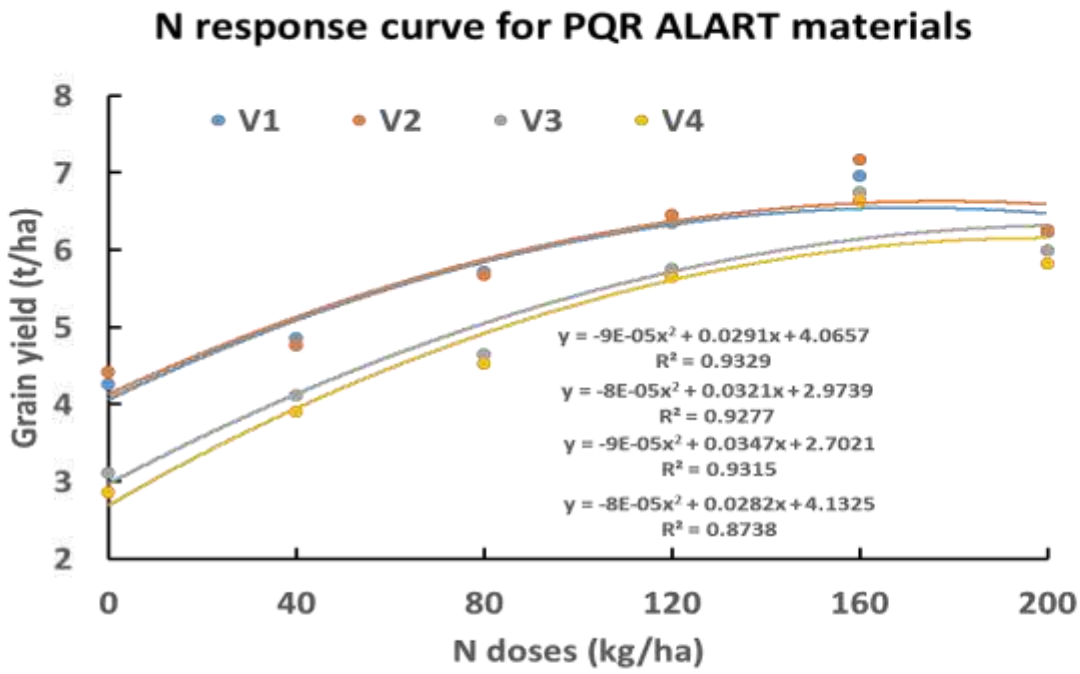


Fig. 2. Nitrogen response curve of PQR ALART materials in Boro 2024-25, BRRI, Gazipur

Conclusion

The calculated economic optimum N dose of PQR ALART material BR11359-4R-181 was 150 kg and for BR11359-4R-279 was 155 kg N ha^{-1}

Expt.3. Determining N requirement of premium quality-Path (PQR-Path) Boro ALART materials

A.T.M. Sakhawat Hossain and Md. Rafiqul Islam

Introduction

Nitrogen (N) is the most yield limiting and widely applied nutrient in Bangladeshi rice field in all rice growing season, and rice crop exhibits stronger response to applied N than other nutrients. Nitrogen management is essential in growing rice and N fertilization can largely improve rice productivity and profitability (Angus et al., 1994; De-Xi et al., 2007). Rice crop generally requires 16-18 kg N for each ton of grain yield under optimum condition. The N requirement of rice varies with the rice genotypes (Jing et al., 2008; Hirzel et al., 2011). Biomass production of irrigated rice is mainly driven by the supply of N (Thein, 2004). Even the demand of the rice plant for other macro-nutrients are also depends on N supply. On the other hand, inappropriate N fertilization adversely affects the crop growth and yield. So, it is necessary to determine the optimum N requirement of promising or advanced rice genotypes before releasing as a new variety. Keeping the above points in mind, a study was undertaken to find out the optimum N doses by evolving N response curves for one cold tolerant rice genotype and two check varieties of Boro season.

Materials and Methods

Field trial was conducted at BRRI farm, Gazipur in Boro 2024-25 season to determine the N requirement of PQR-Path Boro advanced line. One PQR-Path advanced line was compared with two check varieties BRRI dhan50 and BRRI dhan104 in Boro. Six N rates (kg ha^{-1}): N_0, N_{40}, N_{80}, N_{120}, N_{160} and N_{200} were applied for the experiment following split-plot design with 3 replications, where N rates were assigned in main-plot and rice genotypes in sub-plot.

All treatments had received a blanket doses of chemical fertilizers P-K-S-Zn @ 14-70-12-1 $kgha^{-1}$, respectively. All fertilizers except urea were applied as basal at final land preparation. Urea was applied into three equal splits in with one third as basal, 1^{st} top dressing at 20 DAT and the rest one on 5 days before panicle initiation (PI) stage. Thirty-five days old seedlings of each rice genotypes were transplanted. Irrigation, weeding and other cultural management practices were done equally as per needed. At maturity the crop was harvested manually in the area of 5 m^2 at 15 cm above ground level, however, 16 hills from each plot were harvested at the ground level for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. The tiller and panicle number per meter square were recorded. Each ALART line/variety was regressed in a quadratic model of the grain yield vs. Nitrogen rates to find out optimum N rates for the respective rice genotype.

Results and Discussion

Grain yield and N requirements

Grain yield of most genotypes increased with the increasing of N rates up to 160 $kgha^{-1}$ and then decreased. The calculated economic optimum N dose of PQR-Path ALART material was 155 kg N ha^{-1}, and for the check varieties BRRI dhan50 and BRRI dhan104 the doses were 150 and 158 kg N ha^{-1}, respectively **(Fig. 3).**

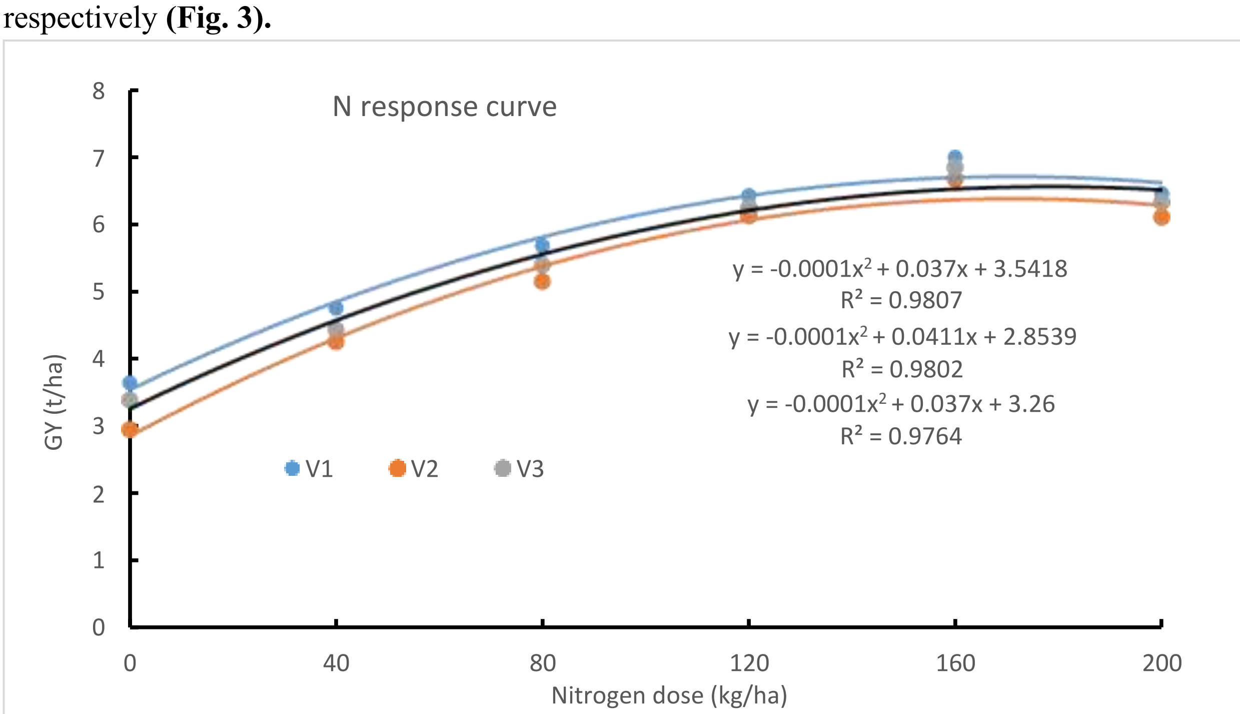


Fig. 3. Nitrogen response curve of PQR-Path ALART materials in Boro 2024-25, BRRI, Gazipur

Conclusion

The calculated economic optimum N dose of PQR-Path ALART material was 155 kg N ha^{-1}

Expt. 4. Determining N requirement of Favorable Boro ALART materials

Fahmida Rahman and Md. Rafiqul Islam

Introduction

Nitrogen (N) is the most yield limiting and widely applied nutrient in Bangladeshi rice field in all rice growing season, and rice crop exhibits stronger response to applied N than other nutrients. Nitrogen management is essential in growing rice and N fertilization can largely improve rice productivity and profitability (Angus et al., 1994; De-Xi et al., 2007). Rice crop generally requires 16-18 kg N for each ton of grain yield under optimum condition. The N requirement of rice varies with the rice genotypes (Jing et al., 2008; Hirzel et al., 2011). Biomass production of irrigated rice is mainly driven by the supply of N (Thein, 2004). Even the demand of the rice plant for other macro-nutrients are also depends on N supply. On the other hand, inappropriate N fertilization adversely affects the crop growth and yield. So, it is necessary to determine the optimum N requirement of promising or advanced rice genotypes before releasing as a new variety. Keeping the above points in mind, a study was undertaken to find out the optimum N doses by evolving N response curves for one cold tolerant rice genotype and two check varieties of Boro season.

Materials and Methods

Field trial was conducted at BRRI farm, Gazipur in Boro 2024-25 season to determine the N requirement of favorable Boro advanced line **BR11318-5R-8**. One favorable Boro advanced line was compared with one check variety BRRI dhan92 in Boro season. Six N rates (kg ha^{-1}): N_0, N_{40}, N_{80}, N_{120}, N_{160} and N_{200} were applied for the experiment following split-plot design with 3 replications, where N rates were assigned in main-plot and rice genotypes in sub-plot.

All treatments had received a blanket doses of chemical fertilizers P-K-S-Zn @ 16-80-12-2 $kgha^{-1}$, respectively. All fertilizers except urea were applied as basal at final land preparation. Urea was applied into three equal splits in with one third as basal, 1^{st} top dressing at 20 DAT and the rest one on 5 days before panicle initiation (PI) stage. Thirty-five days old seedlings of each rice genotypes were transplanted. Irrigation, weeding and other cultural management practices were done equally as per needed. At maturity the crop was harvested manually in the area of 5 m^2 at 15 cm above ground level, however, 16 hills from each plot were harvested at the ground level for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. The tiller and panicle number per meter square were recorded. Each ALART line/variety was regressed in a quadratic model of the grain yield vs. Nitrogen rates to find out optimum N rates for the respective rice genotype.

Results and Discussion

Grain yield and N requirements

The calculated economic optimum N dose of favorable Boro ALART material was 165 kg Nha^{-1}, and for the check variety BRRI dhan92 the dose was 160 kg Nha^{-1}, respectively **(Fig. 4).**

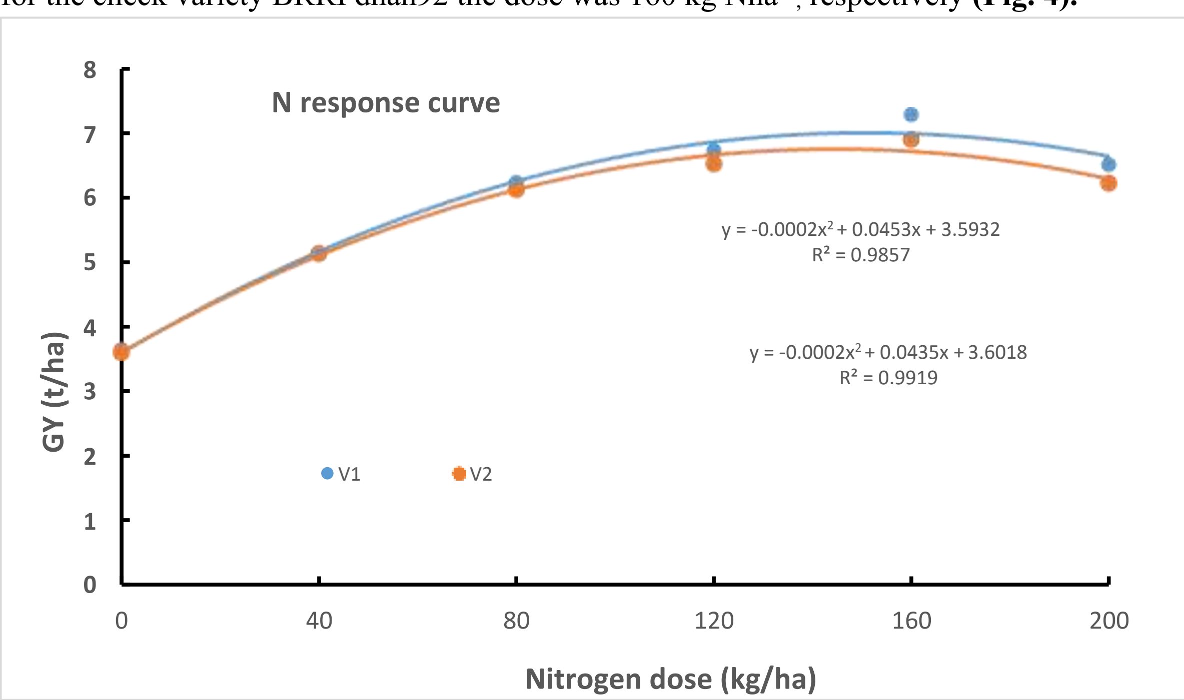


Fig. 4. Nitrogen response curve of favorable Boro ALART materials in Boro 2024-25, BRRI, Gazipur

The calculated economic optimum N dose of favorable Boro ALART material **BR11318-5R-8** was 165 kg Nha^{-1}, and for the check variety BRRI dhan92 the dose was 160 kg N ha^{-1}.

Expt. 5. Effect of Rhizoflo premium biofertilizer on growth and yield of rice

A. Jahan, T. Islam, M. H. Khan, B. Saha, M. S. Islam and M. R. Islam

Introduction

Rice is the most important cereal crop and staple food in Bangladesh, forming the backbone of the country's agriculture and food security. It plays a vital role in the daily diet of the population, providing a substantial amount of daily calories and protein intake (Kamruzzaman et al. 2025). Thus, ensuring sustainable and high-yielding rice production is critical for the country's growing population. However, the increasing dependence on chemical fertilizers and pesticides to boost rice yields has raised concerns. The unregulated and excessive use of these inputs is believed to degrade soil health, disrupt ecosystems, and pose significant risks to human health and the environment (Nellemann et al., 2009). Addressing these challenges is essential for achieving long-term food security and environmental sustainability.

In recent years, biofertilizers have emerged as a sustainable alternative to chemical fertilizers. Biofertilizers are potential environmentally friendly supplemental inputs for healthy plant growth (Suhag, 2016). These are organic fertilizers that increase agricultural production, while enhancing soil fertility. Different biofertilizers are used to boost agricultural productivity because they have been shown to fix nitrogen (N), phosphate (P), and produce phytohormones and Rhizoflo Premium is one such commercially available biofertilizer. However, the specific impact of Rhizoflo Premium on rice growth and yield under varying field conditions remains limited. In this context, the present study aims to assess the effect of Rhizoflo Premium Biofertilizer on growth and yield parameters of rice.

Materials and Methods

To determine the efficacy of Rhizoflo Premium (RP), two field experiments were conducted at BRRI Farm, Gazipur, and BRRI farm, Cumilla, during Boro season, 2024-25. Five treatment combinations were tested: T_1= 100% Chemical Fertilizer (CF), T_2 = 100% CF + Rhizoflo Premium (RP), T_3 = 75% CF + RP, T_4 = 50% CF + RP, and T_5 = Control. Each treatment received N-P-K-S-Zn @ 174-18-80-18-2 kg/ha N-P-K-S-Zn @ 174-18-90-12-3 kg/ha as a flat dose at Gazipur and Cumilla, respectively. The experiments were laid out in a randomized complete block design with three replications. All P, K, S and Zn fertilizers were applied at the time of final land preparation. Urea was applied into three equal splits: 1/3rd as basal, 1/3rd at the early tillering stage and the remaining 1/3rd at 5-7 days before the panicle initiation stage. BRRI dhan102 was used as a test crop at Gazipur and Cumilla sites. Rhizoflo Premium was applied twice at the seedling stage and once after transplanting, at a rate of 2 L/ha. Two to three seedlings/hill were transplanted with 20 cm × 20 cm spacing. The necessary intercultural operations were carried out as required. At maturity, the crop was harvested from a 5 m^2 area at the centre of each plot and grain yield was adjusted to 14% moisture. The plant height, tiller no, panicle no, grain and straw yields were recorded.

Results and Discussion

At the Gazipur site, the grain and straw yields of BRRI dhan102 significantly vary with the application of different treatments. The grain yield ranged between 5.97 to 6.71 t/ha. The highest grain yield (6.71 t/ha) was recorded with 100% Chemical Fertilizer (CF), which was statistically similar with 100% CF + RP treatment. The application of RP with reduced CF (25 and 50%) significantly reduced the grain yield compared to 100% CF and 100% CF+RP.

At the Cumilla site, the application of different treatments significantly influenced grain yield, but straw yields did not vary significantly for BRRI Dhan102, except for the control. The highest grain yield (9.10 t/ha) was found with 75% CF + RP, which was statistically similar to 100% CF and 100% CF + RP **(Table 1).**

Table 1: Effects of Rhizoflo Premium on grain and straw yield (t/ha) of BRRI dhan102 in Boro season

Treatments	Grain yield (t/ha)		Straw yield (t/ha)		% Grain yield increase/decrease over Chemical fertilizer	
	Gazipur	Cumilla	Gazipur	Cumilla	Gazipur	Cumilla
T_1: 100% Chemical Fertilizer (CF)	6.71a	9.09a	7.12a	9.25a		
T_2: 100% CF + Rhizoflo Premium (RP)	6.63a	8.82a	6.89a	8.91a	-1.21	-3.06
T_3: 75% CF + RP	6.00b	9.10a	6.14a	9.15a	-11.83	0.11
T_4: 50% CF + RP	5.97b	7.60b	6.28a	7.56a	-12.40	-19.61
T_5: Control	3.80c	3.18c	4.06b	2.95b	-76.58	-185.85
CV (%)	*5.25*	*4.42*	*12.88*	*12.51*		

Conclusion

At the BRRI Farm in Gazipur and Cumilla, the effectiveness of RP on rice growth and yield was assessed during the Boro season. The performance of RP varied with locations. At the Gazipur site, no significant yield improvement was observed with the application of RP. However, at Cumilla site, application of RP with 75% CF resulted in a similar yield to 100% CF, suggesting that RP can reduce the use of chemical fertilizer without compromising yield. However, as the results were not consistent at different locations, further trials are required to precisely assess the impact of RP on rice growth and yield.

Expt. 6. Effect of siliforce on growth and yield of rice

A. Jahan and M. R. Islam

Introduction

Ensuring optimal growth and high yield in rice cultivation is critical for the country's food security. However, rice plants often face challenges from biotic and abiotic stresses such as pests, diseases, drought, and nutrient deficiencies, which can significantly reduce productivity (Epstein, 1999; Ma & Yamaji, 2006). Recently, silicon-based fertilizers and biostimulants have emerged as a promising strategy to alleviate these stresses in plants by enhancing their growth and yield (Savant et al., 1997).
SILIFORCE is a commercial silicon-based biostimulant that provides soluble and bioavailable silicon to plants. It is designed to enhance nutrient uptake, bolster stress tolerance, and stimulate metabolic activities that support plant vigor and productivity (Kumar et al., 2017; Rodrigues et al., 2020). While the benefits of silicon are well-documented, studies specifically evaluating the impact of SILIFORCE on rice growth and yield remain limited. Therefore, this study seeks to investigate the efficacy of SILIFORCE on the growth and yield performance of rice under field conditions during T. Aman season.

Materials and methods

To determine the efficacy of SILIFORCE, a field experiment was conducted at BRRI Farm, Gazipur, during T. Aman season, 2024. Three treatment combinations were tested: T_1= Recommended Fertilizer (RF) + Three times SILIFORCE spray (Early tillering, Mid tillering and Late tillering stage), T_2 = Recommended Fertilizer + Three times DPN (Disease Preventive Nutrient) solution spray (Early tillering, Mid tillering and Late tillering stage) and T_3 = Control (Recommended Fertilizer). Each treatment received N-P-K-S-Zn @ 90-9-43-7-1 kg/ha as a flat dose. The experiments were laid out in a randomized complete block design with three replications. All P, K, S and Zn fertilizers were applied at the time of final land preparation. Urea was applied into three equal splits: 1/3rd as basal, 1/3rd at the early tillering stage, and the remaining 1/3rd at 5-7 days before the panicle initiation stage. BRRI dhan87 and BRRI dhan90 were used as test crops at Gazipur. SILIFORCE was sprayed 3 times at the following rates: early tillering- 400 ml/ha, mid tillering- 1000 ml/ha, late tillering- 600 ml/ha. Two to three seedlings/hill of forty-five days old were transplanted with 20 cm × 20 cm spacing. The necessary intercultural operations were carried out as required. At maturity, the crop was harvested from a 5 m^2

area at the centre of each plot, and grain yield was adjusted to 14% moisture. The plant height, tiller and panicle number, and the grain and straw yields were recorded.

Results and Discussion

The grain and straw yields of BRRI dhan87 did not vary significantly with the application of different treatments. The grain yield ranged between 4.36 and 4.76 t/ha. However, the highest grain yield (4.76 t/ha) was recorded with RF + DPN solution, which increased the grain yield by about 8.29% over Control (RF). The application of RF + SILIFORCE also showed yield improvement by 6.91% over control (RF).

The grain and straw yields of BRRI dhan90 also did not vary significantly among the applied treatments. However, the highest grain yield (3.44 t/ha) was recorded with the RF + DPN solution, which increased the grain yield by 2.46% over the Control (RF) **(Table 2).**

Table 2: Effects of SILIFORCE on grain and straw yield (t/ha) of BRRI dhan87 and BRRI dhan90 in T. Aman season

Treatments	Grain yield (t/ha)		Straw yield (t/ha)		% Grain yield increase/decrease over Recommended fertilizer	
	BRRI dhan87	BRRI dhan90	BRRI dhan87	BRRI dhan90	BRRI dhan87	BRRI dhan90
T_1: RF + SILIFORCE	4.69	3.17	5.44	3.24	6.91	-5.93
T2: RF + DPN solution	4.76	3.44	5.70	3.61	8.29	2.46
T3: Control (RF)	4.36	3.36	5.29	3.55		
CV (%)	4.85	4.87	14.93	10.37		

* DPN=Disease Preventive Nutrient, RF= Recommended Fertilizer

Conclusion

The efficacy of SILIFORCE on rice growth and yield was evaluated during the T. Aman season at BRRI Farm, Gazipur. Spraying SILIFORCE at different doses did not significantly increase the grain and straw yields of BRRI dhan87 and BRRI dhan90. However, the application of the DPN (Disease Preventive Nutrient) solution with the recommended fertilizers slightly increased the grains yield of BRRI dhan87 and BRRI dhan90.

Expt. 7. Effect of siliforce-4 on growth and yield of rice

A. Jahan, T. Islam, M. H. Khan, M. N. Hasan, A. Islam and M. R. Islam

Introduction

Ensuring optimal growth and high yield in rice cultivation is critical for the country's food security. However, rice plants often face challenges from biotic and abiotic stresses such as pests, diseases, drought, and nutrient deficiencies, which can significantly reduce productivity (Epstein, 1999; Ma & Yamaji, 2006). Recently, silicon-based fertilizers and biostimulants have emerged as a promising strategy to alleviate these stresses in plants by enhancing their growth and yield (Savant et al., 1997).

SILIFORCE-4 is a commercial silicon-based biostimulant that provides soluble and bioavailable silicon to plants. It is designed to enhance nutrient uptake, bolster stress tolerance, and stimulate metabolic activities that support plant vigor and productivity (Kumar et al., 2017; Rodrigues et al., 2020). While the benefits of silicon are well-documented, studies specifically evaluating the impact of SILIFORCE-4 on rice growth and yield remain limited. Therefore, this study seeks to investigate the efficacy of SILIFORCE-4 on the growth and yield performance of rice under field conditions during Boro season.

Materials and Methods

To determine the efficacy of SILIFORCE-4, two field experiments were conducted at BRRI Farm, Gazipur, and BRRI farm, Sonagazi, during Boro season, 2024-25. Three treatment combinations were tested: T_1= Recommended Fertilizer (RF) + Three times SILIFORCE spray (Early tillering, Mid tillering and Late tillering stage), T_2 = Recommended Fertilizer + Three times DPN (Disease Preventive Nutrient) solution spray (Early tillering, Mid tillering and Late tillering stage) and T_3 = Control (Recommended Fertilizer). Each treatment received N-P-K-S-Zn @ 174-18-80-18-2 kg/ha N-P-K-S-Zn @ 174-18-80-18-3 kg/ha as a flat dose, respectively at Gazipur and Sonagazi. The experiments were laid out in a randomized complete block design with three replications. All P, K, S and Zn fertilizers were applied at the time of final land preparation. Urea was applied into three equal splits: 1/3rd as basal, 1/3rd at the early tillering stage, and the remaining 1/3rd at 5-7 days before the panicle initiation stage. BRRI dhan102 was used as test crops at Gazipur and Sonagazi. SILIFORCE-4 was sprayed 3 times at the following rates: early tillering- 400 ml/ha, mid tillering- 1000 ml/ha, late tillering- 600 ml/ha. Two to three seedlings/hill of forty-five days old were transplanted with 20 cm × 20 cm spacing. The necessary intercultural operations were carried out as required. At maturity, the crop was harvested from a 5 m^2 area at the centre of each plot, and grain yield was adjusted to 14% moisture. The plant height, tiller and panicle number, and the grain and straw yields were recorded.

Results and Discussion

At the Gazipur site, the grain and straw yields of BRRI dhan102 did not vary significantly with the application of different treatments. The grain yield ranged between 6.73 and 6.83 t/ha. However, the highest grain yield (6.83 t/ha) was recorded with RF + SILIFORCE, which increased the grain yield by about 1.46% over Control (RF). The application of RF + DPN solution also showed yield improvement by 1.03% over control (RF).

At the Sonagazi site, the grain and straw yields of BRRI dhan102 also did not vary significantly among the applied treatments. However, the highest grain yield (6.58 t/ha) was recorded with the RF + SILIFORCE, which increased the grain yield by 1.82% over the Control (RF). There was no significant variation in straw yields of BRRI dhan102 among the different treatments **(Table 3).**

Table 3: Effects of SILIFORCE on grain and straw yield (t/ha) of BRRI dhan102 in Boro season

Treatments	Grain yield (t/ha)		Straw yield (t/ha)		% Grain yield increase/decrease over Recommended fertilizer	
	Gazipur	Sonagazi	Gazipur	Sonagazi	Gazipur	Sonagazi
T_1: RF + SILIFORCE	6.83	6.58	7.13	6.75	1.46	1.82
T2: RF + DPN solution	6.80	6.32	6.92	6.55	1.03	-2.22
T3: Control (RF)	6.73	6.46	6.84	6.61		
CV (%)	2.90	3.05	11.09	7.97		

* DPN=Disease Preventive Nutrient, RF= Recommended Fertilizer

Conclusion

The efficacy of SILIFORCE-4 on the growth and yield of BRRI dhan102 was evaluated during the Boro season at BRRI Farm, Gazipur and Sonagazi. Spraying SILIFORCE-4 at different doses did not significantly increase the grain and straw yields of BRRI dhan102. However, the application of SILIFORCE-4 with the recommended fertilizers slightly increased the grain yield of BRRI dhan102.

Expt. 8. The impact of water and nitrogen management practices on rice yield and nitrogen losses in paddy field

A. Jahan, S. M. M. Islam, M. S. Rahman, M. K. Milon and M. R. Islam

Introduction

Rice (Oryza sativa) is one of the most important staple foods globally, with large areas of land dedicated to paddy cultivation. Efficient management of both water and nitrogen is crucial for optimizing rice yield while minimizing environmental impacts, particularly nitrogen losses. Nitrogen, a vital nutrient for rice growth, is commonly applied in the form of chemical fertilizers. However, excessive nitrogen use often leads to losses in the form of ammonia volatilization, nitrate leaching, and denitrification, contributing to pollution of surrounding water systems and greenhouse gas emissions (Zhu & Chen, 2002; Ju et al., 2009). In paddy fields, water management practices (such as continuous flooding or intermittent irrigation) are closely linked with nitrogen dynamics. Different irrigation regimes can influence the availability of nitrogen to plants and the microbial processes that cause nitrogen losses. The adoption of appropriate water and nitrogen management practices has the potential to improve nitrogen use efficiency, enhance rice yields, and reduce environmental impacts (Peng et al., 2006; Sapkota et al., 2017). This study aims to assess the combined effect of different water and nitrogen management practices on rice yield and nitrogen losses in paddy fields, providing insights into how these practices can be optimized for both agricultural productivity and environmental sustainability and to evaluate the impact of water management practices (Continuous Standing Water vs. Alternate Wetting and Drying) on rice yield.

Materials and Methods

The experiment was carried out in Boro 2024-25 season at BRRI-Gazipur farm to investigate the effect of nitrogen and water management practices on rice yield as well as to quantify the nitrogen loss and use efficiency. The experiment was comprised of seven treatments: T_1= 100% Broadcast Urea (378 kg ha^{-1}), T_2= 100% Deep Placement Urea by PUA (378 kg ha^{-1}), T_3= 75% Broadcast Urea (284 kg ha^{-1}), T_4= 75% Deep Placement Urea by PUA (284 kg ha^{-1}), T_5= 50% Broadcast Urea (189 kg ha^{-1}), T_6= 50% Deep Placement Urea by PUA (189 kg ha^{-1}) and T_7= N Control. The treatments were applied under alternate wetting drying and continuous standing water conditions following randomized complete block design with three replications. BRRI dhan89 was tested in the Boro Season. All treatments received a blanket dose of P-K-S-Zn
@ 18-80-18-2 kg ha^{-1} respectively. All fertilizers except urea were applied at final land preparation. For treatment T_2, T_3 and T_6, urea was applied in three equal splits at basal, active tillering and seven days before panicle initiation. In treatment T_2, T_4 and T_6, full dose of prilled urea were applied after 10 days of transplanting by applicators.

Results and Discussion

Urea deep placement showed significant yield increase both under AWD and CSW conditions, particularly when 100% of the urea was deep placed. Deep placement of 100% urea (T_2) resulted in 13% and 16% yield increase over the 100% (T_1) urea broadcast in AWD and CSW, respectively. Moreover, when 75% urea of the recommended dose (T_4) was applied as deep placement it produced statistically similar yield to that of 100% urea as broadcast (T_1) under both AWD and CSW conditions. These results indicate that urea deep placement can increase rice yield by minimizing urea loss under both AWD and CSW conditions **(Fig.5).**

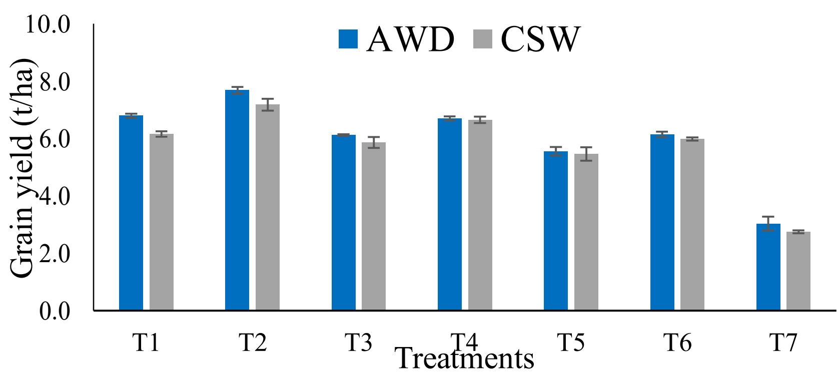


Fig. 5. Effect of nitrogen fertilizer management under different water management in BRRI-Gazipur during Boro 2024-25

Conclusions

Urea deep placement significantly increased rice yield under both AWD and CSW. Applying 100% urea through deep placement raised yields by 13–16% over broadcast, while 75% deep-placed urea produced yields comparable to 100% broadcast.

Expt. 9. Effect of ammonium chloride on growth and yield of rice

A. Jahan, M. H. A. Rashid and M. R. Islam

Ammonium chloride (NH_4 Cl) is an inorganic fertilizer used in agriculture to supply nitrogen (N), an essential nutrient for plant growth. Rice (Oryza sativa), one of the most important staple food crops worldwide, requires substantial N for optimal growth and high yield. The effect of ammonium chloride on rice growth and yield has been a topic of interest due to its potential as a N source in flooded rice ecosystems. As rice cultivation often takes place in flooded conditions, the availability and utilization of nitrogen can be significantly influenced by the form in which it is applied. Ammonium chloride, as a source of ammonium (NH_4^+), is considered to be more efficient in some environments compared to other forms of nitrogen fertilizers such as urea or ammonium nitrate, but there are limited studies on the efficacy of ammonium chloride application in rice soil. However, the application of ammonium chloride can have both positive and negative impacts on rice growth and productivity. On one hand, it can enhance rice growth by supplying a readily available form of nitrogen, leading to improved photosynthesis, leaf area, and tillering. On the other hand, excessive or imbalanced use of ammonium chloride can lead to soil acidification, nutrient imbalances, and potential toxicity, which may adversely affect rice growth and yield. Understanding the precise effects of ammonium chloride on rice growth is crucial for developing effective fertilizer management strategies that optimize yield while minimizing negative environmental impacts. This study explores the role of ammonium chloride in influencing rice and yield under varying application levels during T. Aman season.

Materials and Methods

Ammonium chloride (NH_4 Cl) containing 26% nitrogen is an inorganic fertilizer developed by Smart Grain Agro Industries Ltd, Bangladesh. To find out the efficacy of Ammonium chloride two field experiments were conducted at BRRI Farm, Gazipur and BRRI farm, Rajshahi during T. Aman season, 2024. Five treatment combinations were tested: T_1= urea (195 kg/ha), T_2 = ammonium chloride (347 kg/ha), T_3 = ammonium chloride (434 kg/ha), T_4 = ammonium chloride (260 kg/ha) and T_5 = control (no urea/ ammonium chloride). Each treatment received P-K-S-Zn @ 9-43-7-1 kg ha^{-1} as flat dose. The experiments were laid out in a randomized complete block design with three replications. All P, K, S and Zn fertilizers were applied at the time of final land preparation. Urea and ammonium chloride were applied into three equal splits: 1/3rd as basal, 1/3rd at the early tillering stage and the remaining $1/3^{rd}$ at 5-7 days before the panicle initiation stage. BRRI dhan87 and BRRI dhan103 were used as test crop at Gazipur and Rajshahi sites, respectively. In the Gazipur site, the seedling age of BRRI dhan87 was 50 days. In the Rajshahi site, the seedling age of BRRI dhan103 was 23 days. Two to three seedlings/hill were transplanted with 20 cm × 20 cm spacing. Necessary intercultural operations were done as required. At maturity, the crop was harvested from 5 m^2 area at the centre of each plot and grain yield was adjusted to 14% moisture. The plant height, tiller no, panicle no, grain and straw yields were recorded.

Results and Discussion

In the Gazipur site, the grain and straw yields of BRRI dhan87 did not significantly vary with the application of different treatments. The grain yield ranged between 3.68 and 4.36 ton/ha. The highest grain yield (4.36 t/ha) was recorded with T_2 (ammonium Chloride - 347 kg/ha), which increased the grain yield by about 5.28% over T_1 (urea -195 kg/ha). The lower yield might be due to the use of older seedlings.

In the Rajshahi site, the grain yield of BRRI dhan103 did not vary significantly among the applied treatments except for the control (no urea/ammonium chloride), which gave the significantly lowest yield. However, the highest grain yield (6.63 t/ha) was recorded with T_2 (ammonium Chloride - 347 kg/ha), which increased the grain yield by about 5.88% over T_1 (urea -195 kg/ha). There was no significant variation in straw yields of BRRI dhan103 among the different treatments **(Table 4).**

Table 4: Effects of Ammonium chloride on grain and straw yield (t/ha) of BRRI dhan87 and BRRI dhan103 in T. Aman season

Treatments	Grain yield (t/ha)		Straw yield (t/ha)		% Grain yield increase/decrease over urea fertilizer	
	Gazipur	Rajshahi	Gazipur	Rajshahi	Gazipur	Rajshahi
T_1: Urea-195 kg/ha	4.13	6.24 a	5.34	6.44		
T_2: Ammonium chloride - 347 kg/ha	4.36	6.63 a	5.54	7.70	5.28	5.88
T_3: Ammonium chloride - 434 kg/ha	4.19	6.01 ab	5.40	6.31	1.43	-3.83
T_4: Ammonium chloride - 260 kg/ha	4.28	6.37a	5.49	6.57	3.50	2.04
T_5: Control (no urea/ ammonium chloride)	3.68	5.38 b	4.63	6.04	-12.23	-15.98
CV (%)	*8.11*	*6.53*	*10.46*	*11.54*		

The estimated total variable cost (TVC), gross return, added return, net return and marginal benefit cost ratio (MBCR) are presented in **Table 5a**. Economic analysis was done considering the cost for fertilizer, fertilizer application and labor for the additional products. At Gazipur site, the Ammonium chloride (NH_4 Cl) increased the gross and added return with all the treatments while net return increased with T_2 and T_4 treatment compared to T_1 **(Table 5b).** The gross return from the urea treated plot was about Tk. 182640.00 per ha and the application of Ammonium chloride (NH_4 Cl) increased the gross return, where the highest gross return of Tk. 191740.00 per ha was obtained from the treatment T_2. The highest added return of Tk. 30410.00 was found with T_2. The highest net-return of Tk. 170860.00 per ha was obtained with the treatment T_4 followed by treatment T_1 (Tk. 161320.00 per ha). The highest MBCR was obtained with the treatment T_4 (2.42). The treatment T_4 could be the economically viable fertilizer management packages for T. Aman rice cultivation at BRRI Farm, Gazipur under AEZ 28.

For Rajshahi site, the application of Ammonium chloride (NH_4 Cl) increased the gross, added and net return only in T_2 and T_4 treatments over the urea treated (T_1). The gross return from urea treated plot was about Tk. 258040.00 per ha and the application of Ammonium chloride (NH_4 Cl) increased the gross return of Tk. 283600.00 per ha in treatment T_2. The highest added return of Tk. 55760.00 per ha was obtained with the treatment T_2 followed by Tk. 30200.00 per ha by the treatment T_1.The highest net return of Tk. 259160.00 per ha was obtained with the treatment T_2. In terms of MBCR, the treatment T_2 (Table 2b) performed the best among the Ammonium chloride (NH_4 Cl) applied treatment here under AEZ 11.

Table 5: Economic analysis of Ammonium Chloride in T. Aman rice at BRRI farms

5a. Total variable cost (TVC) in Tk./ha

Treatment	Fertilizer cost*		Fertilizer application cost		Labor cost for additional products		Total Variable cost (BDT ha^{-1})	
	Gazipur Site	Rajshahi site	Gazipur Site	Rajshahi site	Gazipur Site	Rajshahi site	Gazipur Site	Rajshahi site
T1: Urea-195 kg/ha	17420	17420	1200	1200	2700	5160	21320	23780
T2: Ammonium chloride - 347 kg/ha	15740	15740	1200	1200	4080	7500	21020	24440
T3: Ammonium chloride - 434 kg/ha	18350	18350	1200	1200	3060	3780	22610	23330
T4: Ammonium chloride - 260 kg/ha	13130	13130	1200	1200	3600	5940	17930	20270
T5: Control (no urea/ ammonium chloride)	5330	5330	1200	1200	0	0	6530	6530

*Fertilizer cost included chemical fertilizer and Ammonium chloride (NH_4Cl).
Urea = Tk. 62.00 /kg, TSP= Tk 27.00/kg, MoP= Tk.20.00./kg , Gypsum= Tk. 35.00/kg, Zinc= Tk. 320.00 /kg, Ammonium Chloride= Tk. 30 /kg
Labor wage= Tk. 600/day. Two additional man days/ha are required for applying fertilizer, ten man days/ha for per ton additional products including by products

5b. Gross and net return in Tk./ha and marginal benefit cost ratio (MBCR)

Treatment	Yield				Total variable cost		Return						MBCR	
	Grain		Straw				Gross		Added		Net			
	GS	RS	GS	RS	GS	RS	GS	RS	GS	RS	GS	RS	GS	RS
T1: Urea-195 kg/ha	4.13	6.24	5.34	6.44	21320	23780	182640	258040	21310	30200	161320	234260	1.44	1.75
T2:Ammonium chloride - 347 kg/ha	4.36	6.63	5.54	7.7	21020	24440	191740	283600	30410	55760	170720	259160	2.10	3.11
T3:Ammonium chloride - 434 kg/ha	4.19	6.01	5.4	6.31	22610	23330	185100	249710	23770	21870	162490	226380	1.48	1.30
T4:Ammonium chloride - 260 kg/ha	4.28	6.37	5.49	6.57	17930	20270	188790	263370	27460	35530	170860	243100	2.41	2.59
T5: Control (no urea/ ammonium chloride)	3.68	5.38	4.63	6.04	6530	6530	161330	227840	0	0	154800	221310		

GS= Gazipur site, RS= Rajshahi Site, Rice grain price= Tk. 30.00/kg, Rice straw price= Tk. 11.00 /k

Conclusion

Applying ammonium chloride at different doses did not significantly influence the grain and straw yields of BRRI dhan 87 and BRRI dhan103 in the Gazipur and Rajshahi sites, respectively. However, there was a slight increase in the grain yield with the application of 347 kg/ha of ammonium chloride. On the other hand, applying ammonium chloride at a higher dose (434 kg/ha) in the Rajshahi site showed a slight decrease in the grain yield of BRRI dhan103. The trials were conducted during the T. Aman season when native soil nutrients also largely influence rice growth and yields. Therefore, it is recommended that further trials could be conducted during the Boro season to assess the efficacy of ammonium chloride on rice growth and yield precisely.

Expt. 10. Role of ISABION (a PGR) to improve rice yield over recommended nitrogen fertilizer dose in Boro season

M Akter, M N Hasan, A Islam and M R Islam

Introduction

Bangladesh is acutely vulnerable to the escalating impacts of climate change, facing severe threat to its rice production. The climate change impacts are often interacting and creating complex and severe pressure on its major cereal crop rice which is vital for food security in Bangladesh and across South Asia. Increase temperatures during its critical growth stages like flowering and grain filling, substantially reduces rice yields via spikelet sterility, impairing fertilization and seed formation. At seedling stage, cold spells may lead to high seedling mortality, while at reproductive stages especially during booting and heading it may also cause pollen abortion, spikelet sterility, malformation of floral organs, and ultimately leading to significant yield loss. Nitrogen (N) is one of the most important yield limiting nutrients and N fertilizer use in Bangladesh has remarkably increased over the past 42 years. Rice framers widely applied urea to maximize yield. Despite driving productivity, poor N fertilizer use efficiency (30-50%) is characteristic of irrigated rice systems, indicating huge N loss by different loss processes. **Isabion** is a natural bio stimulant (PGR: Plant Growth Regulator) contains 9% total N and provides essential amino acids and peptides to enhance stress (cold, heat, drought) tolerance, improve flowering and fruiting, and support soil health. Isabion application at 4 litre ha^{-1} during transplanting and maximum tillering may increase tillering and improve grain quality resulting 10-15% yield increase, particularly under cold stress (air temperature went below 20°C) (KiBeum P., Syngenta, Korea, 2013). Heat stress when air temperature exceeds 35°C during reproductive stage, cause significant yield losses in rice primarily through spikelet abortion. Application of Isabion at 2 litre ha^{-1} during meiosis or panicle initiation (PI) can effectively mitigate these effects, leading to a substantial increase (9-21%) in rice yield under heat stress conditions. With all these benefits, it is encouraging and crucial to evaluate the application of Isabion plus recommended soil test based (STB) N fertilizer in rice paddy over full dose of STB N fertilizer only. Therefore, this study was conducted to assess the effect of Isabion (a PGR) to improve rice yield and yield contributing characteristics over recommended N fertilizer in Boro season.

Materials and Methods

Two field experiments were conducted during January to May, 2025 at the field of Soil Science Division (23°59'27" N; E: 90°24'14"E) BRRI Gazipur, and at BRRI Sonagazi. Seedlings of BRRI dhan102, a recently released (in 2022) high yielding rice variety (growth duration ~150 days; average yield 8.1 t ha^{-1}) was transplanted on 4 January at BRRI Gazipur and 9 January at BRRI Sonagazi. Overall 15 (5 treatments × 3 replications), $12m^2$ plots and 18 (6 treatments × 3 replications), $20m^2$ plots were established at BRRI Gazipur and BRRI Sonagazi, respectively. The experiment was laid out in a RCB design. The blocks were separated from each other by 1 m irrigation channel and each plot was separated from each other by 40 cm earth bund to prevent lateral exchange of water and fertilizer across the plots. At BRRI Gazipur, the tested five treatments were: T1: 100% STB PKSZn, T2: 100% STB NPKSZn, T3: 100% STB NPKSZn + 1 L ha^{-1} Isabion (2 spray), T4: 100% STB NPKSZn + 2 L ha^{-1} Isabion (2 spray) and T5: 100% STB NPKSZn + 3 L ha^{-1} Isabion (2 spray). While at BRRI

Sonagazi, the tested six treatments were: T1: 100% STB PKSZn, T2: 100% STB NPKSZn, T3: 100% STB NPKSZn + 1 L ha^{-1} Isabion (2 spray), T4: 100% STB NPKSZn + 2 L ha^{-1} Isabion (2 spray), T5: 100% STB NPKSZn + 3 L ha^{-1} Isabion (2 spray) and T6: 100% STB NPKSZn + 4 L ha^{-1} Isabion (2 spray). In case of T2, T3, T4, T5 and T6 treatments for both locations, the STB urea-N rate was 162 kg N ha^{-1}. Nitrogen fertilizer was applied as urea into three equal splits in the T_2, T_3, T_4 and T_5 on 11, 33 and 45 DAT (days after transplanting) at BRRI Gazipur, as well as in the T_2, T_3, T_4, T_5 and T_6 on 9, 30 and 45 DAT at BRRI Songazi. The blanket rates of P-K-S-Zn were 20-102-15-1 kg ha^{-1}, resp. for BRRI Gazipur and 18-80-12-1.7 kg ha^{-1}, resp. for BRRI Sonagazi. All PKSZn fertilizers in both locations were broad-casted and mixed with soil on the day of transplanting in all treatments. The sources of P, K, S and Zn were triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate monohydrate, respectively. Except T1 and T2, Isabion was sprayed twice in all other treatments at specific rates on 51 and 78 DAT at Gazipur, and on 51 and 73DAT at Sonagazi. Throughout the season standard management practices for water and pests were followed. At maturity, 5 m^2 area was harvested from each plot to attain grain yield, 16 hills were cut to record straw yield, tiller and panicle numbers. Data on plant height (average of 10 hills per plot) were taken from all plots under each locations, while filled and unfilled grain data were taken from Gazipur site only. The grain yield was adjusted at 14% moisture content. SPSS16.0 software packages were used for statistical analysis. The MBCR were calculated using the following formula:

$$MBCR = \frac{Gross\ return\ (E) - Gross\ return\ (F)}{TVC\ (E) - TVC\ (F)} = \frac{MVP}{MVC}$$

Results and Discussion

Grain yield and yield contributing characteristics, and economic analysis

Among the studied yield and yield contributing characteristic, grain and straw yields (t ha^{-1}), tiller and panicle no. per m^2 and plant height (cm) were significantly ($p<0.01$) greater in all N fertilizer applied treatments than no N applied treatment (T1) **(Table 6 and 7).** All these parameters were again statistically identical across all N fertilizer applied treatments i.e. between T2, T3, T4 and T5 in Gazipur **(Table 6),** between T2, T3, T4 , T5 and T6 in Sonagazi **(Table 7)**. At Gazipur site, significantly the highest ($p<0.05$) filled grain number and weight ($panicle^{-1}$) were resulted from T5, while their value was the lowest in the T1 **(Table 6).** Across N fertilizer applied treatments, both parameters were again statistically identical. Both unfilled grain number and weight ($panicle^{-1}$) showed non-significant differences among all fertilizer applied treatments at Gazipur site. Despite statistically identical grain yield across all N fertilizer applied treatments, the grain yield increased over 100% STB NPKSZn, T2, were about 5% in T4 and T5 at Gazipur, which were 9% in T3, 21% in T4 and 8% in T6 at Sonagazi site. Compared to 100% STB PKSZn, T1, the MBCR in 100% STB NPKSZn (T2) (8.6 and 7.6) were as always greater than all other treatments with 100% STB NPKSZn plus Isabion sprayed treatments (T3, T4, T5 and T6) in both locations **(Table 8 and 9).** Over 100% STB NPKSZn, T2, the MBCR in T4 and T5 were 2.6 and 2.3 resp., at BRRI Gazipur, and in T3, T4 and T6 were 3.6, 3.4 and 1.7 resp., at BRRI Sonagazi site.

Table 6 Influence of ISABION on rice yield and yield contributing characteristics over recommended fertilizer dose in BRRI Gazipur during Boro 2024-25

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Tiller no. (m^{-2})	Panicle no. (m^{-2})	Filled grain no. ($panicle^{-1}$)	Filled grain wt. ($g\ panicle^{-1}$)	Unfilled grain no. ($panicle^{-1}$)	Unfilled grain wt. ($g\ panicle^{-1}$)	Plant height (cm)
T1: 100% STB PKSZn	2.7±0.07 b	2.6±0.15 b	176±3b	164±4b	91±4b	2.0±0.13b	7±1	0.06±0.01	76±0.8b
T2: 100% STB NPKSZn	6.7±0.04 a	7.1±0.94 a	349±9a	338±9a	118±10ab	2.3±0.15ab	9±2	0.06±0.01	99±0.6a
T3: 100% STB NPKSZn +1 L ha-1 ISABION (2 spray)	6.6±0.17 a	7.2±0.23 a	332±4a	320±4a	113±1ab	2.2±0.03ab	16±2	0.09±0.03	100±0.2a
T4: 100% STB NPKSZn +2 L ha-1 ISABION (2 spray)	7.0±0.10 a	7.7±0.36 a	354±7a	345±5a	119±10ab	2.5±0.10ab	16±4	0.10±0.02	100±0.3a
T5: 100% STB NPKSZn +3 L ha-1 ISABION (2 spray)	7.0±0.14 a	8.0±0.54 a	352±11a	338±8a	132±3a	2.6±0.14a	14±2	0.09±0.02	100±0.5a
p-value	p<0.01	p<0.01	p<0.01	p<0.01	p<0.05	p<0.05	NS	NS	p<0.01

Table 7 Influence of ISABION on rice yield and yield contributing characteristics over rrecommended fertilizer dose in BRRI Sonagazi during Boro 2024-25

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Tiller no. (m^{-2})	Panicle no. (m^{-2})	Plant height (cm)
T1: 100% STB PKSZn	2.7±0.4b	2.1±0.01b	164±10b	142±6b	76±1.4b
T2: 100% STB NPKSZn	5.1±0.4a	4.8±0.72a	286±40a	264±38a	89±0.6a
T3: 100% STB NPKSZn +1 L ha^{-1} ISABION (2 spray)	5.6±0.3a	5.1±0.51a	263±18a	248±20a	91±1.9a
T4: 100% STB NPKSZn +2 L ha^{-1} ISABION (2 spray)	6.2±0.4a	4.5±0.10a	278±18a	261±17a	95±1.3a
T5: 100% STB NPKSZn +3 L ha^{-1} ISABION (2 spray)	5.1±0.5a	3.9±0.14ab	247±18ab	235±20a	92±3.2a
T6: 100% STB NPKSZn +4 L ha^{-1} ISABION (2 spray)	5.6±0.3a	5.1±0.70a	350±24a	336±23a	93±0.8a
p-value	p<0.01	p<0.01	p<0.01	p<0.01	p<0.01

Table 8. Cost and return analysis of ISABION over N control and full soil test based N fertilizer management in BRRI Gazipur during Boro 2024-25

Treatment	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Gross Return (GR) (Tk. ha^{-1})	Over T1 (100%PKSZn)				Over T2 (N0: 100%NPKSZn)			
				Changes in GR (Tk. ha^{-1})	Total Variable Cost (TVC) (Tk. ha^{-1})	Changes in TVC (Tk. ha^{-1})	MBCR over T1	Changes in GR (Tk. ha^{-1})	TVC (Tk. ha^{-1})	Changes in TVC (Tk. ha^{-1})	MBCR over 100%STB NPKSZn (T2)
T1: 100% STB PKSZn	2.7	2.6	105662	-	4151	-	-	-	-	-	-
T2: 100% STB NPKSZn	6.7	7.1	272417	166755	23634	19482	**8.6**		9135	-	-
T3: 100% STB NPKSZn +1 Lha^{-1} ISABION (2 spray)	6.6	7.2	270860	165198	26324	22172	**7.5**	-1557	11825	2690	-0.6
T4: 100% STB NPKSZn+2 Lha^{-1} ISABION (2 spray)	7.0	7.7	287789	182127	29619	25468	**7.2**	15372	15120	5985	**2.6**
T5: 100% STB NPKSZn+3L ha^{-1} ISABION (2 spray)	7.0	8.0	290096	184434	31387	27235	**6.8**	17679	16887	7753	**2.3**

Table 9. Cost and return analysis of ISABION over N control and full soil test based N fertilizer management in BRRI Sonagazi during Boro 2024-25

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Gross Return (GR) (Tk. ha^{-1})	Over T1 (N0: 100%PKSZn)				Over T2 (N0: 100%NPKSZn)			
				Change in GR (Tk. ha^{-1})	TVC) (Tk. ha^{-1})	Change in TVC (Tk ha^{-1})	MBCR over (T1)	Change in GR (Tk. ha^{-1})	TVC (Tk. ha^{-1})	Change in TVC (Tk ha^{-1})	MBCR over 100%STB NPKSZn (T2)
T1: 100% STB PKSZn	2.7	2.1	101734	-	4248	-	-	-	-	-	-
T2: 100% STB NPKSZn	5.1	4.8	201415	99680	17413	13165	**7.6**	-	8611	-	-
T3: 100% STB NPKSZn +1 Lha^{-1} ISABION (2 spray)	5.6	5.1	218321	116586	22054	17806	**6.5**	16906	13252	4641	**3.6**
T4: 100% STB NPKSZn +2 Lha^{-1} ISABION (2 spray)	6.2	4.5	230358	128623	26031	21784	**5.9**	28943	17229	8618	**3.4**
T5: 100% STB NPKSZn +3 Lha^{-1} ISABION (2 spray)	5.1	3.9	193155	91420	24054	19806	**4.6**	-8260	15252	6641	-1.2
T6: 100% STB NPKSZn +4 L ha^{-1} ISABION (2 spray)	5.6	5.1	218331	116596	27375	23127	**5.0**	16916	18573	9962	**1.7**

Conclusions

This one season experimental results on grain yield, relative yield benefits and MBCR, revealed that Isabion plus 100% STB NPKSZn has some beneficial effect on grain yield (5 to 21%) and MBCR (1.7 to 3.6) over 100% STB NPKSZn only irrespective of locations and spraying rates. However, statistically identical results on yield and yield contributing parameters between 100% STB NPKSZn and Isabion plus 100% STB NPKSZn provides no noteworthy outcomes, hence require further verification in more paddy fields under stress conditions to get detail insight or significant outcomes.

Expt. 11. Effect of liquid nano-urea on rice productivity in Boro season

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Introduction

Bangladesh, with its predominantly agrarian economy, heavily relies on rice cultivation for both sustenance and economic stability. The challenge of meeting the escalating demand for rice production has prompted a search for innovative and sustainable agricultural practices. In this context, nano-fertilizer emerges as a promising solution, representing a technological advancement in fertilizer development that holds the potential to revolutionize traditional farming methods.

The geographical and climatic diversity of Bangladesh, coupled with varying soil conditions, provides an ideal backdrop for studying the impact of nano-fertilizers on rice yield. Understanding how this innovative fertilizer interacts with the local agricultural ecosystem is crucial for tailoring its application to the specific needs of Bangladeshi farmers.

Nano-fertilizer (e.g., urea) may offer a more efficient and eco-friendlier alternative to conventional fertilizer. This innovation is designed to overcome the limitations associated with traditional fertilizer applications, such as nitrogen losses through volatilization and leaching. Introducing nano-fertilizers to rice cultivation in Bangladesh may present an opportunity to address these challenges while simultaneously increasing crop yield. The purpose of the trials was to investigate the effectiveness of this innovative product on rice cultivation in Bangladesh.

Materials and Methods

Field experiments were conducted at the BRRI farm of Gazipur, Rangpur and Rajshahi in Boro season 2024-25 to test the effectiveness of liquid nano-urea (LNU) in increasing the grain yield of high-yielding rice varieties. Six treatments **(Table 10)** were assigned in a randomized complete block design (RCBD) with three replications. The unit plot size was 5 m × 4 m. BRRI dhan102 was used as a tested variety in all locations. The recommended dose of N was 174 kg/ha. The blanked dose of P-K-S-Zn @ 12-80-18-2 kg/ha was applied during final land preparation in all treatments. The dose of LNU was 500 ml/acre, and the solution concentration was four ml/L of water. Grain yield was recorded from the central 5 m^2 harvest area in each plot at maturity and reported on a 14% moisture basis. Data were analyzed statistically using the STAR software.

Table 10. Treatment combinations of liquid nano-urea (LNU) trial at different farms of BRRI, Boro 2024-25

Treatments
T_1 = N control
T_2 = 25% recommended dose of prilled urea (RDPU) at basal + 25% RDPU at active tillering
T_3 = 25% RDPU at basal + 25% RDPU at active tillering + two foliar sprays of LNU (at max. tillering and one week before flowering)
T_4 = 33% RDPU at basal + 33% RDPU at active tillering
T_5 = 33% RDPU at basal + 33% RDPU at active tillering + two foliar sprays of LNU (at max. tillering and one week before flowering)
T_6 = 100% RDPU (33% at basal + 33% at active tillering + 34% at max. tillering)

Results and Discussion

Nitrogen fertilizers significantly influenced the rice yield at all tested locations in the Boro 2024-25 season **(Table 11).** N control treatment (T_1) gave the significantly lowest rice yield among the treatments at all locations. In the Rangpur site, there was a significant variation in rice yield between T_6 (6.67 t/ha) and T_5 (5.48 t/ha) treatments, indicating that 66% of RDPU along with LNU (T_5) was not sufficient to get the optimum rice yield at this location in Boro season. Also, there was no yield variation due to LNU application at the same doses of prilled urea (T_2 vs T_3 and T_4 vs T_5). The T_6 treatment gave a statistically similar rice yield to the T_3, T_4, and T_5 treatments in the other two locations (Gazipur and Rajshahi). This suggests that applying 100% of RDPU may not be required for achieving optimal rice yield. A combination of 66% of RDPU with two foliar applications of LNU (Treatment T_5) appears to be an effective alternative for maximizing yield in Gazipur and Rajshahi during the Boro season. However, the highest average net benefit (200631 Tk/ha) of three locations was found in T_6 (100% of RDPU) treatment **(Table 12).** The LNU treated plots of T_3 and T_5 yielded higher net benefits of 169041 and 181831 Tk/ha, respectively, compared to the similar doses of prilled urea (PU) treated plots (T_2 and T_4) of 160543 and 180647 Tk/ha, respectively. These findings also indicate that the LNU performed better at lower doses of PU than higher doses of PU. It can be concluded that recommended doses of PU could be the best option to get maximum benefit. However, further multi-location trials are recommended to validate these findings.

Table 11. Effect of liquid nano-urea on the grain yield of rice in Boro 2024-25

Treatment	**Grain yield (t/ha)**			
	Gazipur	**Rangpur**	**Rajshahi**	**Average**
T_1	3.66 c	2.36 d	4.69 c	3.57 d
T_2	5.69 b	4.41 c	5.70 b	5.27 c
T_3	6.07 ab	4.88 bc	6.34 ab	5.76 bc
T_4	6.21 ab	5.34 b	6.43 ab	5.99 b
T_5	6.67 a	5.48 b	6.56 ab	6.23 ab
T_6	6.32 ab	6.67 a	7.30 a	6.76 a
Level of significance	***	***	***	***
CV	4.95	5.86	5.58	3.68

Means with the same letter are not significantly different. NS = non-significant at 5% level of significance. T_1 = N control; T_2 = 25% recommended dose of prilled urea (RDPU) at basal + 25% RDPU at active tillering; T_3 = 25% RDPU at basal + 25% RDPU at active tillering + two foliar spray of LNU (at max. tillering and one week before flowering); T_4 = 33% RDPU at basal + 33% RDPU at active tillering; T_5 = 33% RDPU at basal + 33% RDPU at active tillering + two foliar spray of LNU (at max. tillering and one week before flowering); T_6 = 100% RDPU (33% at basal + 33% at active tillering + 34% at max. tillering).

Table 12. Economic analysis of liquid nano-urea (LNU) for Boro rice cultivation in 2024-25

Treatments	Fertilizer + LNU cost	Fertilizer + LNU application cost	Cost for additional product & by-product	Total variable cost	Gross benefit (Tk/ha)	Gross cost (Tk/ha)	Net benefit (Tk/ha)
T_1	8780	1500	0	10280	124117	10280	113837
T_2	13870	2000	6587	22457	183000	22457	160543
T_3	18069	4500	8440	31009	200050	31009	169041
T_4	15503	2000	8967	26470	207117	26470	180647
T_5	19702	4500	10167	34369	216200	34369	181831
T_6	18959	2500	12093	33552	234183	33552	**200631**

Urea = 27 Tk/kg, TSP = 27 Tk/kg, MoP = 20 Tk/kg, Gypsum = 20 Tk/kg, Zinc = 350 Tk/kg, liquid nano-urea = 1700 Tk/500 ml (3.4 Tk/ml), price of paddy = 30 Tk/kg, price of straw = 5 Tk/kg, labourer wage = 500 Tk/day, five additional labourers/ha were required for fertilizer application and five for spraying of LNU, four additional labourers were required for one ton additional products and by-products. T_1 = N control; T_2 = 25% recommended dose of prilled urea (RDPU) at basal + 25% RDPU at active tillering; T_3 = 25% RDPU at basal + 25% RDPU at active tillering + two foliar spray of LNU (at max. tillering and one week before flowering); T_4 = 33% RDPU at basal + 33% RDPU at active tillering; T_5 = 33% RDPU at basal + 33% RDPU at active tillering + two foliar spray of LNU (at max. tillering and one week before flowering); T_6 = 100% RDPU (33% at basal + 33% at active tillering + 34% at max. tillering).

Expt. 12. Response of modern rice varieties under deficient phosphorus condition

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Introduction

Phosphorus (P), the second essential macronutrient for agricultural crops, is intimately associated with all life processes and thus it is a vital constituent of every living cell. This element mainly concentrated in the seed and stimulates early root formation and growth of the plant. Phosphorus deficiency restricts the production of ADP and ATP that are essential for supplying energy for plant metabolic activity especially at the time of flower initiation (Ali *et al.,* 2004). Its deficiency in soil extends the lifespan of rice plants, delayed flowering and maturity (Kamrunnahar *et al.,* 2017). It is relatively unavailable for plant uptake due to its highly reactive character. Soluble P may be strongly adsorbed on the surface of Fe and Al oxides or precipitated as Al and Fe phosphate minerals. For these reasons it is a deficient nutrient in most soils (Islam *et al.,* 2004). Phosphorus deficiency problems are frequently reported in well-weathered Oxisols and Ultisols (Saleque *et al.,* 2004). Generally, wetland rice soil possesses higher amount of available P than upland or aerobic soil. Moreover, P availability is higher in T. Aman (wet) season than in Boro (dry) season might be due to seasonal temperature variation (Power *et al*., 1964). For this reason, P deficiency is particularly severe in Boro season (Islam *et al*., 2010). However, inappropriate P management coupled with increasing cropping intensity with modern high yielding varieties causes P depletion in soils and thus, P deficiency occurs in many alluvial soils of Bangladesh (Ali *et al.,* 1997) and thus yield reduction in lowland rice could be 50% or more (Saleque *et al*., 1998). It is very important point to investigate the performance of MV rice under deficient soil P levels. So, the experiments were conducted to find out the response of P fertilizer on BRRI hybrid dhan6 and BRRI hybrid dhan3 in T. Aman and Boro season, respectively.

Materials and Methods

The experiments were conducted at BRRI farm, Gazipur during T. Aman 2024 and Boro 2024-25 season having deficit soil available P condition. Six treatments of P doses calculating from soil test value (STB) viz. T_1= P control, T_2= 50% of STB P, T_3= 75% of STB P, T_4= 100% of STB P, T_5= 125% of STB P and T_6= 150% of STB P were assigned in both T. Aman (wet season) and Boro (dry season). For this T_1= 0, T_2 = 11, T_3 = 16.5, T_4 = 22, T_5 = 27.5, T_6= 33 kg P/ha, respectively were applied in both seasons. BRRI hybrid dhan6 in T. Aman and BRRI hybrid dhan3 in Boro season were used as tested rice varieties. Each plot received 100 kg N, 50 kg K 10 kg S and 1 kg Zn ha^{-1} in T. Aman and 160 kg N, 70 kg K 20 kg S and 2 kg Zn ha^{-1} in Boro seasons as flat dose. Unit plot size was 6 m × 3 m. Potassium, phosphorus, sulfur and zinc fertilizers were applied at final land preparation as basal. Nitrogen (urea) was applied in three equal splits at basal, 15-20 days after transplanting (DAT) and the rest at 5-7 days before panicle initiation (PI) stage. Twenty five and thirty day old seedlings (2 per hill) were transplanted at 15cm×20cm spacing in T. Aman and 20cm×20cm spacing in Boro season, respectively. Crops were grown under fully irrigated condition. At maturity the crops were harvested manually from the center of each plot of 5 m^2 area at 15 to 20 cm above ground level for grain yield; 16 hills from each plot were harvested for straw yield data. Grain yield was recorded at 14% moisture content and straw yield adjusted as oven dry basis. Plant and grain samples were processed properly to measure content and uptake of phosphorus and other nutrients. Analysis of variance (ANOVA) was performed on yield and nutrient uptake data using the STAR software for Windows Version 2.0.1. Least significant difference (LSD) at the 0.05 level of probability was used to compare means.

Results and Discussion

T. Aman 2024

In deficient soil P condition, the P fertilizer has significant effect on grain yield and other yield contributing parameters of BRRI hybrid dhan6 in T. Aman season **(Table 13).** The tiller and panicle number per meter square increased significantly with increasing the P doses up to T_4 (100% STB P) treatments after that tiller and panicle number remain almost similar up to T_6 (150% STB P) treatment and the result was not significant. The grain yield in the P fertilized plot progressively increased with the increasing level of P fertilizer from T_1 (0% STB P) to T_3 (75% STB P) treatment and after that the grain yield obtained almost similar up to (150% STB P) treatment. Although the highest grain yield was obtained with T_5 treatment (6.32 t/ha), but it was statistically similar with and T_4 (6.31 t/ha), T_6 (6.18 t/ha) and T_3 (6.05 t/ha) treatment. The P control plot yielded only 3.01 t/ha. Similar yield trend was observed for straw production.

Table 13. Response of phosphorus on tiller, panicle, grain and straw yield of BRRI hybrid dhan6 in T. Aman 2024 at BRRI farm, Gazipur

Treatment	BRRI hybrid dhan6			
	Tiller m^{-2}	Panicle m^{-2}	GY (t ha^{-1})	SY (t ha^{-1})
T_1 = P control	216	201	3.01	3.31
T_2 = 50% STB P	243	231	5.56	5.83
T_3 = 75% STB P	250	237	6.05	6.27
T_4 =100% STB P	261	246	6.31	6.49
T_5 = 125% STB P	263	248	6.32	6.53
T_6 = 150% STB P	266	250	6.18	6.56
LSD (0.05)	44	45	0.48	0.40
CV (%)	6.18	6.80	3.03	2.44

N.B. T_1 = 0, T_2 = 11, T_3 = 16.5, T_4 = 22, T_5 = 27.5, T_6= 33 kg P ha^{-1}, respectively.

Boro 2024-25

The applied P as triple super phosphate (TSP) fertilizer in different doses has influenced significantly on grain and straw yield of BRRI hybrid dhan3 in Boro season **(Table 14).** Grain yield from the fertilizer P control plot progressively increased with the increasing level of fertilizer P. Under control P condition, grain yield was only 2.50 tha^{-1} and with 50% (T_2) and, or 75% (T_3) applying of fertilizer P, grain yield increased significantly over control and further increasing the P doses (i.e T_4, T_5 and T_6), grain yield remain statistically similar. The highest grain yield obtained with T (7.26 tha^{-1}) treatment but the result was statistically similar with T_5 (7.21 tha^{-1}) and T_6 (7.16 tha^{-1}). Similar trend was obtained in case of tiller, panicle and straw yield of BRRI hybrid dhan3.

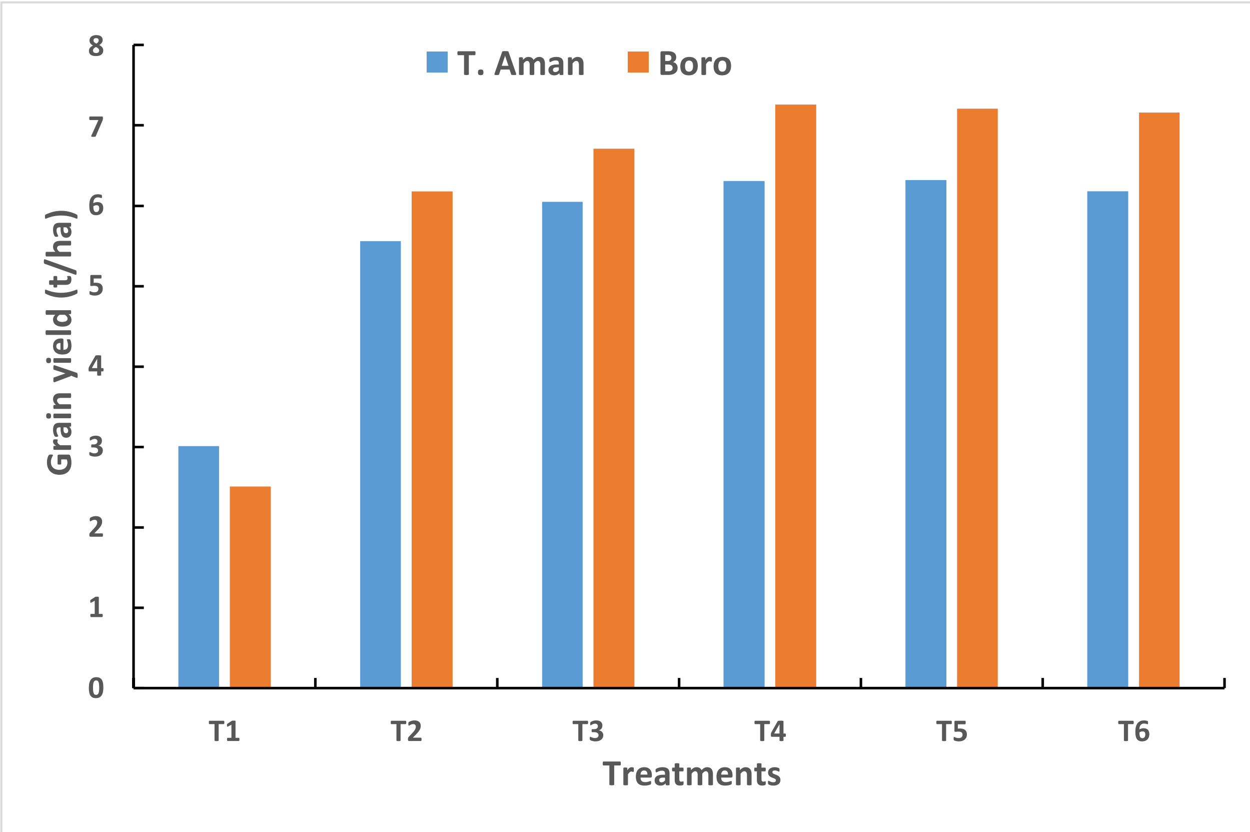
Table 14. Response of phosphorus on grain and straw yield of BRRI hybrid dhan3 in Boro 2024-25 BRRI farm, Gazipur

Treatment	BRRI hybrid dhan3			
	Tiller m^{-2}	Panicle m^{-2}	GY ($t\ ha^{-1}$)	SY ($t\ ha^{-1}$)
T_1 = P control	142	124	2.51	2.59
T_2 = 50% STB P	334	318	6.18	6.43
T_3 = 75% STB P	341	325	6.71	6.96
T_4 =100% STB P	350	335	7.26	7.43
T_5 = 125% STB P	362	343	7.21	7.33
T_6 = 150% STB P	364	346	7.16	7.31
LSD (0.05)	71	67	0.66	0.71
CV (%)	7.92	7.89	3.78	3.93

N.B. T_1 = 0, T_2 = 11, T_3 = 16.5, T_4 = 22, T_5 = 27.5, T_6= 33 kg Pha^{-1}, respectively.

Grain yield in T. Aman and Boro season

A comparative study of T. Aman and Boro rice yield with the application of different doses of P fertilizer in both seasons **(Fig. 6).** Although, higher grain yield in P fertilized plots were observed in Boro season than in T. Aman season, but in P control plot the grain yield was higher in T. Aman than Boro season. Most probably due to comparatively higher temperature in T. Aman than Boro season which mineralized and increased the availability of native soil P (Hossain et. al., 2016)



N.B. $T_1 = 0$, $T_2 = 11$, $T_3 = 16.5$, $T_4 = 22$, $T_5 = 27.5$, $T_6 = 33$ kg Pha^{-1}, respectively.

Fig.6. Effect of different doses of phosphorus on grain yield of T. Aman and Boro rice, BRRI Gazipur, 2024-25

Conclusion

Soil available P levels can be decreased tremendously under wetland rice cultivation in without P fertilizer for a long period of time. Response of rice to applied P under soil P deficit conditions was sharp and the response was much lower in T. Aman (wet season) than in Boro (dry season). Soil test based P application can ensure the better rice yield. Despite the variations in applied P doses, application of optimum dose of P fertilizer might be useful to obtain higher rice yield in both seasons.

Expt. 13. Influence of potassium fertilizer rates on modern rice cultivation

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Introduction

Rice underpins food security and rural livelihoods in Bangladesh, where successive waves of intensification have pushed yields higher but also tightened nutrient constraints in paddy soils.

Among the macronutrients, potassium (K) is often underapplied relative to nitrogen (N) and phosphorus (P), despite its central roles in osmoregulation, stomatal control, enzyme activation, and lodging resistance—traits that directly influence yield formation and resilience under heat, drought, and salinity stresses common to the deltaic landscape. Recent physiological and field evidence shows that adequate K supply enhances root water uptake, maintains leaf water status, and improves harvest index in rice grown under water-limited conditions, indicating important co-benefits for climate adaptation (Damalas and Koutroubas, 2024; Yang et al., 2024).

Long-term nutrient mining and imbalanced fertilization have gradually depleted exchangeable K in many South Asian rice soils. In Bangladesh, agronomic surveys and synthesis reports have highlighted emerging K deficiency in both irrigated Boro and rainfed systems, aggravated by removal or burning of K-rich rice straw. Because straw contains substantial K that is readily leached or lost during burning, off-field straw handling can accelerate K depletion; conversely, returning straw can markedly reduce the mineral K requirement in the subsequent crop (Islam et al., 2016; Sarkar et al., 2017). Meta-analyses and knowledge-bank syntheses report that straw burning causes significant K losses, whereas nutrient cycling through residue retention can cut the K fertilizer need by more than 100 kg K_2O ha^{-1}, depending on target yield and site conditions (Javier, 2009; Liu et al., 2024).

Bangladesh-specific field studies corroborate the yield responsiveness of modern varieties to K. Trials with popular BRRI cultivars have documented significant increases in panicle number, filled grain percentage, and grain yield as K rates rise from omission to recommended levels; similar responses are reported for Boro season rice on floodplain soils, where K fertilization improved plant K status and yield stability (Akter et al., 2024; Islam and Muttaleb, 2016). These findings align with broader regional syntheses that identify K as a limiting nutrient in rice–wheat and rice-based rotations of the Indo-Gangetic region, particularly where residue removal is common and groundwater irrigation intensifies nutrient export (Ladha et al., 2003; Meena et al., 2020).

Despite clear agronomic benefits, optimizing K rates for modern rice remains challenging because demand is highly site- and system-specific: it depends on soil mineralogy (e.g., illitic K fixation and release), historical fertilizer use, groundwater K inputs, and residue management. Bangladesh has considerable heterogeneity across agro-ecological zones—from Old and Young Brahmaputra floodplains to Ganges tidal plains—implying that a single ―blanket‖ K rate is unlikely to be efficient everywhere. Recent reviews for coastal and saline-affected areas emphasize the interplay between salinity management and balanced K fertilization to sustain yields and grain quality, reinforcing the case for site-specific K recommendations linked to soil testing and crop targets (Carciochi et al., 2025).

Against this backdrop, the present study evaluates the influence of K fertilizer rates on modern high-yielding rice in Bangladesh, with a hypothesis: raising K from omission or sub-optimal levels to the agronomic optimum will significantly increase yield components and grain yield.

Materials and Methods

The experiments were initiated in the Boro season, 2002-2003, at BRRI farm, Gazipur, to study the response of modern rice varieties to different K application rates (0-80 kg ha^{-1}). The initial soil characteristics of the experimental plot were as follows: soil pH 5.7 (medium acidic), 0.72% organic carbon (low), 0.07% total nitrogen (very low), 9.3 mg kg^{-1} P (low), 0.18 meq exch. K/100g (medium), 5.4 mg kg^{-1} available S (very low) and 3.7 mg kg^{-1} Zn (very high). From Boro 2010-11, K application rates were changed to 0-200 kg ha^{-1}. From Boro 2013-14, each K treated plot was divided into four parts to include four nitrogen rates to determine the interaction effect of N and K on the yield and nutrition of rice. The experiment was laid out in a split-plot design with three replications, assigning the rates of K in the main plots and those of N in the subplots. From Aman 2024, subplots were again merged to study the response of modern rice varieties to five K application rates. The experiment was laid out in an RCBD design with three replications. The application rate of K was 0, 40, 80, 120 and 160 kg ha^{-1} in both Aman 2024 and Boro 2024-25 seasons. Recommended doses of N, P, S, and Zn (90, 9, 7, and 1 kg ha^{-1} in Aman season and 174, 18, 18, and 2 kg ha^{-1} in Boro season, respectively) were applied to all the plots. The test varieties were BRRI hybrid dhan6 and BRRI dhan102 in Aman and Boro seasons, respectively. Standard cultural practices were followed for raising the crops. Seedlings were transplanted with row-to-row spacing of 20 cm 24 and plant-to-plant spacing of 20 cm. All plots were surrounded by 30 cm soil levees to avoid contamination between plots. At maturity, the crop was harvested manually at 15 cm above ground level. Grain yield was recorded at 14% moisture content.

Results and Discussion

The effect of K rates on rice yield was significant in Aman 2024 and Boro 2024-25 (Table 1). In Aman 2024, K fertilizer increased grain yield compared to the K-control plot (3.32 t ha^{-1}). The highest grain yield was obtained with the K fertilizer application of 80 kg ha^{-1}, which was statistically identical to the other K fertilizer rates. However, no significant yield improvement was observed beyond 40 kg K ha^{-1} **(Table 15).** Therefore, an application rate of 40 kg K ha^{-1} appears sufficient for BRRI hybrid dhan6 to achieve optimum rice yield in the Aman season. In Boro 2024-25, K fertilizer also increased grain yield compared to the K-control plot (3.67 t ha^{-1}). However, no significant yield improvement was observed beyond 80 kg K ha^{-1} (Table 1). Therefore, an application rate of 80 kg K ha^{-1} appears sufficient for BRRI dhan102 to achieve optimum rice yield during the Boro season in Madhupur Tract soil.

Table 15. Effect of K rates on the grain yield of MV rice in Aman 2024 and Boro 2024-25 at BRRI farm, Gazipur.

K rates (kg ha^{-1})	Grain yield (t ha^{-1})	
	Aman 2024 (BRRI hybrid dhan6)	Boro 2024-25 (BRRI dhan102)
0	3.32b	3.67 c
40	3.84a	5.11 b
80	4.01a	6.17 a
120	3.89a	6.65 a
160	3.99a	6.54 a
p-values	<0.01	<0.001
CV	4.07	4.77

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

Conclusion

Potassium fertilization exerts a significant influence on the productivity of modern rice varieties under both Aman and Boro seasons. In Aman 2024, the grain yield of the BRRI hybrid dhan6 increased markedly with the application of K compared to the control, but no additional yield benefit was observed beyond 40 kg K ha^{-1}. This suggests that 40 kg K ha^{-1} is adequate to achieve optimum yields during the Aman season. However, considering the continuous depletion of soil K reserves due to intensive rice cultivation, a higher maintenance dose of 50–60 kg K ha^{-1} is recommended to sustain soil fertility and long-term productivity. In the Boro 2024–25 season, BRRI dhan102 responded positively to K fertilization, with yields increasing up to 80 kg K ha^{-1}, beyond which no significant gains were achieved. Thus, 80 kg K ha^{-1} appears to be the optimum application rate for Boro rice in Madhupur Tract soils. Overall, the study highlights that site- and season-specific K management is essential for modern rice varieties in Bangladesh. Optimized K application not only maximizes yield but also safeguards soil fertility against nutrient mining, thereby contributing to sustainable rice intensification.

Expt. 14. Delineating productivity of rice soils in the ecologically constrained areas of Bangladesh through digital soil mapping (DSM)

M. S. Rahman, M. H. Khan, M. M. Haque, M. Iqbal, T. Islam, A. Islam and R. Islam

Introduction:

Soil fertility determines the yield potentiality of modern rice variety in a particular ecosystem. Identification and mapping of soil fertility parameters aim to optimize the supply of soil nutrients over time and space to match the requirements of crops. Detailed and precise map will guide researchers to develop recommendations for improved management of the identified fertility constraints for sustaining rice yield. The data generated by analyzing important soil properties of the various rice producing ecosystems serve as the background of digital soil map (DSM) developed from the predictions by the machine learning (ML) models. The study was undertaken with the following objectives:

- To determine the productive potentiality of rice soils in the ecologically constraint areas of Bangladesh through development of DSM and applying site specific nutrient management (SSNM)
- To generate recommendations for effective soil fertility management in the constraint areas.

Materials and methods:

This study was initiated during 2023-24 to in the ecologically constraint areas of Bangladesh. Soil sampling locations were selected from the Barind tract and drought prone areas under Rajshahi region. A total of 159 locations covering all the eight districts of Rajshahi Division were sampled based on AEZ, land type and cropping pattern (Fig. 1a). Georeference of the sampling points were recorded by handheld GPS. Soil samples were dried, crushed and analyzed for basic soil properties in the laboratory. Soil pH (1:2.5) was measured by glass electrode. Soil organic C was determined by Walkley and Black wet oxidation method. Soil K was extracted by 1 M NH_4OAc (pH 7.0) and de-ionised water. Soil exchangeable K was calculated by subtracting the conc. of water-soluble K from the conc. of NH_4OAc-extractable K. Soil nutrient maps were developed using QGIS software (version 3.40), by IDW method of interpolation. Further analytical data is being generated for the development of digital soil map through machine learning models along with collection of legacy data and natural co-variates.

Results and discussion

Soil pH: Soil pH ranged from 4.43 (very strongly acidic) in Joypurhat district to as high as 8.32 (slightly alkaline) in Chapai Nawabganj **(Table 16).** The highest mean soil pH was 7.57 in Pabna district which was statistically equal to those of Rajshahi, Natore and Chapai Nawabganj districts.

Table 16. Distribution of soil pH in different districts of Rajshahi Division during 2023-24.

District	N	Mean*	SD	Min	Max	Skewness	Kurtosis
Bogura	26	5.97 bc	0.63	4.76	7.39	0.44	0.06
Ch. Nawabganj	11	7.07 a	0.82	5.56	8.32	-0.19	-0.29
Joypurhat	10	5.34 c	0.46	4.43	6.16	-0.45	1.41
Naogaon	28	5.76 bc	0.61	4.98	7.27	0.80	-0.06
Natore	14	7.48 a	0.41	6.98	8.09	0.34	-1.67
Pabna	17	7.57 a	0.51	6.45	8.20	-0.68	-0.25
Rajshahi	30	7.51 a	0.71	5.90	8.30	-0.76	-0.32
Sirajganj	23	6.12 b	0.35	5.48	6.71	-0.12	-0.48

* Values followed by same letter in a column are not significantly different at 5% significance level.

On the contrary, the lowest mean soil pH was observed in Joypurhat district (5.34) which was similar to those of Naogaon and Bogura districts. Thus, there was significant variation in soil pH among the districts of Rajshahi region **(Table 16).** The data of soil pH were normally distributed in most of the cases, as observed by their low and insignificant values of skewness and kurtosis **(Table 16).** The interpolated map shows that the northern part of Rajshahi region had acidic pH while the southern and western part shows high soil pH **(Fig. 7b).** The alkaline pH of soils implies a decreased availability of micronutrients in the studied soils while the strongly acidic soil pH indicates a possible deficiency of phosphorus in the soils due to fixation of P by oxides of aluminum and iron.

Soil organic C (SOC): The content of SOC ranged from 0.52% in Rajshahi district to as high as 2.13% in Natore **(Table 17).** The data were normally distributed in all the districts as observed by the low skewness values.

Table 17. Distribution of SOC (%) in the districts of Rajshahi Division during 2023-24.

District	N	Mean*	SD	Min	Max	Skewness	Kurtosis
Bogura	26	1.28 a	0.36	0.67	1.94	0.16	-0.79
Ch. Nawabganj	11	1.16 a	0.22	0.95	1.58	0.71	-0.82
Joypurhat	10	1.37 a	0.33	0.81	1.92	-0.23	0.01
Naogaon	28	1.23 a	0.31	0.58	1.8	-0.05	-0.75
Natore	14	1.33 a	0.37	0.79	2.13	0.72	0.28
Pabna	17	1.30 a	0.32	0.91	1.97	0.52	-0.73
Rajshahi	30	1.18 a	0.27	0.52	1.74	0.19	0.42
Sirajganj	23	1.23 a	0.32	0.64	2.06	0.19	1.07

*Values followed by same letter in a column are not significantly different at 5% significance level.

The mean SOC contents (1.16-1.37%) of all the studied districts of Rajshahi division were statistically similar **(Table 17).** The highest mean SOC content (1.37%) was observed in Joypurhat followed by Natore (1.33%) and Pabna (1.30%) **(Table 17).** The interpolated map of SOC shows that major part of Rajshahi Division contained medium level of organic C (0.99-1.97%) **(Fig. 7c).** A higher organic C content of the soils implies a higher soil fertility and, hence, higher crop yield is expected.

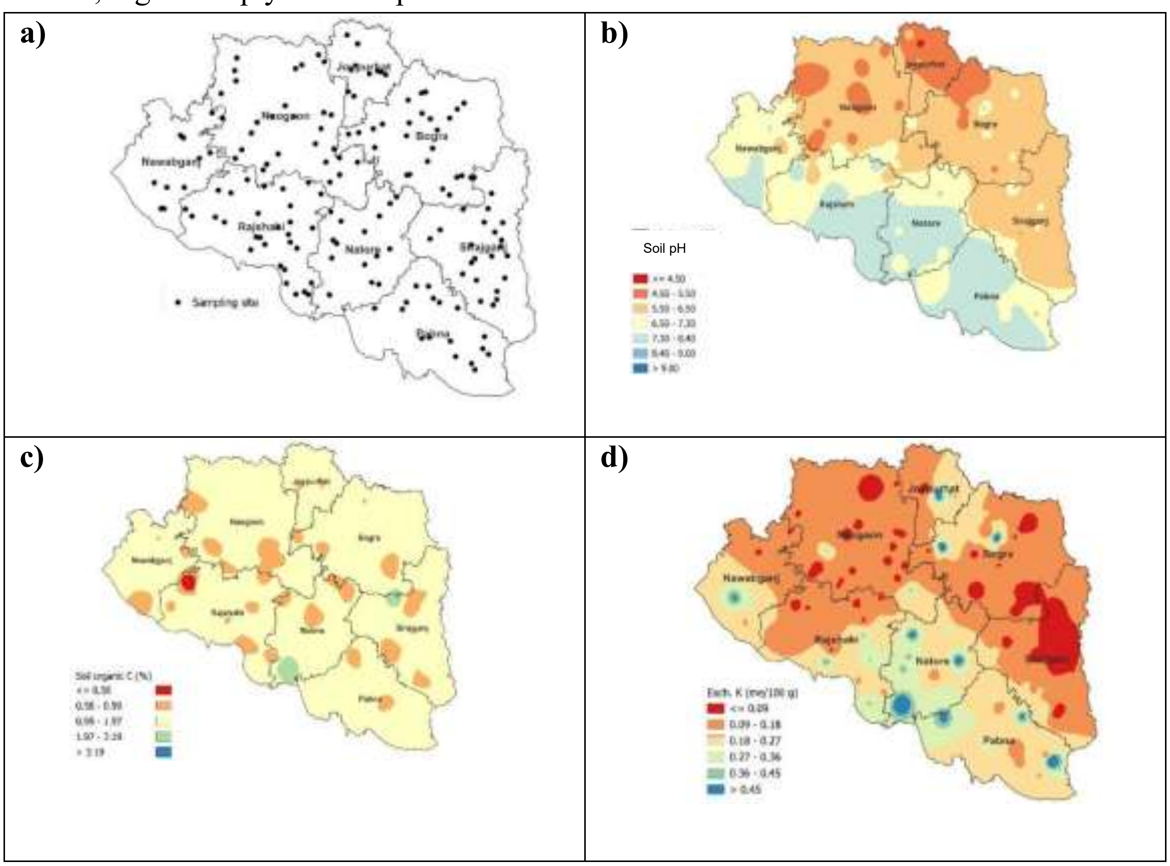

Fig. 7. Interpolated surface showing a) the location of the sampling sites, b) soil pH, c) org. C (%) and d) soil exch. K conc. in different districts of Rajshahi Division during 2023-24.

Soil exchangeable potassium (K):

The district-wise distribution of soil exchangeable K is shown in **Table 18.** The concentration of exch. K ranged from 0.02 meq/100 g to 0.82 meq/100 g. However, the highest values e.g., 0.82 and 0.74 meq K/100 g are not usually observed in the field and can be treated as outliers.

Table 18. Distribution of soil exchangeable K (meq/100 g) in the districts of Rajshahi Division during 2023-24.

District	N	Mean*	K-fertility class	SD	Min	Max	Skewness	%samples BCL[a]
Bogura	26	0.14 c	Low	0.16	0.02	0.65	2.61	54
Ch. Nawabganj	11	0.20 abc	Medium	0.13	0.04	0.48	1.08	27
Joypurhat	10	0.21 abc	Medium	0.20	0.03	0.66	1.69	30
Naogaon	28	0.11 c	Low	0.09	0.02	0.39	2.22	68
Natore	14	0.34 a	Optimum	0.20	0.10	0.82	1.10	8
Pabna	17	0.28 ab	Optimum	0.18	0.10	0.74	1.43	18
Rajshahi	30	0.20 bc	Medium	0.12	0.04	0.45	0.50	33
Sirajganj	23	0.09 c	Very low	0.07	0.03	0.29	1.52	78

* Values followed by same letter in a column are not significantly different at 5% significance level.

[a] BCL = below critical limit (0.12 meq K/100 g soil).

The highest mean soil exch. K conc. (0.34 meq/100 g) was observed in Natore, followed by Pabna (0.28 meq/100 g). The lowest K conc. (0.11 meq/100 g) was found in Naogaon district. The high positive skewness values of exch. K in Bogura, Naogaon and Sirajganj indicate that the K conc. was not normally distributed and that many samples have K conc. lower than the mean K conc. in these three districts. The mean K conc of these districts are classified as 'low to very low K fertility' class (Table 18). As shown in Table 3, 78%, 68% and 54% of samples in Sirajganj, Naogaon and Bogura districts, respectively, showed below critical limit (0.12 meq/100 g) of soil K **(Table 18).** This should be addressed seriously, as the result imply that the soil K reserve is under risk of mining largely under intensive cropping and imbalance fertilization in these districts.

The interpolated map shows that the northern and western part of Rajshahi region had very low to low exch. K, while the southern part (Natore, Pabna and part of Rajshahi) shows optimum to high soil K **(Fig. 7d).**

Conclusion

The interpolated maps of the soil nutrients revealed the general scenario of soil fertility in the agricultural soils of Rajshahi Division. This helps the researchers and the farmers to take necessary steps for appropriate management of the soil for sustainable crop production and secured soil health.

Expt. 15. Assessment of soil properties in paddy field with spatial variability by sensor and lab methods

M Akter, M S Rahman, M H Khan, A Islam and M R Islam

Introduction

Traditional measurement of soil moisture, pH, electrical conductivity (EC), mineral nitrogen (N), available phosphorus (P) and potassium (K) accurately for paddy field with wide spatial variation are time-consuming, costly and difficult due to their high spatial variability. Also, application of uniform rates of fertilizers for larger fields with high spatial variation in these soil properties has shortcomings from both economic and environmental perspectives. Likewise, uniform rates may result over or under application of fertilizers instead of variable rates of fertilizers via identifying spatial variability of soil properties. To reduce fertilizer costs and environmental harm, adjusting fertilizer application rates by creating several high-resolution soil maps require collection and analysis of huge number of soil samples in many separate grids of larger field which are costly, time-consuming and laborious. Precision technology and site specific nutrient management (SSNM) could potentially improve the efficiency of nutrient management, increase soil productivity and minimize nutrient surpluses and deficiencies at farm scale. Recent use of portable soil sensor allows to generate quick results on soil moisture, pH, EC, mineral N, available P and K**.** Therefore, this study was conducted to **1°** to assess spatial variability of soil pH, organic carbon (OC), total N, C:N, available P and K; **2°** to compare the outcomes on soil pH, EC, mineral N, available P and K measured by soil sensor and standard lab methods.

Materials and Methods

In December 2024, 141 soil samples (0-15 cm) were collected in 50 m×50 m grid system covering 37 ha rice growing area of BRRI Sonagazi (22°48′6.6′′ to 22°48′17.97′′N, 91°23′1.75′′ to 91°23′27.53′′E). The farm has General soil type of Calcareous Alluvium Seasonally Saline 1b under AEZ 18: Young Meghna Estuarine Flood Plain. The collected soil samples were air dried, ground and sieved by 2mm mesh sieve, stored and used for laboratory analysis of soil OC (method by Walkley and Black), pH-H_2O (1:2.5), total N (using Kjeldahl digestion- steam distillation method), available P and K (Ammonium-acetate EDTA pH 4.65 method by Cottenie et al., 1982). Ordinary kriged maps of spatial distribution for soil properties were produced using surfer11 software.

Results and Discussion

Descriptive statistics for soil pH-H_2O (1:2.5), OC, total N, C:N and available K had shown in **Table 1**. Mean and median values of all soil properties were identical and had skewness values ranged from -0.1 to 0.5 indicating approximately symmetrical or close to normal distributions of the data. Across soil properties the coefficients of variation (CV) (%) ranged from 8.3 (for soil pH-H_2O) to 15.6 (for available K). Soil pH-H_2O varied in a range of 5.3 to 7.6 with a mean value of 6.1 **(Table 19 and Fig. 8).** While the soil OC (0.9-1.8%), total N (0.1-0.2%) and C:N (8-16) varied a factor 2 within the field but overall had coefficient of variations of 14.1, 13.4 and 13.0, respectively **(Table 19, Fig. 8 and Fig. 9).** The available K (meq 100^{-1} g soil) ranged from (0.2 to 0.6) with mean/median value of 0.4 indicating its noticeable variation (varied by factor 2.5) within BRRI Sonagazi farm soil. Overall the values of soil pH-H_2O and available K attained via soil sensor and laboratory measurement were almost analogous **(Fig. 10).**

Table 19. Descriptive statistics for studied chemical properties of soil collected during pre-harvest Boro season 2025 in BRRI Sonagazi Farm.

Properties	Min.	Max.	Mean	Median	Std. Dev.	CV (%)	Skewness
SOC (%)	0.9	1.8	1.4	1.4	0.2	14.1	-0.1
Total N (%)	0.1	0.2	0.1	0.1	0.0	13.4	0.3
C:N	8	16	11	11	1	13.0	0.4
pH-H_2O (1:2.5)	5.3	7.6	6.1	6.1	0.5	8.3	0.5
Available K (meq $100g^{-1}$)	0.2	0.6	0.4	0.4	0.1	15.6	0.1

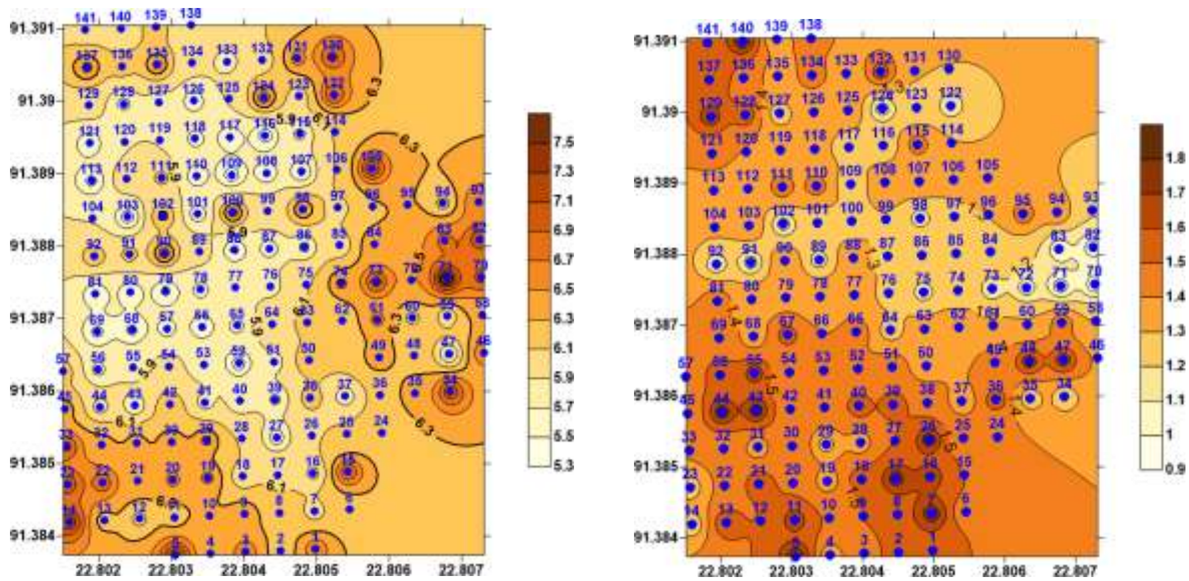

Fig. 8. Interpolated map showing spatial variability of pH-H_2O (left) and OC (right) across soil collected during pre-harvest Boro season 2025 in BRRI Sonagazi Farm.

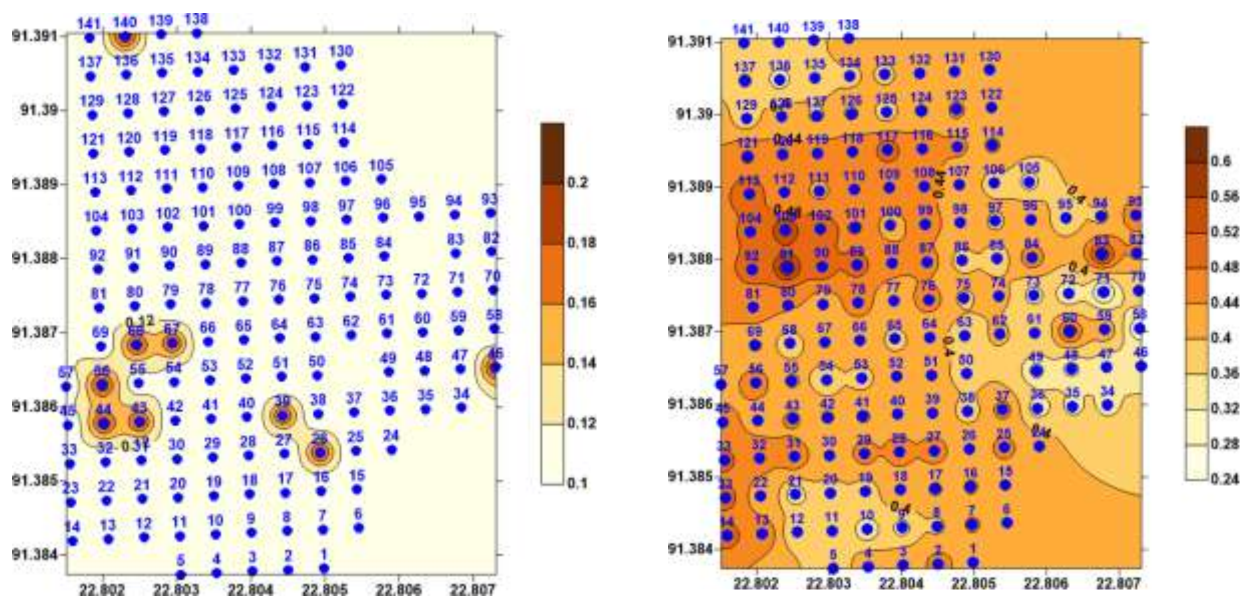

Fig.9. Interpolated map showing spatial variability of total N (left) and exchangeable K (right) across soil collected during pre-harvest Boro season 2025 in BRRI Sonagazi Farm.

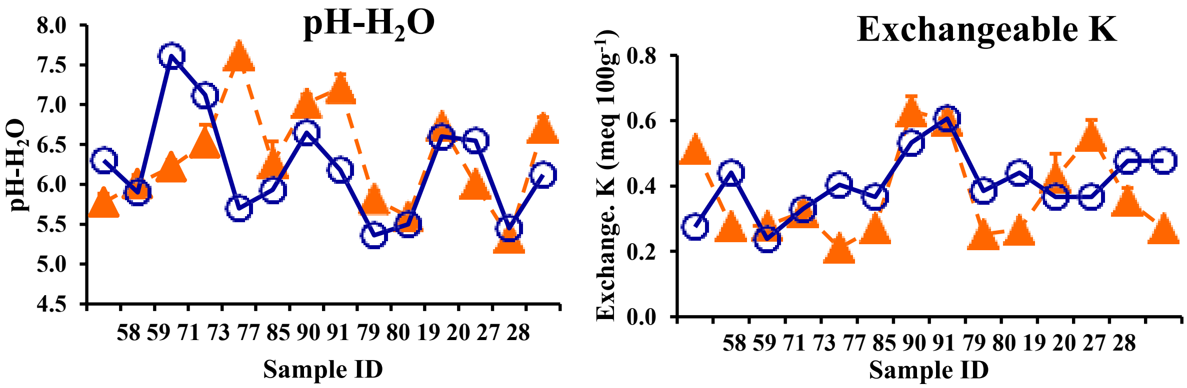

Fig. 10. Soil pH-H_2O (1:2.5) (left) and exchangeable K (right) measured in by lab methods (circle) & soil sensor (triangle).

Conclusions

The selected BRRI Sonagazi farm has wide spatial variation in the most important soil properties like pH-H_2O, OC, total N and available K, hence could be suitable to do research on identifying variable rates of N and K fertilizers instead of their uniform rates. Further verification requires validating data generate via use of quality soil sensor and handheld Vis-NIR spectroscopy on *in-situ* soil moisture, temperature, pH, OC, total N, available P and K.

Expt. 16. Effect of soil and foliar application of zinc on growth, yield, and nutrition of zinc-enriched rice cultivars

S.M.M. Islam, M.N. Islam, A. Jahan, M.S. Rahman, M. Hossain, M.R. Islam

Introduction

Applying zinc (Zn) fertilizers to leaves and soil enhances Zn uptake and its transfer to edible parts of the plant. Foliar application is widely accepted as a safe and effective method for crop enrichment, as Zn solutions can penetrate through the cuticle or stomata. Studies indicate that applying Zn during the flowering stage significantly increases Zn levels in rice grains (Feng et al., 2008). However, leaf-applied Zn faces challenges, as sprayed solutions often drip off or are washed away by rain, decreasing absorption efficiency.

Applying Zn to soil also increases grain Zn content and yield (Wu et al., 2020). Research shows that proper supplementation supports rice growth and improves productivity (Naik et al., 2008; Yang et al., 2021). However, soil oxides, clays, and humus can immobilize Zn ions, reducing fertilizer efficiency. Additionally, unabsorbed Zn can build up, creating risks for the agroecosystem. Therefore, developing new Zn fertilizers with higher efficiency and lower environmental impact is crucial for sustainable rice production.

Research on the role of nanotechnology in agriculture has expanded rapidly in recent decades (Kah et al., 2019). Recent findings indicate that nano-zinc can be effectively absorbed and utilized by crops, leading to higher grain yields and enhanced Zn concentration (Dimkpa et al., 2020). For example, Dimpkpa et al. (2020) reported that zinc oxide nanoparticles (ZnO NPs) improved growth, nutrient uptake, and Zn accumulation in sorghum even under low NPK fertilization. Similarly, research indicates that ZnO NPs can enhance salt tolerance in plants by regulating the potassium (K^+)/sodium (Na^+) ratio and stimulating antioxidant enzyme activity (Mu et al., 2023; Seleiman et al., 2023). Since the K^+ /Na^+ ratio is a crucial factor for salt tolerance, higher ratios are associated with greater physiological stability, as K^+ is essential for enzyme activation, osmoregulation, and maintaining membrane potential (Munns and Tester, 2008). Nano-zinc fertilizers have also been shown to increase grain Zn content, promote root development, and enhance rice growth (Ali et al., 2019). In addition, several studies have highlighted the role of ZnO NPs in mitigating cadmium (Cd) toxicity in plants (Rizwan et al., 2019).

Due to their nanoscale properties, ZnO NPs exhibit high chemical activity, with greater surface area and binding energy compared to bulk materials (Dimkpa et al., 2019). This makes them less influenced by soil texture and colloidal interactions, allowing easier plant absorption. They are often combined with conventional fertilizers or used as seed coatings to improve efficiency. Despite these promising outcomes, limited research has focused specifically on the effects of nano-Zn on rice yield formation and grain Zn enrichment. This study, therefore, investigates the effects of foliar nano-Zn application on growth, yield, and nutrition of zinc-enriched rice cultivars, providing a basis for improving grain quality.

Materials and Methods

The field experiments were conducted at the Bangladesh Rice Research Institute (BRRI) farm in Gazipur, Rajshahi, and Satkhira. BRRI dhan84 (Zn-enriched) and BRRI dhan104 were used for the experiment. Four fertilizer treatments were tested: (T1) Zn control, (T2) 100% of recommended zinc (RZ), (T3) 50% of RZ, and (T4) 50% of RZ with two foliar sprays of nano-zinc at the maximum tillering and one week before flowering stages. The nano-zinc spray rate was 1.5kg/ha per 1000 L of water. Nutrients viz. N, P, K, S & Zn were used as basal at the recommended rate to all plots. PU was applied in three equal splits. The crop was harvested at full maturity. After harvest, the crop was bundled separately and brought to the threshing floor, where it was manually threshed. The rice grains were cleaned and weighed. Then, the sundry grain weight was recorded for every plot, and the weight in g $plot^{-1}$ was adjusted to 14% moisture and finally expressed in t/ha. The sundry weight of straw was also recorded plot-wise and expressed as t/ha.

Results and Discussion

Fertilizer treatments and variety interaction had no significant impact on rice yield **(Table 20).** However, fertilizer treatment showed a significant variation in rice yield in Rajshahi only.

Application of 50% Zn with two foliar sprays of nano-zinc at the maximum tillering stage and flowering stage resulted in significantly higher yields than the Zn control treatment **(Table 20).** This could be attributed to variations in soil and environmental conditions. However, BRRI dhan104 produced significantly higher grain yields than BRRI dhan84 across all locations, which could be linked to the variation in the yield potential of the variety.

Similar to grain yield, the interaction between fertilizer treatments and variety had no significant effect on straw yield **(Table 21).** However, BRRI dhan104 produced significantly higher grain yields than BRRI dhan84 at the BRRI farms of Gazipur and Rajshahi. In contrast, straw yield showed no significant variation among treatments across the locations.

Table 20. **Effects of zinc rates and sources on grain yield (t/ha) at different locations**

Treatments	Gazipur Mean of 2 varieties		Satkhira Mean of 2 varieties		Rajshahi Mean of 2 varieties	
Zn Control	5.21		5.68		5.41b	
Recommended Zn (RZ)	5.53		6.32		5.77ab	
50% of RZ	5.46		5.96		5.66ab	
50% of RZ with 2 sprays of nano-Zn	5.74		6.25		6.08a	
Effects of variety	V1 4.99B	V2 5.97A	V1 5.82B	V2 6.28A	V1 5.44B	V2 6.03A
ANOVA (p values)						
Treatment (T)	ns		ns		*	
Variety (V)	*		*		*	
T × V	ns		ns		ns	

V1 and V2 indicate BRRI dhan84 and BRRI dhan104, respectively.

Table 21. **Effects of zinc rates and sources on straw yield (t/ha) at different locations of Bangladesh**

Treatments	Gazipur Mean of 2 varieties		Satkhira Mean of 2 varieties		Rajshahi Mean of 2 varieties	
Zn Control	5.19		5.76		5.44	
Recommended Zn (RZ)	5.39		5.83		5.52	
50% of RZ	5.43		6.06		5.49	
50% of RZ with 2 sprays of nano-Zn	5.57		5.91		5.86	
Effects of variety	V1 4.86B	V2 5.93A	V1 5.73A	V2 6.05A	V1 5.31B	V2 5.85A
ANOVA (p values)						
Treatment (T)	ns		ns		*	
Variety (V)	*		ns		*	
T × V	ns		ns		ns	

V1 and V2 indicate BRRI dhan84 and BRRI dhan104, respectively.

Conclusion

These findings are preliminary, and further research across diverse ecosystems with comparable soil and environmental conditions is required to obtain more accurate and consistent results.

Expt. 17. Screening of nitrogen use efficient breeding lines

M. H. Khan, U. A. Naher, K. M. Maniruzzaman and M. R. Islam

Introduction

Rice (*Oryza sativa*) is a staple food for over half of the world's population, especially in Asia, where it serves as a primary source of calories (IRRI, 2021). Nitrogen (N) is a crucial nutrient for rice growth, but its excessive application has led to significant environmental issues, including water pollution and greenhouse gas emissions (Tayefeh et al., 2018). Conversely, insufficient nitrogen can limit rice productivity, highlighting the need for efficient nitrogen management in rice cultivation (Liu et al., 2025).

Improving nitrogen use efficiency (NUE) in rice is vital for sustainable agriculture. NUE refers to the ability of plants to utilize nitrogen effectively for growth and development. In rice, NUE can vary significantly among different varieties, and this genetic variability offers opportunities to select breeding lines that require less nitrogen while maintaining optimal yields (Liu et al., 2022; Wang et al., 2022).

It is necessary to develop high-yielding nitrogen use efficient rice varieties. Therefore, this study was undertaken to identify high-yielding nitrogen use efficient breeding lines for low input suitable for Boro season. Objective of the study was to find the N use efficient breeding lines.

Materials and Methods

A set of four advanced lines (L_1= BR28NILQRL6.1-01, RL_1= BR28Ref-01, L_2= BR29NILQRL6.1-03, RL_2= BR29Ref-01) along with two check varieties were grown in BRRI HQ farm, Gazipur to find out the N use efficient breeding lines **(Table 22).** BRRI dhan88 and BRRI dhan89 were used as check varieties. Four different N fertilizer doses (kg/ha); N_0, N_{50}, N_{75}, and N_{100} were tested among the lines following split-plot design with three replications, where, different N doses were assigned in the main-plot and advanced lines in the sub-plot. Flat doses of P-K-S-@ 18-77-10 (kg/ha) and 18-100-10 (kg/ha) were applied along with different N treatments for lines L_1= BR28NILQRL6.1-01, RL_1= BR28Ref-01, CK_1= BRRI dhan88 and L_2= BR29NILQRL6.1-03, RL_2= BR29Ref-01, CK_2= BRRI dhan89 respectively. About 35 days old seedlings were grown. Rice seedlings were transplanted at 20 x 20 cm^2 spacing. Urea-N was applied into three equal splits at final land preparation, active tillering and 5-7 days before panicle initiation (PI) stage. Rests of the fertilizers were applied at final land preparation. The other management practices were applied as and when necessary and equally. The individual main plot size was 7m×3m. The flooded water level at 5-7 cm depth was maintained during rice cultivation, and then drained 21 days before rice harvesting. At maturity, the tiller and panicle number per meter square and grain and straw yield data were recorded. Grain yield was harvested from total areas of the individual line of each plot and 16 hills were collected for tiller, panicle and straw yield for each line. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. Data were analyzed statistically by the software STAR and Microsoft Excel.

Table 22. Treatment combinations of Screening of N use efficient breeding lines at BRRI, Gazipur in Boro 2024-25

	Treatments combination	
	Fertilizer dose (kg/ha)	Breeding line
T_1 =	N_0-P-K-S	L_1= BR28NILQRL6.1-01
T_2 =	N_{100}-P-K-S	RL_1= BR28Ref-01
T_3 =	N_{75}-P-K-S	CK_1= BRRI dhan88
T_4 =	N_{50}-P-K-S	L_2= BR29NILQRL6.1-03
		RL_2= BR29Ref-01
		CK_2= BRRI dhan89

For BRRI dhan88 N-P-K-S = 138-18-77-10 (kg/ha);

For BRRI dhan89 N-P-K-S = 170-18-100-10 (kg/ha)

Results and Discussion

Grain yield and N requirement

The grain yield was significantly varied with the application of different doses of N fertilizer on the selected breeding lines in Boro season 2024-25 (Table 23 & 24). The highest grain yield was obtained with the check variety BRRI dhan89 (8.01 t/ha) in N_{75}-P-K-S treatment followed by line L_2= BR29NILQRL6.1-03 (7.63 t/ha), CK_2= BRRI dhan89 (7.62 t/ha), RL_2=BR29Ref-01 (7.14 t/ha), respectively in N_{100}-P-K-S treatment. L_2= BR29NILQRL6.1-03 (7.10 t/ha) line also performed well in N_{75}-P-K-S treatment. Moderate performance was observed in N_{50}-P-K-S treatment for all the lines and lowest performance was observed in N_0-P-K-S treatment **(Table**

24). Tested line L_1= BR28NILQRL6.1-01 produced 6.95 t/ha and 6.43 t/ha grain yield in N_{100}-P-K-S and N_{75}-P-K-S treatment, respectively. L_1= BR28NILQRL6.1-01 gave higher yield compared to other line (RL_1= BR28Ref-01) and check variety (CK_1= BRRI dhan88) in all treatments except N_0-P-K-S **(Table 23).** Moreover, moderate performance was observed in N_{50}-P-K-S treatment and lowest performance was observed in N_0-P-K-S treatment for all the three lines **(Table 23).**

Table 23. Screening of N use efficient short duration breeding lines in 2024-25, BRRI, Gazipur

Fertilizer treatment	Advanced line/ variety		
	L_1= BR28NILQRL6.1-01	RL_1= BR28Ref-01	CK_1= BRRI dhan88
N_0-P-K-S	3.45 d	3.96 c	3.56 c
N_{100}-P-K-S	6.95 a	6.47 a	5.25 a
N_{75}-P-K-S	6.43 b	6.24 a	4.44 b
N_{50}-P-K-S	5.38 c	5.29 b	4.32 b
CV (%) Fertilizer		6.95	
CV (%) Variety		4.49	

N.B. Means with the same letter in the same column are not significantly different from each other

Table 24. Screening of N use efficient long duration breeding lines in 2024-25, BRRI, Gazipur

Fertilizer treatment	Advanced line/ variety		
	L_2= BR29NILQRL6.1-03	RL_2= BR29Ref-01	CK_2= BRRI dhan89
N_0-P-K-S	4.45 c	4.96 c	4.56 c
N_{100}-P-K-S	7.63 a	7.14 a	7.62 a
N_{75}-P-K-S	7.10 a	6.38 b	8.01 a
N_{50}-P-K-S	5.52 b	6.37 b	7.01 b
CV (%) Fertilizer		6.77	
CV (%) Variety		4.21	

N.B. Means with the same letter in the same column are not significantly different from each other

Conclusion

Tested line L_1= BR28NILQRL6.1-01 seems to be more nitrogen efficient in terms of short duration breeding lines as it gave statistically higher yield than the check variety CK_1= BRRI dhan88. So, this breeding line may proceed for further trial to develop N use efficient rice variety. In case of long duration breeding lines, the performance of tested line L_2= BR29NILQRL6.1-03 was statistically similar to check variety CK_2= BRRI dhan89. In case of 100% N fertilizer application, check variety CK_2= BRRI dhan89 gave higher yield than the other two breeding lines.

Expt. 18. Effect of calcium silicate fertilizer on growth and yield of rice

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Introduction

Silicon (Si) is widely recognized as a beneficial element for the healthy growth and development of rice crops. As a high Si accumulator, the rice plant absorbs substantial amounts of this element throughout its lifecycle (Bhattacharya, 2019). Numerous studies have demonstrated that Si application enhances root development and nutrient uptake by increasing the availability of nutrients in the soil (Wang et al., 2020). Additionally, Si contributes to improved photosynthetic efficiency and strengthens the plant's resistance to drought, pests, and diseases (Kim et al., 2022). However, in intensive cropping systems, continuous cultivation often leads to the depletion of freely available soil nutrients. In rice-based systems, the decline in Si availability has been linked to reduced yield and productivity (Meena et al., 2014). Although Si constitutes approximately 30% of the total soil weight and can account for less than 1% to as much as 45% of plant dry weight (Sommer et al., 2006), its bioavailability is typically low in tropical and subtropical soils. This is further exacerbated by desilication, a natural leaching process that results in the gradual loss of Si from the soil profile (Meena et al., 2014).

Given its critical role in maintaining soil fertility and enhancing crop performance, the exogenous application of Si has been shown to offer multiple agronomic benefits (Ahmed et al., 2019; Agostinho et al., 2017). Modern rice farming has adopted a variety of Si sources to improve soil health, including calcium silicate slag, calcium meta-silicate (wollastonite), soluble potassium and sodium silicates, and slow-release potassium silicate formulations (Liang et al., 2015; Pereira et al., 2004). Among these, calcium silicate stands out as a particularly promising option due to its dual contribution of both calcium and silicon. The synergistic effects of calcium and silicon make calcium silicate a compelling soil amendment for sustainable rice production systems. Therefore, this study aims to evaluate the effects of calcium silicate fertilizer on the growth and yield of rice.

Materials and Methods

To determine the efficacy of calcium silicate, two field experiments were conducted at BRRI Farm, Gazipur, and BRRI farm, Sonagazi during Boro season, 2024-25. Four treatment combinations were tested: T_1= 100% Recommended Fertilizer (RF), T_2 = 100% RF + Calcium silicate fertilizer (CSF) @ 247 kg/ha, T_3 = 100% RF + CSF @ 494 kg/ha and T_4 = 100% RF + CSF @ 741 kg/ha. Each treatment received N-P-K-S-Zn @ 174-18-80-18-2 kg/ha and N-P-K-S-Zn @ 174-18-80-18-3 kg/ha as a flat dose at Gazipur and Sonagazi sites, respectively. The experiments were laid out in a randomized complete block design with three replications. All P, K, S and Zn fertilizers were applied at the time of final land preparation. Urea was applied into three equal splits: 1/3rd as basal, 1/3rd at the early tillering stage and the remaining 1/3rd at 5-7 days before the panicle initiation stage. Calcium Silicate Fertilizer was incorporated into the soil during the final stage of land preparation. BRRI dhan102 was used as a test crop at the Gazipur and Sonagazi sites. Two to three seedlings/hill were transplanted with 20 cm × 20 cm spacing. The necessary intercultural operations were carried out as required. At maturity, the crop was harvested from a 5 m^2 area at the centre of each plot and grain yield was adjusted to 14% moisture. The plant height, tiller number, panicle number, grain and straw yields were recorded.

Results and Discussion

At the Gazipur site, the grain and straw yields of BRRI Dhan102 did not vary significantly with the application of different treatments. The grain yield ranged between 6.71 to 6.92 t/ha. However, the highest grain yield (6.92 t/ha) was observed with the application of 100% Recommended Fertilizer (Control), although this was not statistically different from the other treatments.

At the Sonagazi site, application of different treatments significantly influenced the grain yield of BRRI dhan102, but straw yield did not vary significantly. The highest grain yield (7.82 ton/ha) was found with the combined application of 742 kg/ha CSF and 100% RF, which increased the grain yield by about 14%. However, application of CSF at lower rates (247 and 494 kg/ha) with the 100% RF gave similar grain yield to 100% RF only **(Table 25).**

Table 25: Effects of Calcium Silicate Fertilizer on grain and straw yield (t/ha) of BRRI dhan102 in Boro season

Treatments	Grain yield (t/ha)		Straw yield (t/ha)		% Grain yield increase/decrease over recommended fertilizer	
	Gazipur	Sonagazi	Gazipur	Sonagazi	Gazipur	Sonagazi
T_1: 100% Recommended Fertilizer	6.92	6.69a	6.94	7.68		
T_2: 100% RF + CSF @ 247 kg/ha	6.71	6.95a	6.81	8.12	-3.12	3.74
T_3: 100% RF + CSF @ 494 kg/ha	6.76	7.07a	7.09	8.21	-2.37	5.37
T_4: 100% RF + CSF @ 741 kg/ha	6.80	7.82b	7.45	8.45	-1.76	14.45
CV (%)	*4.18*	*4.82*	*11.63*	*8.31*		

The estimated total variable cost (TVC), gross return, added return, net return and marginal benefit cost ratio (MBCR) are presented in **Table 26**. Economic analysis was done considering the cost of fertilizer, fertilizer application and labor for the additional products. At the Gazipur site, the calculated added return and MBCR indicated that the application of CSF is not economically viable compared to the 100% RF.

At the Sonagazi site, the application of CSF at different doses with 100% RF resulted in a considerable increase in the gross, added and net return compared to 100% RF only. The highest gross (Tk. 327550.00), added (Tk. 42370.00) and net (Tk. 286257.00) returns were found with the CSF @ 741 kg/ha + 100% RF. The estimated MBCR values were greater than 1 in the combined application of CSF at different rates and 100% RF compared to 100% RF only. The highest MBCR (2.40) was obtained with the application of CSF @ 247 kg/ha + 100% RF.

Table 26: Economic analysis of calcium silicate fertilizer (CSF) in Boro rice at BRRI farms

a. Total variable cost (TVC) in Tk./ha

Treatment	Fertilizer cost*		Fertilizer application cost		Labor cost for additional products		Total Variable cost (BDT ha^{-1})	
	Gazipur Site	Sonagazi site	Gazipur Site	Sonagazi site	Gazipur Site	Sonagazi site	Gazipur Site	Sonagazi site
T_1: 100% Recommended Fertilizer	21308	22198	1200	1200	0	0	22508.00	23398.00
T_2: 100% RF + CSF @ 247 kg/ha	25013	25903	1200	1200	0	1560	26213.26	28662.86
T_3: 100% RF + CSF @ 494 kg/ha	28718	29608	1200	1200	0	2280	29918.26	33087.86
T_4: 100% RF + CSF @ 741 kg/ha	32423	33313	1200	1200	0	6780	33623.26	41292.86

*Fertilizer cost included chemical fertilizer and Calcium silicate fertilizer (CSF).

Urea = Tk. 27.00 /kg, TSP= Tk 27.00/kg, MoP= Tk.20.00./kg , Gypsum= Tk. 35.00/kg, Zinc= Tk. 320.00 /kg, Calcium silicate = Tk. 15/kg

Labor wage= Tk. 600/day. Two additional man days/ha are required for applying fertilizer, ten man days/ha for per ton additional products including by products

b. Gross, added and net returns in Tk./ha and marginal benefit cost ratio (MBCR)

Treatment	Yield				Total variable cost		Return						MBCR	
	Grain		Straw				Gross		Added		Net			
	GS	SS	GS	SS	GS	SS	GS	SS	GS	SS	GS	SS	GS	SS
T_1: 100% Recommended Fertilizer	6.92	6.94	6.69	7.68	22508.26	23397.86	283940	285180			261432	261782		
T_2: 100% RF + CSF @ 247 kg/ha	6.71	6.81	6.95	8.12	26213.26	28662.86	276210	297820	-8970	12640	249997	269157	-2.09	2.40
T_3: 100% RF + CSF @ 494 kg/ha	6.76	7.09	7.07	8.21	29918.26	33087.86	280790	302410	-4390	17230	250872	269322	-0.43	1.78
T_4: 100% RF + CSF @ 741 kg/ha	6.8	7.45	7.82	8.45	33623.26	41292.86	285950	327550	770	42370	252327	286257	0.18	2.37

GS= Gazipur site, SS= Sonagazi Site, Rice grain price= Tk. 30.00/kg, Rice straw price= Tk. 11.00 /kg

SUB-SUB PROGRAM II: IDENTIFICATION AND MANAGEMENT OF NUTRITIONAL DISORDERS IN RICE

Project 2. Nutritional Problems in Soil

Expt. 19. long-term effect of organic and inorganic nutrients on yield and yield trend of lowland rice

F. Rahman, A.T.M. S. Hossain, M.M. Haque and M.R. Islam

Introduction

The missing element trial is an effective technique for soil fertility status evaluation (Shah et al., 2008). Long-term missing element experiment is also a mirror image for studying rice response behavior under nutrient stress and optimal conditions. Such type of experimentation is valuable in understanding decade-scale transformations in grain yield and soil properties (Bi et al., 2014). Simultaneously, it can be considered as an effective medium where different rice genotypes could be judged for yield response behavior in both nutrient stress and sufficient conditions and well-adapted rice genotypes under these two situations for maximum yield. So, a long-term field experiment is on-going at BRRI, Gazipur farm soil to evaluate changes in soil physical, chemical and biological properties and to determine management options for solution of soil problem(s).

Materials and Methods

The experiment was initiated on a permanent layout at the BRRI farm, Gazipur since 1985 Boro season. Twelve treatments in RCB design with 4 replications were imposed **(Table 27).** From Boro 2000, each plot was sub-divided to include a reverse treatment and additional varieties, BRRI dhan29 and BRRI dhan31 to evaluate the reverse trends of missing elements. In Boro, NPKSZn @ 120-25-35-20-5 kgha^{-1} was used but in T. Aman season it was 100-25-35-20-5 kg ha^{-1}. After 47th crop, the treatments were modified with omission of Zn fertilizer because of its sufficiency in soil. The STB dose of NPKS was 138-10-80-5 kgha^{-1} and 100-10-80-5 kgha^{-1}, respectively. The rate was calculated from complete fertilizer treatment after 47th crop using Fertilizer Guide-2005 (BARC, 2005) with a yield target of 7.5 tha^{-1} and 6.5 tha^{-1} for Boro and T. Aman, respectively. In this STB dose, K fertilizer required more than double of previous K rate. Higher level of available S in control plot compared to initial soil may be due to recent industrial urbanization effect and the resultant S dose was reduced. Urea N was applied in three equal splits at final land preparation, active tillering stage and 5-7 days before PI stage equally. Rests of the fertilizers were applied at final land preparation.

Again, in Boro 2009-10, organic materials were used as third modification in T_5, T_8, T_9 T_{10} and T_{11} treatment. Different sources of organic materials were used in selected treatment such as oil cake (OC, 2 tha^{-1}), saw dust (SD, 3 tha^{-1}), cow dung (CD, 3 tha^{-1}), mixed manure (CD: PM: SD: OC= 1:1:1:0.5) and poultry manure (PM, 2 tha^{-1}) in T_{10}, T_9, T_5, T_{11} and T_8 treatment, respectively. Only N @ 138 kgha^{-1} was applied as top dress in organic source added plots. However, during this modification both missing and reverse management plot were merged and considered as one treatment for making 12 treatments. Again in T. Aman 2011-12, T_9 and T_{10} treatments were changed to add two K doses (60 and 40 kgha^{-1}, respectively). In T. Aman 2011, NPKSZn @ 100-7-80-3-5 kg ha^{-1} and in Boro 2012, it was 138-7-80-3-5 kg ha^{-1}. Different sources of organic materials were used in selected treatment such as CD (3 tha^{-1}), PM (2 tha^{-1}) and VC (2 tha^{-1}) in T_5, T_8 and T_{10} treatment, respectively. The treatment details are provided in Table 1. The STB doses of NPKSZn were 160-12-80-5-2 kg ha^{-1} and 100-10-80-5-1 kg ha^{-1} for Boro and T. Aman, respectively. In T. Aman 2024, the variety was BRRI dhan87 and in Boro 2024-25, it was BRRI dhan92.The crop was harvested at maturity and grain yield was recorded at 14% moisture content and straw yield as oven dry basis. The data were statistically analyzed using STAR software.

Table 27. Treatment details of the long-term missing element experiments, 1985-2025

Treat.	Original (1985)	Reverse (2000)	Treatment (2009-10)	Treatment (2011-24-25 -T. Aman/Boro)
T_1	NPKSZn	All missing	NPKSZn	NPKSZn@160/100-12/10-80-5-2 kg ha^{-1}
T_2	NPSZn (-K)	NSZn (+ K)	NPSZn (-K)	NPSZn (-K)
T_3	NKSZn (-P)	NKSZn (+ P)	NKSZn (-P)	NKSZn (-P)
T_4	PKSZn (-N)	PKSZn (+ N)	PKSZn (-N)	PKSZn (-N)
T_5	NSZn (-PK)	NSZn (+ PK)	CD @ 3.0 t ha^{-1}	CD (3 t ha^{-1}) + IPNS based fert.
T_6	NPKS (-Zn)	NPKS (+ Zn)	NPKS (-Zn)	NPKS (-Zn)
T_7	NPKZn (-S)	NPKZn (+ S)	NPKZn (-S)	NPKZn (-S)
T_8	NPK (-SZn)	NPK (+ SZn)	PM @ 2 t ha^{-1}	PM (2 t ha^{-1}) + IPNS based fert.
T_9	NP (-KSZn)	NP (+ KSZn)	SD @ 3 t ha^{-1}	NPKSZn @ 150/100-12/10-60-5-2 kg ha^{-1}
T_{10}	NK (- PSZn)	NK (+ PSZn)	OC @ 2.0 t ha^{-1}	VC (2t ha^{-1}) + IPNS based fert.
T_{11}	N (-PKSZn)	N (+ PKSZn)	Mixed Manure	NPKSZn@ 160/100-12/10-40-5-1 kg ha^{-1}
T_{12}	All missing	+ NPKSZn	Control	Control (native nutrients)

Results and Discussion

T. Aman 2024

In the T. Aman season, long-term omission of N, P and K significantly decreased rice grain and straw yield compared to complete fertilizer treatment **(Table 28).** The fertilizer control treatment gave the lowest grain yield (3.45 tha^{-1}). Among the applied organic materials, PM+IPNS, CD+ IPNS and VC+ IPNS gave statically similar higher grain yield (5.58 t ha^{-1}), (5.52 t ha^{-1}) and (5.26 t ha^{-1}), respectively, but the result was statistically similar in compared to complete fertilizer (5.34 t ha^{-1}). The omission of S (5.28 t ha^{-1}) and Zn (5.20 t ha^{-1}) also gave statistically similar grain yield compared to full dose of chemical fertilizer. Moreover, more yield penalty was found in reduce K dose i.e. 5.12 tha^{-1} grain yield in 40 kg Kha^{-1} compared with 60 kg kha^{-1} (5.25 tha^{-1}) and full K fertilizer treatment (5.34 tha^{-1} grain yield in K 80 kg ha^{-1}). Similar trend was obtained for tiller, panicle and straw production in different treatment combinations in T. Aman season.

Table 28. Effect of organic and inorganic amendments on growth and yield of BRRIdhan87 in T. Aman 2024 at BRRI HQ, Gazipur

Treatments	T. Aman 2024			
	Tiller (m^{-2})	Panicle (m^{-2})	GY (t ha^{-1})	SY (t ha^{-1})
T_1=NPKSZn@100-10-80-5-1 $kgha^{-1}$	216	202	5.34	5.46
T_2 = NPSZn (-K)	223	195	4.67	5.19
T_3 = NKSZn (-P)	225	199	4.79	5.07
T_4 = PKSZn (-N)	177	153	3.62	3.83
T_5 = CD (3 t ha^{-1}) + IPNS fert.	223	209	5.52	5.83
T_6 = NPKS (-Zn)	215	199	5.20	5.38
T_7 = NPKZn (-S)	217	203	5.28	5.54
T_8 = PM (2 t ha^{-1}) + IPNS fert.	224	208	5.58	5.84
T_9=NPKSZn@100-10-60-5-1 $kgha^{-1}$	220	201	5.25	5.55
T_{10} = VC (2 t ha^{-1}) + IPNS fert.	222	208	5.26	5.40
T_{11}=NPKSZn@100-10-40-5-2 $kgha^{-1}$	205	192	5.12	5.34
T_{12} = Control (native nutrients)	173	156	3.45	3.60
CV (%)	*6.97*	*7.68*	*3.92*	*4.11*
LSD (0.05)	*37*	*37*	*0.48*	*0.53*

Boro 2024-25

In the Boro season, the data revealed that control plot showed the lowest grain yield (2.01 tha^{-1}) where the complete fertilizer treatment gave highest grain yield (6.81 tha^{-1}). Omission of N, P and K nutrient showed significantly reduction in grain yield than complete fertilizer. Although omission of S and Zn showed slightly yield penalty compare to complete fertilizer treatment but the result was statistically insignificant. The highest grain yield declines (2.76 tha^{-1}) was found with omission of N followed by P (4.38 tha^{-1}) and K (4.58 tha^{-1}). Among the IPNS based treatment PM+IPNS fertilizer gave the highest grain yield (7.22 tha^{-1}) followed by CD+IPNS (6.85 tha^{-1}) and VC + IPNS (6.79 tha^{-1}), which was statistical identical with complete fertilizer. Moreover, huge amount of yield difference was found among reduce K doses (T_9: K 60 and T_{11}: K 40 kg ha^{-1}) in compared to complete K dose (T_1: K 80 kg ha^{-1}) **(Table 29).** Similar yield trend was found in tiller, panicle and straw production in Boro season.

Table 29. Effect of organic and inorganic amendments on rice growth and yield of BRRI dhan92 in Boro 2024-25 at BRRI, Gazipur

Treatments	Boro 2024-25			
	Tiller (m^{-2})	Panicle (m^{-2})	GY (t ha^{-1})	SY (t ha^{-1})
T_1 = NPKSZn@160-12-80-5-2 $kgha^{-1}$	311	298	6.81	7.10
T_2 = NPSZn (-K)	310	295	4.58	4.55
T_3 = NKSZn (-P)	242	226	4.38	4.15
T_4 = PKSZn (-N)	149	130	2.76	2.39
T_5 = CD (3 t ha^{-1}) + IPNS fert.	270	258	6.85	6.90
T_6 = NPKS (-Zn)	306	294	6.49	6.30
T_7 = NPKZn (-S)	298	287	6.45	6.54
T_8 = PM (2 t ha^{-1}) + IPNS fert.	208	293	7.22	7.12
T_9 = NPKSZn @140-12-60-5-2 $kgha^{-1}$	313	301	6.65	6.60
T_{10} = VC (2 t ha^{-1}) + IPNS fert.	314	274	6.79	6.69
T_{11} = NPKSZn@140-12-40-5-2 $kgha^{-1}$	309	297	6.55	6.56
T_{12} = Control (native nutrients)	135	126	2.01	1.88
CV (%)	12.31	14.10	6.73	6.22
LSD (0.05)	*83*	*90*	*0.94*	*0.90*

Annual yield trend of IPNS based organic treatments

The annual yield trend of IPNS based treatment compared with complete chemical fertilizer and control treatments were showed in **Fig. 11.** The IPNS based organic matter treatment showed better annual yield achievement than only chemical fertilizer. In all cases, the increasing annual yield trend for replacement and introduced of new modern rice varieties and improve management but a decreasing or stagnating yield trend of fertilizer control treatment due to soil fertility deterioration.

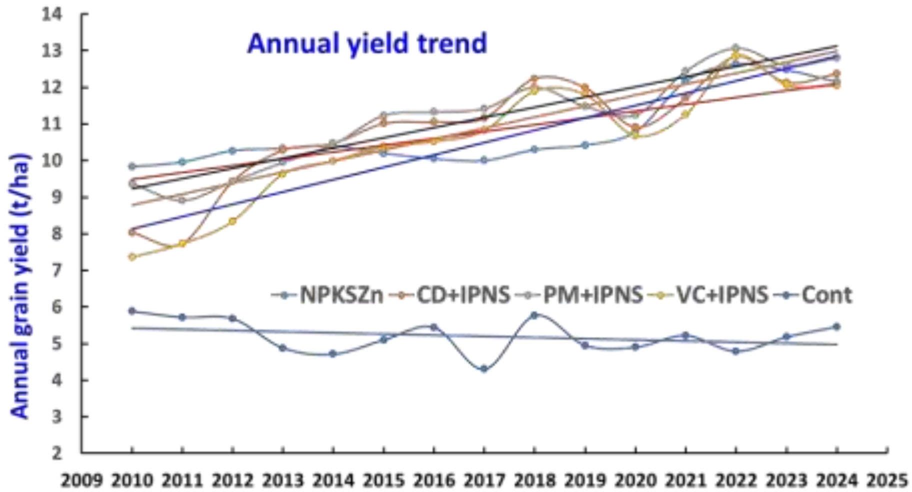

Fig. 11. Annual yield trend of IPNS based treatment compared with complete chemical fertilizer and control treatment, 2023-24, BRRI, Gazipur

Conclusion

Long-term omission of N, P and K adversely affected rice yield in Grey Terrace soil of BRRI farm, Gazipur (AEZ 28, Modhupur Tract) in both T. Aman and Boro seasons. Omission of S and Zn has less or no yield reduction in both seasons. Application of IPNS based chemical and organic fertilizers have great positive impact on sustaining rice yield as well as maintaining soil fertility. So, IPNS based fertilizer management is necessary for sustainable rice production in Bangladesh.

Expt. 20. Long-term Missing Element Trial at Different BRRI Regional Stations

(Funded by PARTNER Project, BRRI)

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Introduction

Long-term missing element experiment is a mirror image for studying rice response behavior under nutrient stress and optimal conditions. The missing element trial is an effective technique for soil fertility status evaluation (Shah et al., 2008). Such type of experimentation is valuable in understanding decade-scale transformations in grain yield and soil properties (Bi et al., 2014). Rational fertilization and management of soil fertility could be one of the most important measures to improve rice productivity and soil quality because inadequacy of five nutrient elements (NPKSZn) in many paddy soils of Bangladesh is responsible for reaping high yields (Shah et al., 2008).Simultaneously, it can be considered as an effective medium where different rice genotypes could be judged for yield response behavior in both nutrient stress and sufficient conditions and well-adapted rice genotypes under these two situations for maximum yield. In general, missing of one nutrient element from complete fertilization reduced grain yield of rice, but it was reversible when missing nutrients were added (Dobermann et al.,2000). Researcher also found that if limiting nutrient is corrected through reverse management in a long-term missing element experiment, rice yields switch back to initial status of complete (NPKSZn) fertilization (Shah et al., 2008). So, the long-term field experiments were set up at different BRRI regional stations to assess the effect of long-term missing of chemical nutrient sources on rice yield and soil properties in rice fallow rice cropping patterns.

Materials and methods

The field experiments were initiated in permanent layout at nine (9) BRRI regional station (RS) farms during Boro, 2024-25 combining seven treatments: T_1= Fertilizer control, T_2= NPKSZn, T_3= PKSZn (-N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn) in RCB design with three replications. Fertilizer dose of Boro season of different regional stations are given in **Table 30.** Fertilizer was applied based on soil test basis (STB). Urea-N was applied into three equal splits at final land preparation, active tillering and 5-7 days before panicle initiation (PI) stage. Rest of the fertilizers were applied at final land preparation as basal. Thirty five to forty days old seedling (2 to 3 per hill) were transplanted at 20cm×20cm spacing in Boro season. Crops were grown under fully irrigated condition. Other management practices were done as and when necessary. At maturity the crops were harvested manually from the center of each treatment plot of 5 m^2 area at 15 to 20 cm above ground level for grain yield; 16 hills from each plot were harvested for straw yield data. Grain yield was recorded at 14% moisture content and straw yield adjusted as oven dry basis. Grain and straw samples were processed properly to measure nutrient content and uptake. Analysis of variance (ANOVA) was performed on yield and nutrient uptake data using the STAR software for Windows Version 2.0.1. Least significant difference (LSD) at the 0.05 level of probability was used to compare means.

Results and Discussion

Table 30. Fertilizer doses of long-term missing element trial at different BRRI regional stations farm, Boro, 2024-25

Regional station	Fertilizer dose (kg/ha) N	P	K	S	Zn
Rangpur	145	10	60	15	2.0
Sonagazi	160	20	80	10	2.0
Habiganj	150	16	80	12	2.0
Sirajganj	160	15	80	15	2.0
Cumilla	143	31	77	13	1.5
Rajshahi	150	20	80	10	2.0
Kushtia	135	20	70	15	2.0
Barishal	150	10	36	15	1.5
Satkhira	174	18	80	18	1.5

Grain yield and limiting nutrient in Boro 2024-25

In the first crop of Boro 2024-25 season and in all locations complete fertilizer (NPKSZn) treatment gave significantly higher yield than omission nutrient plots. The omission of N and P in Boro season from complete fertilizer significantly reduced the grain yield of rice at all BRRI RS farm **(Table 31).** Among the major nutrient elements, the omission of N appeared as the most yield-limiting nutrient followed by P and K omission for rice at all locations in Boro season. Yet the S and Zn omission have less effect on yield reduction at all BRRI RS farm, except Habiganj farm where S and Zn omission had a little effect on grain yield in Boro season.

Conclusion

The omission of N in in Boro season from complete fertilizer significantly reduced the grain yield of rice at all BRRI RS farm. Among the major nutrient elements, omission of N appeared as the most yield limiting nutrient followed by P and K omission for rice in Boro season. Yet the S and Zn omission have less effect on yield reduction at all BRRI regional station farm. Further investigation is going on in T. Aman 2025.

Table 31. Effect of long-term missing element on grain yield at different BRRI RS farm, Boro, 2024-25

Treatment	Rangpur (BRRI dhan89)	Sonagazi (BRRI dhan102)	Habiganj BRRI dhan102)	Sirajganj (BRRI dhan102)	Cumilla (BRRI dhan89)	Rajshahi (BRRI dhan102)	Kushtia (BRRI dhan100)	Barishal (BRRI dhan74)	Satkhira (BRRI dhan74)
T_1 = Control	2.82 d	4.50 c	5.13 d	4.35 c	3.18 b	2.28 e	2.26 b	3.01c	4.25 d
T_2 = NPKSZn	7.38 a	7.48 a	8.39 a	8.57 a	7.12 a	6.02 a	6.20 a	7.19 a	7.55 a
T_3 = PKSZn (-N)	3.05 d	4.84 c	6.18 c	4.94 b	3.50 b	4.36 d	2.32 b	3.31 b	4.85 c
T_4 = NKSZn (-P)	5.75 c	6.61 b	8.32 a	8.35 a	6.97 a	5.39 c	6.10 a	7.11 a	7.22 a
T_5 = NPSZn (-K)	6.94 b	6.80 ab	8.04 ab	8.14 a	6.84 a	5.79 b	6.17 a	7.13 a	6.85 b
T_6 = NPKZn (-S)	7.33 a	6.93 ab	7.73 b	8.49 a	6.79 a	5.43 c	6.02 a	6.76 a	7.13 b
T_7= NPKS (-Zn)	7.23 ab	6.71 ab	7.84 ab	8.38 a	6.79 a	5.80 a	5.99 a	6.97 a	7.25 a
CV%	*2.20*	*5.78*	*2.63*	*2.20*	*2.97*	*4.53*	*5.08*	*5.60*	*5.59*

Expt. 21. Effect of intensive rice cropping on rice yield under continuous wetland condition.

A. Jahan and M. R. Islam

Introduction

Food demand in Bangladesh is increasing but agricultural lands are decreasing day by day due to rapid urbanization. To meet such demand cropping intensity needs to be increased. As plants grow, they absorb nutrients (N, P, K, S, etc.) from the soil. Harvesting crops remove these nutrients from the soil. Unless nutrients are restored through fallow, leguminous crop rotation, or application of organic or inorganic fertilizers, soils eventually show nutrient deficiencies (MEA, 2005). However, flooding also influences physical, chemical and electrochemical properties of soil (De Datta, 1981; Narteh and Sahrawat, 1999). Considering these points, the experiment was designed to harvest three rice crops per year with evaluation of the consequences of intensive rice cropping under continuous wet land conditions and to monitor soil fertility changes over time.

Materials and Methods

The experiment was designed to harvest three rice crops per year with evaluation of the consequences of intensive rice cropping under continuous wet land conditions and to monitor soil fertility changes over time. This experiment was initiated in 1971 in a permanent layout with NPK fertilizer application. Since Boro 2000, the experiment was modified to accommodate six treatments viz. control (native nutrient), reverse control (NPKSZnCu), NPK, NPKS, NPKSZn and NPKSZnCu after several revision in the year of 1982, 1984 and 1991. In Boro 2020-21, the N and K fertilizer were revised again from 140 to 160 and 80 to100 kg ha^{-1}, respectively. The varieties tested in T. Aus, T. Aman and Boro seasons were BRRI dhan48, BRRI dhan87 and BRRI dhan84, respectively. The NPK doses used were 160-25-100, 60-15-80 and 60-10-60 kg ha^{-1} for Boro, T. Aman and T. Aus, respectively. Sulfur, Zn and Cu were applied at 10, 4 and 1 kg ha^{-1} in Boro season only.

Results and Discussion

Grain yield and yield trend

The annual rice production trend from 1981 to 2024 was decreasing because of continuous rice cultivation with no fertilizer application. However, from 2001 the reverse control treatment produced grain yield almost similar to complete fertilized treatment **(Fig.12).** In 2024, annual rice production in control plot was 5.27 t ha^{1}, while its reversed management (addition of NPKSZnCu fertilizer) resulted in 13.05 t $ha^{-1}yr^{-1}$ grain production, which was close to complete fertilizer treatment (14.01 t $ha^{-1}yr^{-1}$). It indicates that complete fertilization can recuperate soil productivity even after a long period of rice cultivation. Results indicated that additional use of Zn and Cu once in a year with NPKS increased annual grain yield by more than about 1.0 t ha^{-1} than the application of NPKS alone.

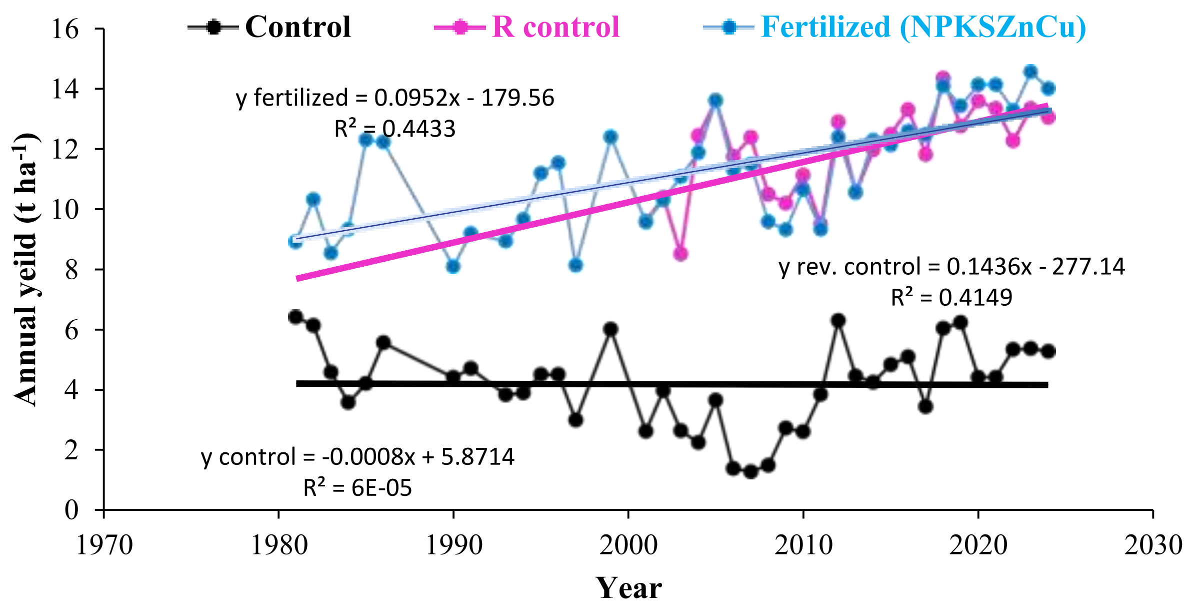


Fig. 12. Annual rice production trend under intensive wetland conditions in BRRI-Gazipur during 1981-2024

Conclusion

Intensive rice cropping with NPKSZn resulted in highest annual yield of rice compared to other fertilizer treatments. On the other hand, when the fertilizer control plot was reversed with complete fertilization after a long time resulted in yield similar to fertilized treatments which indicated that complete fertilization could recuperate soil productivity even after a long period of rice cultivation. Application of Zn and Cu fertilizer showed positive effect on rice yield.

SUB-SUB PROGRAM III: INTEGRATED NUTRIENT MANAGEMENT

Project 3: Integrated Nutrient Management for Intensive Rice Cropping

Expt. 22. Integrated nutrient management for double and triple rice cropping for maximizing productivity

M.M. Haque, M. Iqbal, and M. R. Islam

Introduction

Rice plays a significant role in food security of Bangladesh and its demand is increasing with increasing population. Available data indicate that the fertility of most of our soils has deteriorated over the years (Karim et al., 1994 and Ali et al., 1997), which is responsible for stagnating and in some cases even declining yields (Cassman et al., 1995). Moreover, about 70% of the net cultivable area in high and medium lands has soil organic matter content below 2% (Bhuiyan et al., 1991). This low and declining organic matter content may be one of the main reasons for declining/stagnating productivity of many soils in Bangladesh. Unless the organic matter factor is seriously considered in our cropping systems, we may not achieve the goal of increased and sustained soil productivity. Now, it is the demand of the time to develop an integrated inorganic-organic soil fertilization program for higher crop yield and improved soil health. Besides, the use of organic fertilizer reduces the need of chemical fertilizer. Keeping this view in mind, a field experiment was setup to evaluate the effects of fertilizers and integrated nutrient management under continuous wetland culture for sustainable soil health and productivity.

Materials and Methods

The experiment was initiated in Boro 2008-09 at BRRI farm Gazipur clay loam soil. Initially in double cropping pattern (Boro–Fallow-T. Aman), BRRI dhan29 and BRRI dhan49 and in triple cropping pattern (Boro-T. Aus-T. Aman) BRRI dhan29, BRRI dhan43 and BR22 were used as test variety. In Boro 2020-21, BRRI dhan89 and BRRI dhan96 was included in double and triple cropping pattern respectively. Moreover BRRI dhan87 as a replacement of BRRI dhan49 and BRRI dhan46 in T.Aman 2021, BRRI dhan98 instead of BRRI dhan48 in T.Aus 2021 was included. Four treatment combinations were tested viz. T_1= control, T_2= STB dose (NPKS @ 160-25-60-20 kg ha^{-1} for Boro, 70-12-48-10 kg ha^{-1} for T. Aus and 84-15-54-14 kg ha^{-1} for T. Aman), T_3= STB (50%) + Mixed manure (MM) (cow dung 2 t ha^{-1} + ash 1 t ha^{-1} as oven dry basis), T_4 = Farmers' practice (FP) (NPKS @ 80-10-20-10 kg ha^{-1} for Boro, 70-10-15-0 kg ha^{-1} for T. Aus and 70-10-15-0 kg/ha for T. Aman). The experiment was laid out in a RCB design with three replications.

Results and Discussion

Grain yield

Figures 13 and 14 show the changes of grain yields during 2008-2024 under double and triple cropping systems. Control and farmers practices (FP) showed a decreasing yield trend with the increment of time under both cropping system. However, 100% STB fertilization and 50% STB with mixed manure fertilization showed significantly higher grain yield compare to other treatments during the study period **(Figure 13 and 14).** Soil properties also increased by using mixed manure compared to onlt STB fertilization (Table 32).

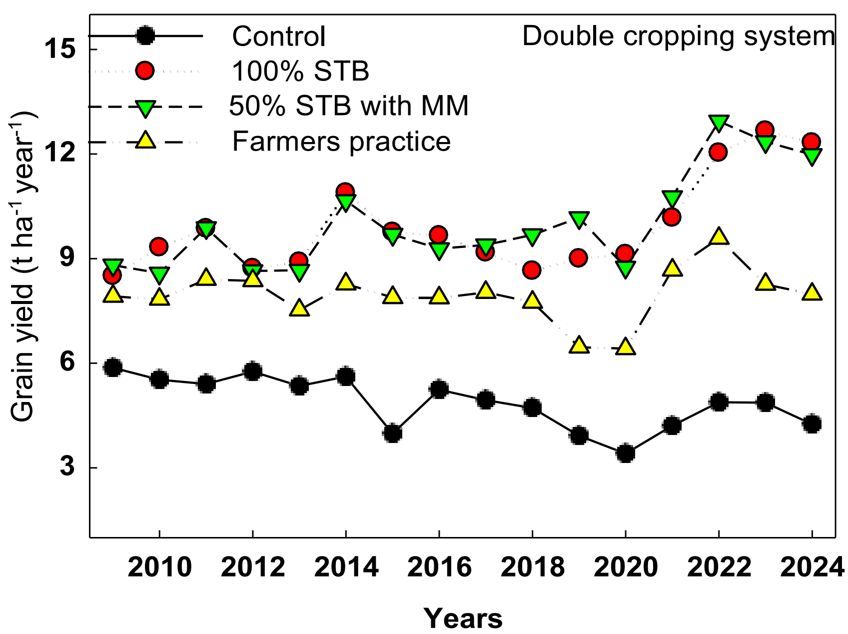


Figure 13. Annual rice production trend under integrated nutrient management for double rice cropping for maximizing productivity during 2009-2024 in BRRI, Gazipur.

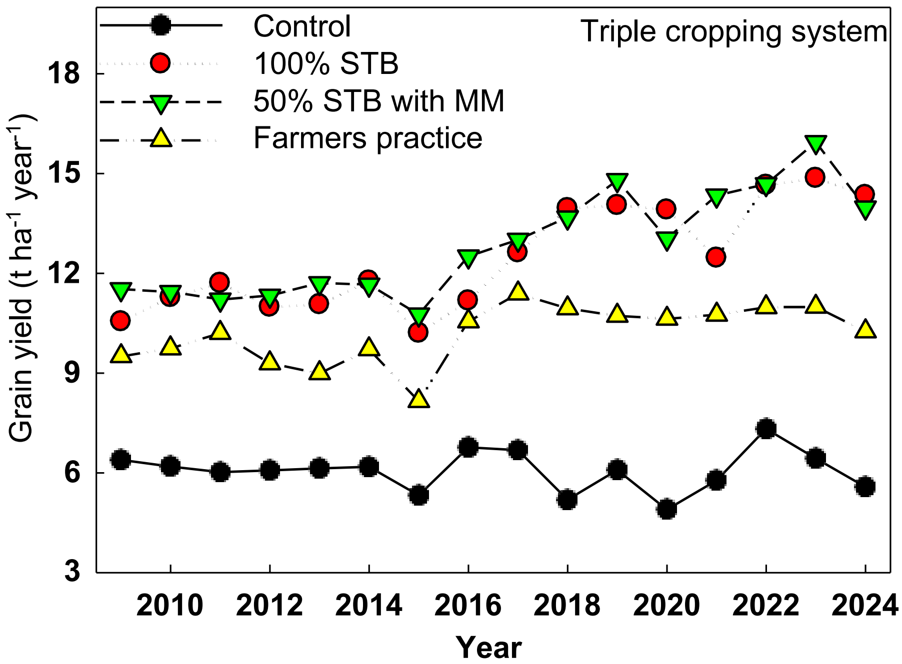


Figure 14. Annual rice production trend under integrated nutrient management for triple rice cropping for maximizing productivity during 2009-2024 in BRRI, Gazipur.

Table 32. Scenario of changes in soil chemical properties after a certain period of time

Soil parameter	Initial status Boro 2008-09	After Boro 2015-16		After Boro 2020-21	
		STB (100%)	STB(50 %)+MM	STB (100%)	STB(50%)+MM
Soil pH (1:2.5)	6.1	7.0	7.1	7.1	7.1
Organic C (%)	1.10	1.11	1.20	1.14	1.25
Total N (%)	0.11	0.11	0.12	0.12	0.12
Available P (ppm)	5.9	5.9	7.4	6.3	9.2
Available K (meq/100g soil)	0.16	0.18	0.18	0.15	0.16
Available S (ppm)	15.3	20.1	17.0	22.5	18.4

Conclusions

Soil test based (STB) and 50% STB + mixed manure (2 t cow dung and 1 t ash ha^{-1}) is one of the good options for sustaining crop productivity and soil health improvement under intensive rice culture.

Expt. 23. Best nutrient management practices: to increase rice productivity and soil health

A.T.M. Sakhawat Hossain, M. Akter, F. Rahman and M. R. Islam

Introduction

Bangladesh is now the door of food self-sufficiency especially for cereal (rice). Now we are looking towards for safe food sufficiency. To achieve the SDGs in agriculture, we need to increase yield as well as maintain soil health for sustainable rice production. To export rice in the ethnic market and to increase farm productivity, we have to produce safe and quality rice. Best Soil Management Practice (BSMP) is obviously a new concept or idea for rice or other crop production in our country. Very recently Bangladesh published the ―Good Agriculture Practice 2020‖ (GAP 2020) Principals with the guidance of BARC and MoA. To achieve the GAP targets we need to follow the BSMP for rice cultivation. In future we like to include the rice crop in GAP protocol for healthy and safe food production for all. That’s why the experiment has been conducted to satisfy the following objectives.

i) To obtain quality and safe rice and

ii) To sustainable increase of rice yield while maintain soil health

Materials and Methods

The experiment was initiated at BRRI farm, Gazipur during Boro 2022-23. The soil of the experimental field was clay loam in texture having pH 6.70. The other nutrient status was as follows: organic carbon 1.15%, total N 0.10%, exchangeable K 0.12 meq/100 g soil, available S 11 mg kg $^{-1}$ and available Zn (DTPA extraction) 1.0 mg kg^{-1}. The experiment was conducted in RCB design with three replications. In 2024-25 the tested rice variety for T. Aman was BRRI dhan90 and in Boro season it was BRRI dhan104. The BRRI dhan90 is a small and finest rice variety with minimum aroma and the BRRI dhan104 rice variety is a good yielded, premium and aromatic rice which we can used for domestic and export purpose. The individual plot size was 4m×5m i.e. 20m^2. Eight different treatments of inorganic and organic combinations calculating the total nutrients from the soil test value (STB) were assigned. The treatments were as follows; T_1: Fertilizer control, T_2: 100% STB dose (fully inorganic), T_3: 125% STB dose (fully inorganic), T_4: 75% STB + CD @ 2 tha^{-1} , T_5: 75% STB + PM @ 1 tha^{-1}, T_6: 50% STB + CD @ 3 tha^{-1}, T_7: 50% STB + PM @ 2 tha^{-1} and T_8: CD @ 3 tha^{-1}+ mustard oil cake @ 2 tha^{-1} (fully organic). The decomposed organic materials such as CD and PM were applied 5 days before transplanting of rice seedlings and incorporated in to the soil nicely. All chemical fertilizers except urea were applied as basal at final land preparation. U rea was applied into three equal splits in with one third as basal, 1st top dressing at 25-30 days after transplanting (DAT) and the rest one on 5 days before panicle initiation (PI) stage. Thirty five days old seedlings of BRRI dhan104 was transplanted maintaining 20 cm x 20cm spacing on the 2 nd week of December and 30 days old seedlings of BRRI dhan90 was transplanted maintaining 15 cm x 20 cm spacing on the 1st week of August . Mustard oil cake was applied in two times of top dress and 1 st one at early tillering (10-15 DAT) and 2nd one at mid-tillering stage and incorporated to the soil in T_8 treatment. Irrigation, weeding and other cultural management practices were done equally as per needed. In Boro 2024-25 we didn’t apply any pesticide to rice field, actually there was no need to apply any pesticide. Because from the beginning or early stage, we made perching and sweeping in the rice field regularly. At maturity the crop was harvested manually in the area of 5 m^2 at 15 cm above ground level, however, 16 hills from each plot were harvested at the ground level for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. Rice plant and rice grain samples were processed properly to measure nutrient content and nutrient uptake. After completing the three rice cycles, post-harvest soil parameters will be analyzed. Analysis of variance (ANOVA) was performed on yield and nutrient uptake data using the STAR software for Windows Version 2.0.1. Least significant difference (LSD) at the 0.05 level of probability was used to compare treatment means.

Results and Discussion

Growth and yield of T. Aman 2024

The growth and yield parameters of BRRI dhan90 have influenced greatly with the application of variable organic sources and rates and inorganic fertilizers **(Table 33).** The grain yield increased significantly with application of different fertilizer combinations over control. The highest grain yield was obtained with T_7 treatment (5.46 tha^{-1}) which was statistically similar with all other treatments except control. All organic and inorganic combinations gave similar result compared to 100% STB dose. The sole use of organic materials i.e. T_8 (3 ton CD and 2 ton mustard oil cake per hectare) also gave comparable grain yield (5.43 tha^{-1}) to chemical fertilizer application. The over use of chemical fertilizer (125% STB) gave cooperatively lower grain yield (5.22 tha^{-1}) than other INM and organic treatments. Similar trend was obtained with tiller, panicle and straw yield production **(Table 33).**

Table 33. Effect of organic and inorganic fertilizer on T. Aman rice (BRRI dhan90) yield and yield contributing characters, BRRI, Gazipur 2024

Treatment	Tiller m^{-2}	Panicle m^{-2}	GY (tha^{-1})	SY (tha^{-1})
T_1: Fertilizer control	262	244	3.37	5.27
T_2: 100% STB dose (inorganic)	372	354	5.17	5.74
T_3: 125% STB dose (inorganic)	375	355	5.22	6.73
T_4: 75% STB + CD @ 2 tha^{-1}	342	328	5.40	5.80
T_5: 75% STB + PM @ 1 tha^{-1}	364	345	5.28	5.78
T_6: 50% STB + CD @ 3 tha^{-1}	352	330	5.29	5.75
T_7: 50% STB + PM @ 2 tha^{-1}	364	349	5.46	5.68
T_8: CD @ 3 tha^{-1}+ Mustard oil cake @ 2 tha^{-1} (organic)	368	350	5.43	5.50
CV (%)	5.55	5.92	3.70	3.00
LSD (0.05)	56	56	0.51	0.49

Growth and yield of Boro 2024-25

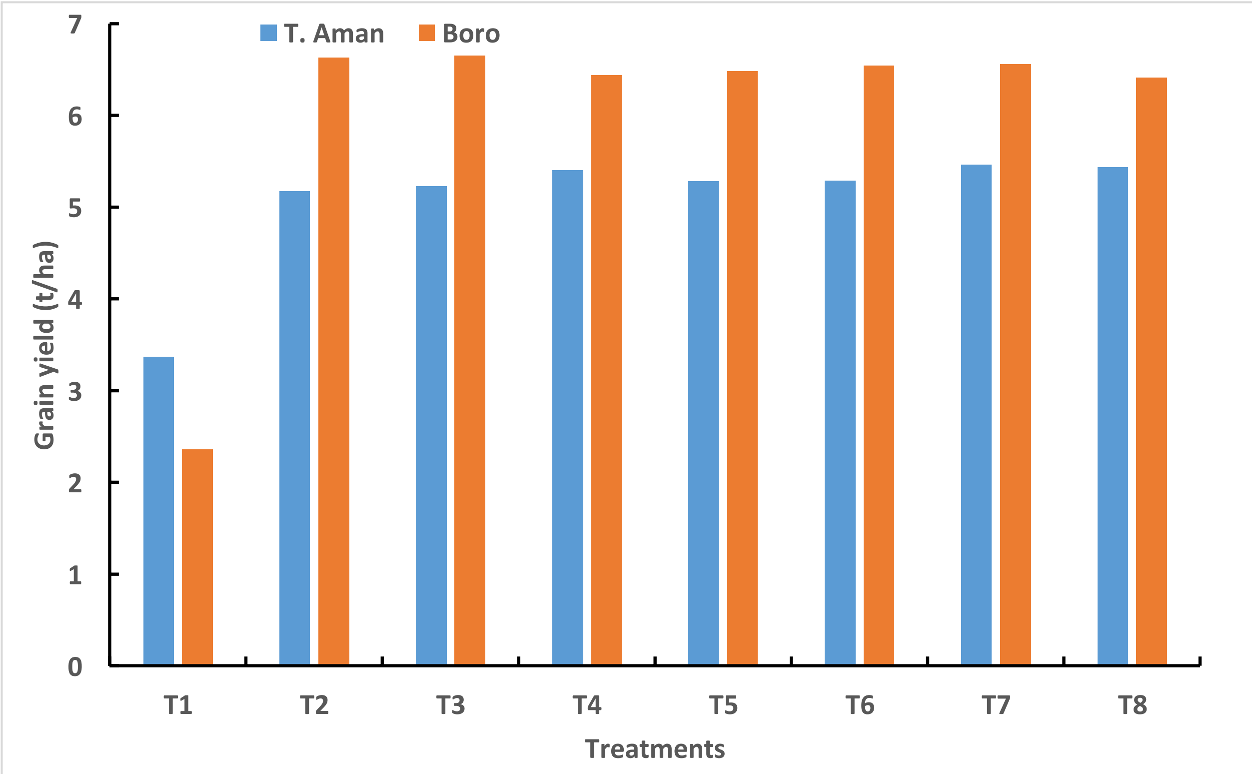
The growth and yield parameters of BRRI dhan104 have influenced significantly with the application of different rates and sources of organic and inorganic fertilizers **(Table 34).** The grain yield increased significantly with application of different fertilizer combinations over control. Although the highest grain yield was obtained with 125% STB dose (6.65 tha^{-1}) which was statistically similar with other organic and inorganic fertilizer treatments. Application of higher doses of chemical fertilizer i.e. T_3 (6.65 tha^{-1}) did not gave significantly higher yield than 100% chemical fertilizer i.e. T_2 (6.63 tha^{-1}). The combinations of organic and inorganic treatments gave statistically similar and satisfactory grain yield compare to chemical fertilizer alone. The fully organic treatment i.e. T_8 (6.41 tha^{-1}) also gave statistically similar grain yield in compared to other INM and chemical fertilizer treatments. Similar trend was obtained with tiller, panicle and straw yield production in Boro season **(Table 34).**

Table 34. Effect of organic and inorganic fertilizer on Boro rice (BRRI dhan104) yield and yield contributing characters, BRRI, Gazipur 2024-25

Treatment	Tiller m^{2-1}	Panicle m^{2-1}	GY (tha^{-1})	SY (tha^{-1})
T_1: Fertilizer control	201	188	2.36	1.92
T_2: 100% STB dose (inorganic)	366	352	6.63	5.96
T_3: 125% STB dose (inorganic)	409	384	6.65	6.15
T_4: 75% STB + CD @ 2 tha^{-1}	348	334	6.44	5.67
T_5: 75% STB + PM @ 1 tha^{-1}	343	329	6.48	5.71
T_6: 50% STB + CD @ 3 tha^{-1}	341	327	6.54	5.58
T_7: 50% STB + PM @ 2 tha^{-1}	344	329	6.56	5.62
T_8: CD @ 3 tha^{-1}+ Mustard oil cake @ 2 tha^{-1} (organic)	350	335	6.41	5.67
CV (%)	5.02	4.97	3.34	12.66
LSD (0.05)	49	46	0.58	1.92

Grain yield in T. Aman and Boro season

A comparative grain yield study of T. Aman and Boro with the application of different chemical, INM and organic fertilizer doses in both seasons was shown in **Fig. 15**. In all cases higher grain yields were obtained with Boro season than T. Aman season. In control plot, T. Aman yield was higher than Boro due to temperature and mineralized effect of native nutrients (Hossain *et. al.,* 2016).



N. B.: T_1: Fertilizer control, T_2: 100% STB dose (inorganic), T_3: 125% STB dose (inorganic), T_4: 75% STB + CD @ 2 tha^{-1}, T_5: 75% STB + PM @ 1 tha^{-1}, T_6: 50% STB + CD @ 3 tha^{-1}, T_7: 50% STB + PM @ 2 tha^{-1}, T_8: CD @ 3 tha^{-1}+ Mustard oil cake @ 2 tha^{-1} (organic)

Fig. 15. Effect of different organic and inorganic fertilizer combinations on T. Aman (BRRI dhan90) and Boro rice (BRRI dhan50) yield in 2024-25, BRRI, Gazipur

Conclusion

Best soil and nutrient management practices is now the time demanding option for producing healthy and satisfactory yield for sustainable rice production. It helps to achieve the higher yield as well as maintain soil health for rice farmers in Bangladesh. INM combinations using PM and CD with 25-50% reduced doses of chemical fertilizers can produce satisfactory rice yield. It can save chemical fertilizers cost in a significant amount and may minimize the environmental pollution in both soil, water and air with judicial use or less use of chemical fertilizer.

Expt.24. Integrated Nutrient Management for Fine and Fragrant Rice in North-western part of Bangladesh

A.T.M. Sakhawat Hossain, Fahmida Rahman and M. Rafiqul Islam

Introduction

Rice (*Oryza sativa* L.) is the most important cereal food grain crop and is consumed by the majority of the world's human population. Among all cultivars, fragrant/aromatic rice is preferred by the better part of the human population because of its aroma, taste and cooking quality. But most of the fragrant rice varieties are low yielding and easily sensitive to the surrounding environmental condition. Among different cultural or agronomic performances, proper nutrient management can improve the yield of fragrant rice not only by giving the required amount of nutrients but also by maintaining the health of the soil and the quality of the produce (BRRI Annual Res. Report 2020 and Newton et al., 2021). In most cases, traditional agricultural practices degraded soil health and increased environmental pollution which leads to inferior grain quality. On the other hand, excessive application of chemical fertilizers reduced the nutrient status of the soil and badly affected the soil productivity and environmental stability. Therefore, a suitable approach of nutrient management is required to keep the production of fragrant rice to a notable amount and increase the nutrient use efficiency of soil. Application of manures and fertilizers in an appropriate dose which is the main object of nutrient management is required for its utmost importance in the growth and development of the crop that finally results in better yield and grain quality. So, nutrient management is an important aspect in aromatic rice production to attain sustainable grain yield and high economic return with better quality of produce. Therefore, the following objectives were chose to achieve the target.

- To observe the reduction of grain yield and quality of fine rice
- To develop an integrated fertilizer management package for increase the yield of fine-aromatic rice and
- To improve or maintain the grain qualities through proper fertilizations

Materials and Methods

The north-western part of Bangladesh is the hot spot of growing best quality fine and aromatic rice especially in Dinajpur district**.** Field experiments were conducted in rice fallow rice cropping pattern at five farmer's field in different villages of Sadar upazilla, Dinajpur in Boro 2024-25 to find out the optimum fertilizer doses of fine aromatic rice for sustaining rice productivity. Four fertilizer treatment combinations viz. T_1: Fertilizer control (except urea), T_2: 100% STB chemical fertilizer, T_3: 50% STB chemical fertilizer + Cowdung (CD) @ 2 tha^{-1}, and T_4: 75% STB chemical fertilizer + CD @ 1 tha^{-1} were evaluated in split plot design with 5 replications. Each farmer field was considered as one replication. Initial soil physico-chemical properties were shown in **Table 35.** BRRI released two latest fine aromatic rice varieties viz. BRRI dhan104 and BRRI dhan107 were tested in Boro season. Other cultural management practices were done uniformly for all farmers' case. Data were generated for yield and grain quality. Decomposed organic matters were applied at 5 days before rice transplantation. Potassium, phosphorus, sulfur and zinc fertilizers were applied at final land preparation as basal. Nitrogen (urea) was applied in three equal splits; at basal, in 15-20 days after transplanting (DAT) and the rest at 5-7 days before panicle initiation (PI) stage. Thirty five day old seedlings (2-3 per hill) were transplanted at 20 cm×20 cm spacing in Boro season. Crops were grown under fully irrigated condition. At maturity the crops were harvested manually from the center of each plot of 5 m^2 area at 15 to 20 cm above ground level for grain yield; 16 hills from each plot were harvested for straw yield data. Grain yield was recorded at 14% moisture content and straw yield adjusted as oven dry basis. Plant height, leaf samples at panicle initiation (PI) stage, tiller and panicle number per meter square, 1000 grain weight were also taken. Plant samples, grain and straw samples were processed properly to measure different nutrient content and uptake. Related grain quality were also analyzed in Grain Quality and Nutrition division's laboratory, BRRI. Analysis of variance (ANOVA) was performed on yield and nutrient uptake data using the STAR software for Windows Version 2.0.1. Least significant difference (LSD) at the 0.05 level of probability was used to compare means.

Table 35. Initial soil properties of five farmers field at Sadar Upazilla, Dinajpur in Boro 2024-45

SN.	Farmer's Name	Soil Texture	Soil pH	OM (%)	TN (%)	Ava. P (mg/kg)	Exch. K (meq/100)	Ava. S (mg/kg)	Ava. Zn (mg/kg)
1	Abdul Bari	Silty Clay	6.63 (±0.055)	2.11 (±0.065)	0.106 (±0.003)	25.53 (±2.06)	0.097 (±0.003)	15.33 (±1.96)	1.098 (±0.100)
2	Abu Syed	Silty Clay	6.85 (±0.087)	1.55 (±0.125)	0.078 (±0.006)	18.17 (±1.45)	0.092 (±0.003)	12.45 (±1.77)	0.849 (±0.095)
3	Roton Roy	Silty Clay	5.97 (±0.110)	1.38 (±0.055)	0.069 (±0.003)	14.22 (±1.58)	0.054 (±0.004)	11.25 (±1.96)	0.744 (±0.074)
4	Jogot Mohon	Silty Clay	5.48 (±0.070)	1.92 (±0.060)	0.096 (±0.003)	21.47 (±2.86)	0.085 (±0.004)	14.44 (±1.12)	0.951 (±0.031)
5	Faridul Islam	Silty Clay	6.82 (±0.055)	1.71 (±0.070)	0.086 (±0.004)	20.12 (±2.01)	0.076 (±0.004)	13.29 (±1.96)	0.868 (±0.029)

Results and Discussion

Plant height, tiller and panicle production in Boro 2024-25

Application of chemical fertilizer as 100% STB or INM practices have significantly increased the plant height, tiller and panicle number per meter square over control treatment in both BRRI dhan104 and BRRI dhan107 rice varieties in Boro season **(Table 36).** Significantly higher plant height was observed in INM treatments than 100% STB treatment in both varieties. Similar trend was observed in case of tiller and panicle production for both rice varieties in Boro season.

Table 36. Effect of INM on plant height, tiller and panicle production of fine and aromatic Boro rice at Sadar upazilla, Dinajpur in Boro 2024-25

Treatment	Plant height (cm)		Tiller no. m^{-2}		Panicle no. m^{-2}	
	BRRI dhan104	BRRI dhan107	BRRI dhan104	BRRI dhan107	BRRI dhan104	BRRI dhan107
T_1	100.66	101.90	307	313	285	289
T_2	103.90	104.74	387	334	357	301
T_3	105.54	105.34	356	402	321	375
T_4	105.74	106.14	354	384	323	362
Treat.	3.76		6.17		6.54	
Var.	4.31		10.91		10.78	
T x V	NS		NS		NS	
LSD 0.05)	1.06		21		38	

N.B.: T1 = Fertilizer control (except N), T2: 100% STB fertilizer, T3= 50% STB fert. + 2 ton CD/ha and T4= 75% STB fert. + 1 ton CD/ha.

Grain and straw yield in Boro 2024-25

The grain and straw yield of BRRI dhan104 and BRRI dhan107 increased greatly with application of sole chemical fertilizer or integrated use of organic and inorganic fertilizer in Boro season **(Table 37).** The control plot yielded only 5.38 (BRRI dhan104) and 5.63 (BRRI dhan107) tha^{-1} and the application of 100% STB chemical fertilizer or the INM practices, the grain yield increased significantly. Although STB chemical fertilizer gave the highest yield but within the fertilizer treatment plots, increment of grain yield was insignificant **(Table 37).** Here both the rice variety gave similar grain yield with organic and inorganic fertilization. Similar trend was observed in straw yield production.

Table 37. Effect of INM on grain and straw yield of fine and aromatic Boro rice at Sadar upazilla Dinajpur in Boro 2024-25

Treatment	Grain yield (tha^{-1})		Straw yield (tha^{-1})	
	BRRI dhan104	BRRI dhan107	BRRI dhan104	BRRI dhan107
T_1	5.38	5.63	5.90	5.75
T_2	7.66	7.45	7.75	7.36
T_3	7.39	7.35	7.52	7.54
T_4	7.47	7.39	7.60	7.52
Treat.	3.33		5.67	
Var.	5.02		6.75	
T x V	NS		NS	
LSD (0.05)	0.23		0.39	

N.B .: T1 = Fertilizer control (except N), T2: 100% STB fertilizer, T3= 50% STB fert. + 2 ton CD/ha and T4= 75% STB fert. + 1 ton CD/ha.

Comparison of two varieties grain yield in Boro 2024-25

Integrated nutrient management with CD @ 2 or 1 ton per hectare and 50 or 75% STB chemical fertilizer, respectively can gave comparable grain yield with 100% STB chemical fertilizer in both rice varieties (BRRI dhan104 and BRRI dhan107) **(Fig.16).**

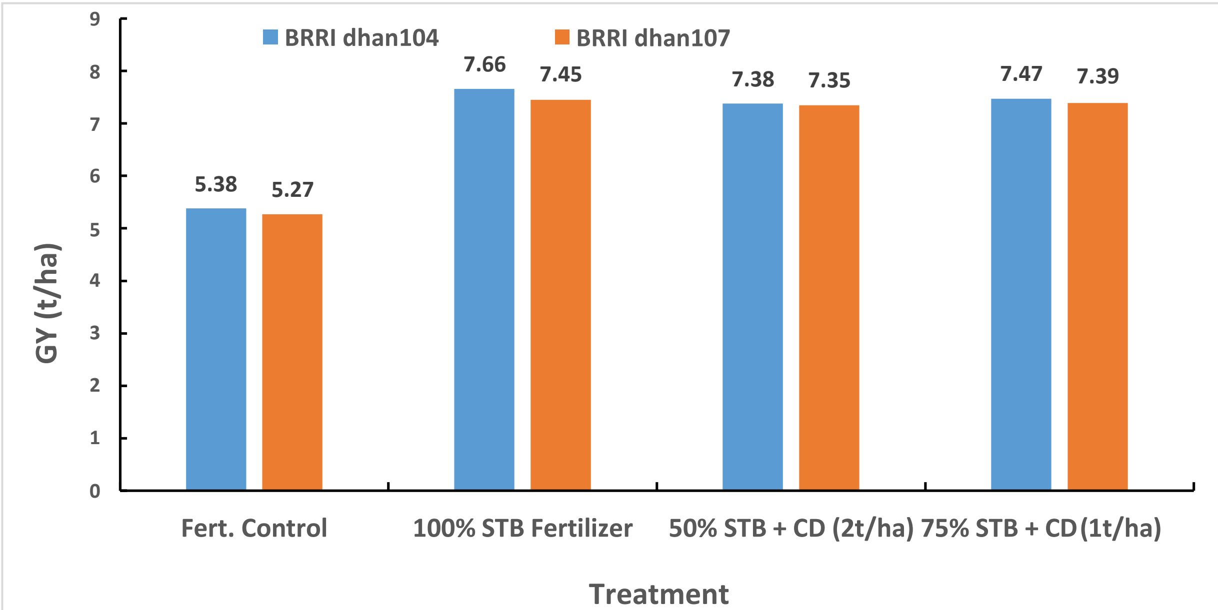


Fig.16. Effect of INM on grain yield of fine and aromatic Boro rice at Sadar upazilla, Dinajpur in Boro 2024-25.

Conclusion

Integrated nutrient management has great impact on increasing rice yield of fine and aromatic rice in north–western part of Bangladesh. Both the rice varieties BRRI dhan104 and BRRI dhan107 gave satisfactory yield with application of reduce doses (25-50%) of chemical fertilizer with 1-2 ton cowdung per hectare. Which may increase the quality of grain (analysis is going on) as well as maintain soil health. Around 25-30% yield increase was observed with INM practices over fertilizer control and similar yield was obtained in comparison with 100% chemical fertilizer in both varieties. The findings may reduce the production cost with saving the excess fertilizer cost. The research work in T. Aman season is going on.

Expt.25. Potassium Fertilizer Management in Rice based Cropping Pattern in Old Himalayan Piedmont Soil of Bangladesh

A.T.M. Sakhawat Hossain, Fahmida Rahman and M. Rafiqul Islam

Introduction

Potassium (K) is an essential and major nutrient for rice and around 20-21 kg K is needed for per ton rice production. The Old Himalayan Piedmont soil (AEZ-1) is inherently deficient in K, low soil pH, light soil texture and low in soil organic matter. Potassium mining increased day by day due to increased cropping intensity and poor K management in AEZ 1 (Saleque *et al.*, 2003). Crop response to added K is high in rice-wheat cropping pattern in AEZ 1 (Saleque *et al.*, 2004). Rice straw (RS) incorporation or RS + inorganic K fertilizer together increased crop yield and K balance in rice wheat cropping pattern (Saha *et al.*, 2008). Less attention has been given for the north-western part of Bangladesh especially for K management. Balanced fertilization especially K helps to obtain the SDG target of food security in Bangladesh. Considering these, the field experiments in farmer's condition were undertaken to achieve the following objectives.

- To identify the K deficiency in soil and plant in those area
- To determine the K contribution for rice crop
- To increase rice yield in the respective cropping pattern and
- To maintain soil fertility especially for K

Materials and Methods

Intrusion of HYVs and increasing cropping intensity increases the K deficiency in those areas. Field experiments were conducted at five farmer's field in AEZ 1 of Birganj upazilla, Dinajpur in Boro 2024-25 to find out the optimum potash fertilizer doses of HYV rice for sustaining rice productivity. Four fertilizer treatment combinations viz. T_1: K fertilizer control, T_2: 100% STB K fertilizer, T_3: 50% STB K fertilizer + 50% K from rice straw, and T_4: 50% STB K fertilizer + 50% K from rice husk ash were evaluated in split plot design with 5 replications. Each farmer field was considered as one replication. The initial soil properties were shown in **Table 38.** BRRI released two latest HYV rice varieties for Boro season viz. BRRI dhan102 and BRRI dhan105 were evaluated as test variety. Other cultural management practices were done uniformly for all farmers field. Rice straw was chopped and applied at 7 days before rice transplanting. Phosphorus, sulfur and zinc fertilizers were applied at final land preparation as basal. Two-third K and full dose of rice straw and rice husk ash were applied before transplanting. Nitrogen (urea) was applied in three equal splits; at basal, in 25 days after transplanting (DAT) and the rest at 5 days before panicle initiation (PI) stage. Thirty five days old seedlings (2-3 per hill) were transplanted at 20 cm×20 cm spacing in Boro season. Crops were grown under fully irrigated condition. At maturity the crops were harvested manually from the center of each plot of 5 m^2 area at 15 to 20 cm above ground level for grain yield; 16 hills from each plot were harvested for straw yield data. Grain yield was recorded at 14% moisture content and straw yield adjusted as oven dry basis. Plant height, leaf samples at panicle initiation (PI) stage, tiller and panicle number per meter square, 1000 grain weight were also taken. Plant samples, grain and straw samples were processed properly to measure different nutrient content and uptake. Analysis of variance (ANOVA) was performed on yield and nutrient uptake data using the STAR software for Windows Version 2.0.1. Least significant difference (LSD) at the 0.05 level of probability was used to compare means.

Table 38. Initial soil properties of five farmers field at Birganj Upazilla, Dinajpur in Boro 2024-45

S.N.	Farmer's Name	Soil Texture	Soil pH	OM (%)	TN (%)	Ava. P (mg/kg)	Exch. K (meq/100)	Ava. S (mg/kg)	Ava. Zn (mg/kg)
1	Tofazzal Hossain	Loam	5.61 (±0.145)	2.61 (±0.145)	0.112 (±0.023)	20.943 (±1.70)	0.055 (±0.004)	7.127 (±0.701)	0.840 (±0.105)
2	Joyontu Roy	Loam	5.55 (±0.140)	2.62 (±0.131)	0.133 (±0.025)	12.647 (±1.76)	0.056 (±0.007)	8.483 (±0.751)	0.750 (±0.130)
3	Liton Hossain	Loam	5.72 (±0.125)	2.56 (±0.125)	0.134 (±0.008)	14.333 (±1.92)	0.043 (±0.006)	7.317 (±0.607)	0.720 (±0.105)
4	Ali Hossain	Loam	5.59 (±0.135)	2.64 (±0.110)	0.131 (±0.007)	16.173 (±1.41)	0.066 (±0.006)	7.867 (±0.455)	0.770 (±0.121)
5	Jamir Ali	Loam	5.53 (±0.130)	2.77 (±0.092)	0.145 (±0.015)	18.287 (±1.73)	0.059 (±0.008)	9.217 (±0.819)	0.730 (±0.080)

Results and Discussion

Plant height, tiller and panicle production of Boro 2024-25

Application of K fertilizer as 100% STB K or integrated K practices have significantly increased the plant height, tiller and panicle number per meter square over K control treatment in both BRRI dhan102 and BRRI dhan105 rice varieties in Boro season of AEZ 1 **(Table 39).** Significantly higher plant height was observed in RS or rice husk or chemical K treatment than K control treatment in both varieties. Similar trend was observed in case of tiller and panicle production for both rice varieties in Boro season.

Table 39. Effect of different sources of potash fertilizer on plant height, tiller and panicle production of HYV Boro rice at Birganj upazilla, Dinajpur in Boro 2024-25

Treatment	Plant height (cm)		Tiller no. m^{-2}		Panicle no. m^{-2}	
	BRRI dhan102	BRRI dhan105	BRRI dhan102	BRRI dhan105	BRRI dhan102	BRRI dhan105
T_1	101.34	103.30	222	234	205	216
T_2	105.10	107.42	284	273	268	258
T_3	106.08	107.68	278	269	262	250
T_4	106.24	108.06	274	268	260	252
Treat.	1.11		9.41		9.49	
Var.	0.85		9.39		9.59	
T X V	NS		NS		NS	
LSD (0.05)	1.14		24		23	

N.B.: T1= K control, T2= 100% STB K, T3= 50% STB K + % K from RS, T4= 50% STB K + 50% K from rice husk ash.

Grain and straw yield of Boro 2024-25

The grain and straw yield of BRRI dhan102 and BRRI dhan107 increased greatly with application of sole chemical K fertilizer or integrated use of organic and inorganic K fertilizer in Boro season **(Table 40).** The control plot yielded only 6.46 (BRRI dhan102) and 6.38 (BRRI dhan105) tha^{-1} and the application of 100% STB K chemical fertilizer or the INM K practices, the grain yield increased significantly. The STB chemical K fertilizer did not shown any yield benefit than integrated application of RS or ash with chemical K treatment **(Table 40).** Here BRRI dhan102 gave comparatively higher grain yield than BRRI dhan105 with organic and inorganic K fertilization. Similar trend was observed in straw yield production.

Table 40. Effect of different sources of potash fertilizer on grain and straw yield of HYV Boro rice at Birganj upazilla, Dinajpur in Boro 2024-25

Treatment	**Grain yield (tha^{-1})**		**Straw yield (tha^{-1})**	
	BRRI dhan102	BRRI dhan105	BRRI dhan102	BRRI dhan105
T_1	6.46	6.38	6.58	6.56
T_2	8.69	8.28	8.84	8.46
T_3	8.74	8.19	8.90	8.37
T_4	8.68	8.09	8.86	8.30
Treat.	3.01		3.02	
Var.	2.45		2.51	
T X V	NS		NS	
LSD (0.05)	0.28		0.27	

N.B .: T1= K control, T2= 100% STB K, T3= 50% STB K + % K from RS, T4= 50% STB K + 50% K from rice husk ash.

Grain yield comparison of two rice varieties in Boro 2024-25

Potash fertilizer management in Old Himalayan Piedmont Soil of AEZ-1 significantly increase the grain yield of both Boro varieties compared to K control treatment **(Fig.17).** Comparable yield obtained with application of 100% chemical K fertilizer and the integrated use of chemical K with rice straw or ash applied treatments.

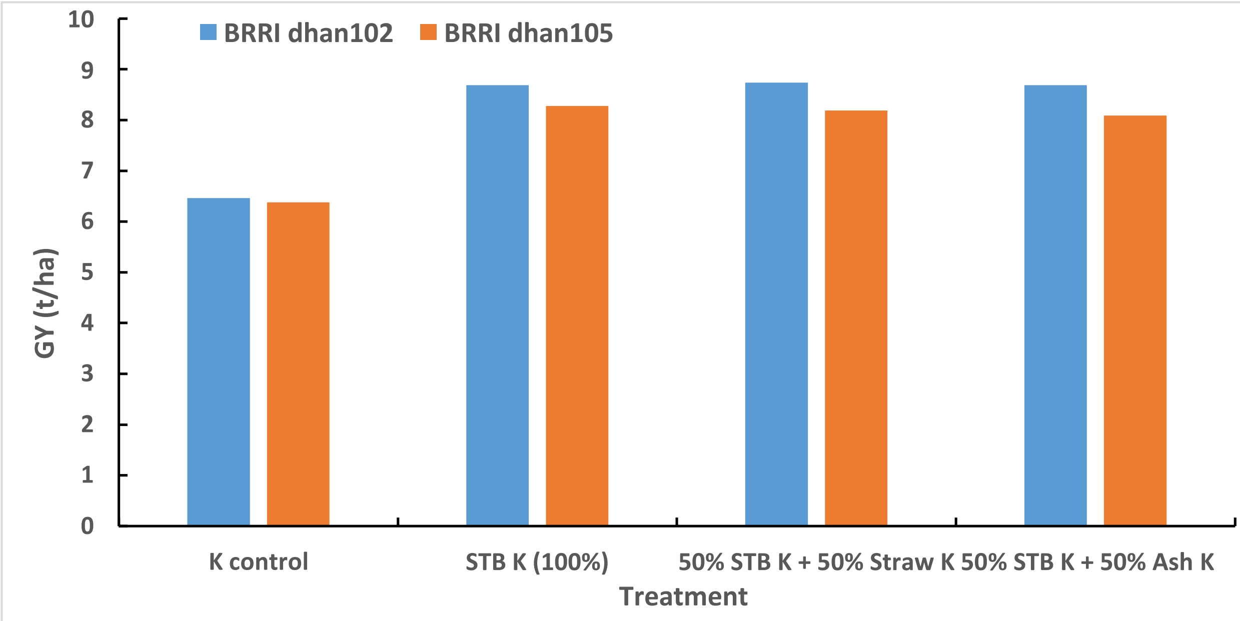


Fig.17. Effect of different sources of K fertilizer on grain yield of HYV Boro rice at Birganj upazilla, Dinajpur in Boro 2024-25

Conclusion

Application of soil test based K as chemical fertilizer or integrated use of chemical K plus rice straw or rice husk ash have remarkable effect on increasing grain yield of both varieties in old Himalayan Piedmont soil of AEZ 1. On an average 30% yield increase observed in application of K fertilizer over K control in for both rice varieties in Boro season. The research work on K fertilization in T. Aman season 2025 in AEZ 1 is going on.

SUB-SUB PROGRAM IV: SOIL MICRONUTRIENTS, HEAVY METALS AND ENVIRONMENTAL PROBLEMS

Project 04: Problem soil management and greenhouse gas emission

Expt. 26. Effectivity of Chitosan to Mitigate Salinity of Rice Cultivation in the Coastal Ecosystem of Bangladesh

T. Islam, U. A. Naher, M. R. Islam

Introduction

Bangladesh's coastal zone faces chronic soil and water salinity that depresses rice growth and nutrient availability. Chitosan (CTS) is a de-acetylated chitin biopolymer has emerged as a low-risk plant bio stimulant that enhances antioxidant defenses, ion homeostasis and water relations under salt stress (Song *et al.,* 2023). In rice and other crops, CTS or CTS-nanomaterials often improve biomass, photosynthesis, antioxidant capacity and ionic balance under NaCl stress. Different studies in rice and other species (e.g., tomato, rosemary, hibiscus) consistently show improved chlorophyll, lower lipid peroxidation and better Na^+ exclusion and K^+ retention under salinity after CTS application (Stefanello *et al.,* 2024). So, this investigation was conducted to mitigate the adverse salinity effects in rice cultivation by identifying an effective CTS rate (with RFD) that improves early nutrient dynamics in saline soil.

Materials and Methods

We conducted a controlled incubation (completely randomized design with four replications at 28 °C) study to screen six treatments: T_1 = Recommended Fertilizer Dose (RFD); T_2 = RFD + 25 mg CTS; T_3 = RFD + 50 mg CTS; T_4 = RFD + 75 mg CTS; T_5 = RFD + 100 mg CTS; T_6 = Control (no inputs).

Soil was collected from BRRI, Satkhira to set this incubation study and samplings were done from initial stage, at day 1, day 3, day 7, day 14, day 21 and day 35 of incubation period. Total N (%), Available P (ppm), Exchangeable K (meq/100 g soil) was analyzed using standard Kjeldahl, Olsen and Ammonium Acetate methods, respectively of initial soil to day 3 soil samples.

Results and Discussion

A line graph **(Fig. 18.)** was constructed to visualize the relative changes in total nitrogen (%), available phosphorus (ppm) and exchangeable potassium (meq/100 g soil) across six treatments at three incubation stages: Initial Soil, Day 1 and Day 3.

At the initial soil stage, notable variability was observed among treatments, with T_6 exhibiting the highest relative nitrogen content, while T_2 showed elevated potassium levels. Available phosphorus was relatively low across most treatments at this stage, except for T_5 and T_6 which exhibited comparatively higher P availability.

By day 1, phosphorus availability markedly increased across all treatments, forming the dominant axis of nutrient availability. Treatments T_2 and T_6 consistently showed higher values across the three nutrients, indicating an early nutrient release effect. Potassium levels were moderately stable, with slight increases in T_3 and T_6 compared to their initial values.

At day 3, distinct nutrient partitioning was evident. Phosphorus availability stabilized across treatments but remained the major nutrient fraction. Nitrogen levels showed a general upward trend in T_1, T_2, T_4 and T_5 with T_2 recording the highest nitrogen accumulation. Conversely, potassium dynamics shifted with T_3 and T_4 reaching peak values while T_2 declined compared to earlier stages.

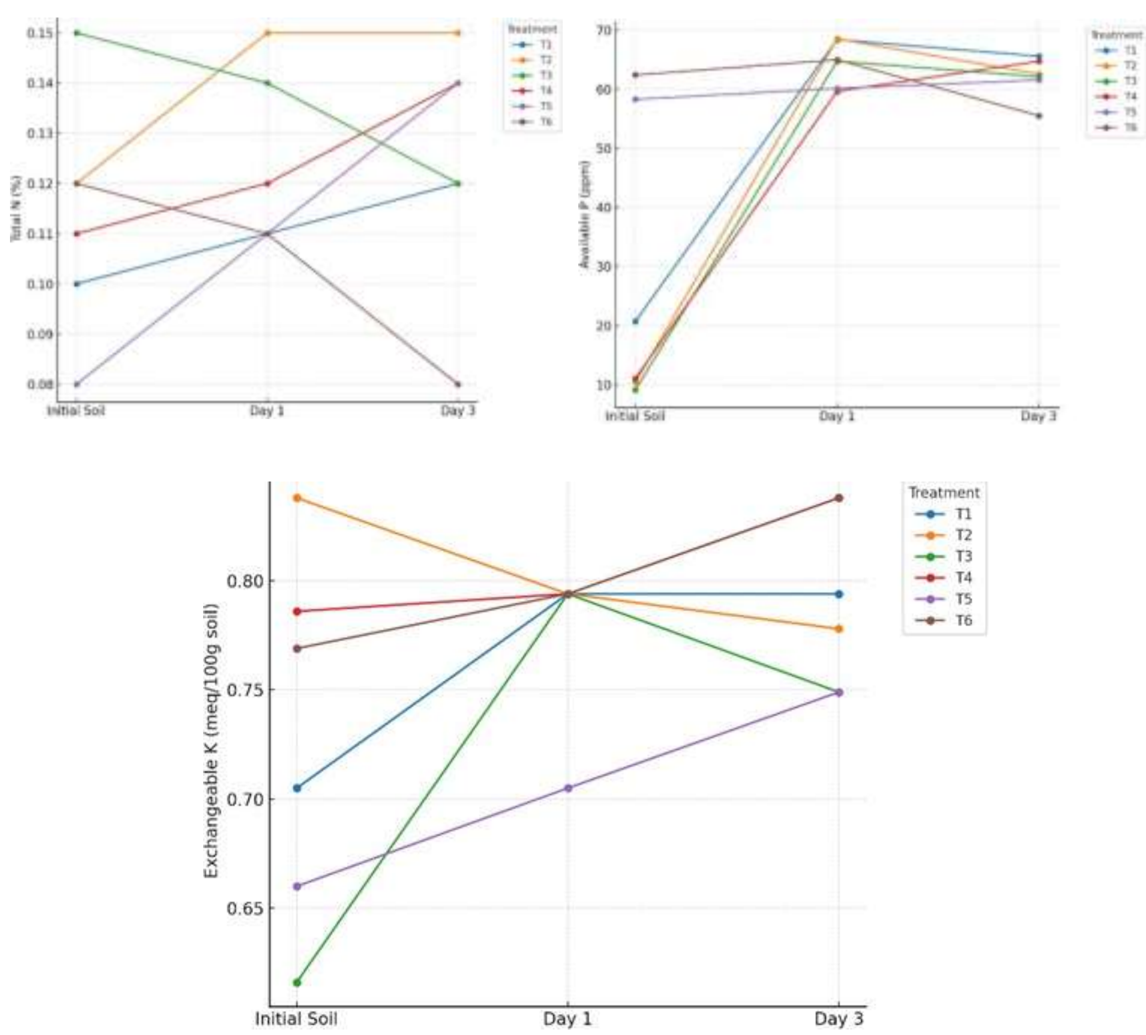


Fig. 18. Effects of Chitosan in nutrient availability at different incubation periods.

Conclusion

Overall, the study highlights the temporal nutrient release patterns of the treatments. T_2 emerged as the most balanced treatment with consistently higher N and P availability, whereas T_6 demonstrated early nutrient release followed by a decline. From a coastal Bangladesh perspective, a low-dose CTS + RFD (T_2) treatment is attractive with phosphorus showing the greatest variability relative to nitrogen and potassium. Since the findings are from initial soil to day 3 soil samples, it could be continued to perform analysis of other incubated samples to draw the conclusive results.

Expt. 27. Effect of water management on mitigating of greenhouse gas emission at Gazipur and kushtia

M. M. Haque and M. R. Islam

Introduction

Soil moisture content plays an important role in controlling the release and consumption of GHGs. Frequent irrigation increases plant biomass and soil microbial activity lead to increases in CO_2 and N_2O emissions compared to rainfed or non-irrigated soils. This is because increased soil water content accelerates microbial respiration of soil organic matter, which enhances CO_2 flux. Alternate wetting and drying (AWD) irrigation in irrigated rice (Boro rice) cultivation reduced emission factor of CH_4 (22–36%) but increased water productivity by 25–27% compared to continuous flooding (CF) method along with 14–43% reduction in GHG intensity (Haque et al., 2021). Methane emission flux showed the increasing trend after transplanting and reached its peak at 35-40 DAT following AWD irrigation (Haque et al., 2021). However, irrigation suspension during the Boro and T. Aman season may lessen the peak emission as well as total global warming potential without sacrificing grain yield. Thus, the study was undertaken to find out the suitable water management options based on GHG emission, global warming potential and sustainable rice production.

Materials and Methods

The study was undertaken to find out the suitable water management options based on GHG emission and sustainable rice production. The study was conducted in Bangladesh Rice Research Institute farm, Gazipur during and farmer’s field at Kushtia during Boro, 2025. The experimental each plot size was 4 m x 5 m with four replication in a randomized block design. Thirty five day old (BRRI dhan92) seedlings was transplanted at 20 cm x 20 cm spacing during Boro season. In Boro season, the experiment was carried out with three irrigation management treatments as T_1 = Continuous standing water (CSW), T_2 = AWD (Supplemental irrigation when water level goes 15 cm below ground surface), T_3 =AWD (Supplemental irrigation when water level goes 25 cm below ground surface). The amount of applied irrigation was measured with a flow meter and was documented. The recommended chemical fertilizer rates were 138-10-80-5-5 kg ha^{-1} as N from urea, P from triple super phosphate, K from muriate of potash, S form gypsum and Zn from zinc sulphate for the both locations.

Gas sampling and analysis

Carbon dioxide, methane, and nitrous oxide emissions were measure by using static chamber methods during Boro rice cultivation (Haque et al., 2013, 2020). Transparent glass chambers (0.62m x 0.62 m and height 1.12 m) were placed permanently in the plots after rice transplanting for N_2O and CH_4 gas collection. There were 2 holes at the bottom of a chamber for maintaining 5-7 cm water level above soil surface. Each chamber enclosed 9 hills. However, another smaller close chambers (20 cm x 50 cm) were placed in between rice plants for measuring CO_2 emission rates (Lou et al., 2004; Xiao et al., 2005; Iqbal et al., 2008; Haque et al., 2015b). All chambers were equipped with a circulating fan for gas mixing and a thermometer to record inside temperature. Chambers remained open all the time except during gas sampling.

Gas samples were collected in 50 ml air-tight syringes at 0 and 30 min after closing the chamber. Gas samplings were drawn off from the chamber headspace equipped with 3-way stop cock at 8:00–12:00–16:00 hours in a day from each treatment. Collected gas samples were transferred into 20-ml air-evacuated glass vials sealed with a butyl rubber septum for analyses in future.

Collected samples were analyzed by Gas Chromatography (Shimadzu, GC-2014, Japan) equipped with Porapak NQ column (Q 80–100 mesh). Nitrous oxide, carbon dioxide and methane were quantified by flame ionization different detector such as ECD, TCD and FID. Colum temperatures were 100, 45 and 70°C for CH_4, CO_2 and N_2O. The injector and detector were adjusted at 60, and 100 °C for CH_4, 75 and 270°C for CO_2 and 80 and 320°C for N_2O. Argon and helium gas were used as carrier. Air and H_2 were used as burning gases.

The GHG emission rates were calculated from the increase in its concentrations per unit surface area of the chamber for a specific time interval. Closed-chamber equation of Lou et al., 2004 was used to estimate seasonal fluxes as follows:

$$M = Q \times (W/B) \times (\Delta d/\Delta p) \times (273/T)$$

where, M is the CO_2 and CH_4 emission rate in mg m^{-2} hr^{-1}, and N_2O emission rate ug m^{-2} hr^{-1}, Q is the gas density of CH_4, CO_2 and N_2O in mg cm^{-3}, W is the volume of chamber in m^3, B is the surface area of chamber in m^2, $\Delta d/\Delta p$ is the rate of increase of GHG concentrations in mg m^{-3} hr^{-1} and T is the absolute temperature (273 + mean temperature) in °C of the chamber.

The seasonal CO_2, CH_4, N_2O (SCCN) fluxes were computed according to Singh et al. (1999):

$$\text{SCCN flux} = \sum_f^e (U_i \times V_i)$$

where, U_i is the rate of CO_2, CH_4 and N_2O flux in g m^{-2} d^{-1} during i^{th} sampling interval, V_i is the number of days in the f^{th} sampling interval, and e the number of sampling.

The relative ability of measured gases were expressed in terms of carbon dioxide equivalent according to Robertson et al. 2000, and GWP was calculated considering 28 for methane, and 265 for nitrous oxide (IPCC, 2014):

GWP (CO_2 equivalent) = Methane × 28 + Carbon dioxide × 1 + Nitrous oxide × 265.

Greenhouse gas emission intensity (GHGI) was calculated as follows:

GHGI= Total GWP/ Grain yield

Results and Discussion

Yield in Boro season. Yield of Boro rice varied insignificantly in different water management options at Gazipur and Kushtia **(Table 41).** Statistically insignificant grain yield (ranged from 6.40 to 6.70 t ha^{-1} and 6.75 to 7.00 t ha^{-1}) were found among the treatments and location.

GHG and GWP during Boro season. The total CH_4 flux was not significant different because of two AWD condition at different location. However, the AWD, 15 cm and AWD, 25 cm treatment reduce about 34-36% and 32-38% of total CH_4 flux than CSW at Gazipur and Kushtia. The GWP reduce about 33-35% and 30-36% by AWD than CSW **(Table 41).**

Table 41. Total GHG and GWP under varying irrigation management during Boro 2025

Treatment	Location							
	Gazipur				Kushtia			
	GHG emission (kg ha^{-1})			Grain Yield (t ha^{-1})	GHG emission (kg ha^{-1})			Grain Yield (t ha^{-1})
	CH_4	GWP	GHGI		CH_4	GWP	GHGI	
CSW	174	5075	0.77	6.70	175	5046	0.72	7.00
AWD,15 cm	127	3805	0.60	6.50	119	3531	0.51	6.90
AWD, 25 cm	113	3507	0.56	6.40	108	3236	0.48	6.75
$LSD_{0.05}$	30	311	0.10	0.32	20	250	0.10	0.26

Conclusion

Water management is the key factor for reducing the CH_4 flux and GWP at different locations in Bangladesh. The AWD reduce about 35-39% of GWP than CSW but yield is not significant different during the study period.

Expt. 28. Comparison of global warming potential between rain fed and continuous irrigation in haor region during T Aman-Boro season

M. M. Haque and M. R. Islam

Introduction

Soil moisture content plays an important role in controlling the release and consumption of GHGs. Frequent irrigation increases plant biomass and soil microbial activity lead to increases in CO_2 and N_2O emissions compared to rainfed or non-irrigated soils. This is because increased soil water content accelerates microbial respiration of soil organic matter, which enhances CO_2 flux. Alternate wetting and drying (AWD) irrigation in irrigated rice (Boro rice) cultivation reduced emission factor of CH_4 (22–36%) but increased water productivity by 25–27% compared to continuous flooding (CF) method along with 14–43% reduction in GHG intensity (Haque et al., 2021). Methane emission flux showed the increasing trend after transplanting and reached its peak at 35-40 DAT following AWD irrigation (Haque et al., 2021). However, irrigation suspension during the rice cropping season may lessen the peak emission as well as total global warming potential without sacrificing grain yield. Thus, the study was undertaken to find out the suitable water management options based on GHG emission, global warming potential and sustainable rice production.

Materials and Methods

Treatments, design and management

The study was conducted at farmers field, Habiganj during T. Aman and Boro, 2024-25. Popular rice cultivar BRRI dhan87 and BRRI dhan92 for T. Aman and Boro were the test variety. The experiment involved randomized complete block design (RCBD) with three replications. Individual plot size was 70 m^2 with 1 m buffer zone in each sides. In T. Aman season, twenty-day old rice seedlings were transplanted on 27 July, 2024 at a rate of 2-3 seedlings per hill. In Boro season, trirty five day old rice seedlings were transplanted on 7 th January, 2025 at a rate of 2-3 seedling per hill. Recommended chemical fertilizer was applied during the study period. Urea fertilizer was applied at three equal split application at land preparation, 20 days after planting (DAT). In T. Aman and Boro season, the experiment was carried out with three irrigation management treatments as T_1 = Rainfed condition, T_2 = AWD (Supplemental irrigation when water level goes 15 cm below ground surface), T_3 =CSW (Continuous standing water). The amount of applied irrigation was measured with a flow meter and was documented. The grain yield and yield contributing parameters of each treatment were recorded for statistical analysis

Gas sampling and analysis

Carbon dioxide, methane, and nitrous oxide emissions were measure by using static chamber methods during Boro rice cultivation (Haque et al., 2013, 2020). Transparent glass chambers (0.62m x 0.62 m and height 1.12 m) were placed permanently in the plots after rice transplanting for N_2O and CH_4 gas collection. There were 2 holes at the bottom of a chamber for maintaining 5-7 cm water level above soil surface. Each chamber enclosed 9 hills. However, another smaller close chambers (20 cm x 50 cm) were placed in between rice plants for measuring CO_2 emission rates (Lou et al., 2004; Xiao et al., 2005; Iqbal et al., 2008; Haque et al., 2015b). All chambers were equipped with a circulating fan for gas mixing and a thermometer to record inside temperature. Chambers remained open all the time except during gas sampling.

Gas samples were collected in 50 ml air-tight syringes at 0 and 30 min after closing the chamber. Gas samplings were drawn off from the chamber headspace equipped with 3-way stop cock at 8:00–

12:00–16:00 hours in a day from each treatment. Collected gas samples were transferred into 20-ml air-evacuated glass vials sealed with a butyl rubber septum for analyses in future.

Collected samples were analyzed by Gas Chromatography (Shimadzu, GC-2014, Japan) equipped with Porapak NQ column (Q 80–100 mesh). Nitrous oxide, carbon dioxide and methane were quantified by flame ionization different detector such as ECD, TCD and FID. Colum temperatures were 100, 45 and 70°C for CH_4, CO_2 and N_2O. The injector and detector were adjusted at 60, and 100 °C for CH_4, 75 and 270°C for CO_2 and 80 and 320°C for N_2O. Argon and helium gas were used as carrier. Air and H_2 were used as burning gases.

The GHG emission rates were calculated from the increase in its concentrations per unit surface area of the chamber for a specific time interval. Closed-chamber equation of Lou et al., 2004 was used to estimate seasonal fluxes as follows:

$$M = Q \times (W/B) \times (\Delta d/\Delta p) \times (273/T)$$

where, M is the CO_2 and CH_4 emission rate in mg m^{-2} hr^{-1}, and N_2O emission rate ug m^{-2} hr^{-1}, Q is the gas density of CH_4 , CO_2 and N_2O in mg cm^{-3}, W is the volume of chamber in m^3, B is the surface area of chamber in m^2, $\Delta d/\Delta p$ is the rate of increase of GHG concentrations in mg m^{-3} hr^{-1} and T is the absolute temperature (273 + mean temperature) in °C of the chamber.

The seasonal CO_2, CH_4, N_2O (SCCN) fluxes were computed according to Singh et al. (1999):

$$\text{SCCN flux} = \sum_{f}^{e} (U_i \times V_i)$$

where, U_i is the rate of CO_2, CH_4 and N_2O flux in g m^{-2} d^{-1} during i^{th} sampling interval, V_i is the number of days in the f^{th} sampling interval, and e the number of sampling.

The relative ability of measured gases were expressed in terms of carbon dioxide equivalent according to Robertson et al. 2000, and GWP was calculated considering 28 for methane, and 265 for nitrous oxide (IPCC, 2014):

GWP (CO_2 equivalent) = Methane × 28 + Carbon dioxide × 1 + Nitrous oxide × 265.

Greenhouse gas emission intensity (GHGI) was calculated as follows:

GHGI= Total GWP/ Grain yield

Results and Discussion

In T. Aman season; Yield varied insignificantly in different water management options **(Table 42).** Sufficient rainfall in the whole growing season created no water stress during 2024 in T Aman season. Thus, no supplemental irrigation was applied both in continuous flooding and supplemental irrigation treatments. Statistically insignificant grain yield (ranged from 4600 to 4780 kg ha^{-1}) were found among the treatments. The GWP was significantly affected under different water management during T. Aman season **(Table 42).** About 12-18 % of GWP reduce by rainfed irrigation system than other irrigation system. **In Boro season;** The GWP was significantly affected under different water management during Boro season **(Table 42).** About 15-25 % of GWP reduce by rainfed and AWD irrigation system than continuous flooding system. Rain fed irrigation system is not suitable for enhancing rice yield as well as mitigation of GWP than AWD irrigation. However, AWD reduce about 45% of CH_4 and 15% of GWP than CSW.

Table 42. Total GHG and GWP under varying irrigation management during T. Aman-Boro season, 2024-25 at Habiganj

Treatment	Season					
	T. Aman			Boro		
	GWP	GHGI	Yield	GWP	GHGI	Yield
T_1 (Rainfed)	4566	0.99	4600	5914	0.93	6380
T_2 (AWD)	5076	1.06	4780	6368	0.97	6540
T_3 (CSW)	5293	1.11	4765	7479	1.08	6920
$LSD_{0.05}$	289	0.09	210	425	0.07	360

Conclusion

In T. Aman and Boro season, Rain fed and AWD are the important water management system for reducing GHG, GWP but not significant different of grain yield than CSW irrigation system.

Expt. 29. Improving rice yield and mitigating greenhouse gas emissions using nano-urea and zeolite in rice cultivation

S.M.M. Islam, M.N. Islam, M.L.H. Mondol, M.R. Islam

Introduction

Rice is the staple food crop in Bangladesh and is cultivated in 11.4 million hectares (ha) across three crop-growing seasons per year (Islam et al., 2018). Of the three seasons, Boro (dry season, December/January to March/April) results in an area under rice crop (irrigated rice) production of 4.8 million ha (BBS, 2020). The total rice production in Bangladesh was 36.6 million tons in 2019-20, and Boro rice contributed the majority of the total production (BBS, 2020). Although rice plays a critical role in food security, it is associated with environmental pollution due to the emissions of greenhouse gases (GHGs), particularly methane (CH_4).

Rice cultivation has been considered a significant anthropogenic source of CH_4 and nitrous oxide (N_2O) emissions. Magnitudes of emissions depend on crop management practices. It is reported that inappropriate agricultural practices, including imbalanced or excessive use of fertilizers, overuse of groundwater, and burning of crop residues, increase emissions (Romasanta et al., 2017). Inefficient fertilizer management may not only affect crop productivity but also increase emissions (Gaihre et al., 2015, Malayan et al., 2016; Islam et al., 2022). In contrast, efficient N fertilizer management could substantially improve rice yield and nitrogen use efficiency (Islam et al., 2016, 2018b) and reduces GHG emissions (Islam et al., 2020, Islam et al., 2022). Therefore, mitigation of these gases from agricultural systems requires optimized agricultural practices, namely improved fertilizer management, efficient rice cultivars etc.

Nitrogen loss presents a significant challenge at the crossroads of agriculture and climate change, causing decreased crop yields, environmental degradation, increased production costs, and rising risks to food and nutrition security. Once nitrogen fertilizers are applied, they quickly transform, leading to rapid losses before plants can absorb them. These losses release greenhouse gases (GHG) such as nitrous oxide (N_2O) and nitric oxide (NO), and also result in atmospheric ammonia (NH_3) pollution and nitrate (NO_3^-) contamination of groundwater (Gaihre et al., 2015; Islam et al., 2018). The use of nitrification inhibitors has been shown to reduce N_2O emissions by as much as 70% and can boost yields by approximately 20%. Nanofertilizers can inhibit ammonification and nitrification (Dimkpa et al., 2020). Nonetheless, large-scale field trials remain limited, especially in understanding how these materials help reduce nitrogen losses along with methane (CH_4) emissions.

However, the impacts of zeolite and nano-urea on rice yield and CH_4 emissions are not well documented. Therefore, the present investigation was conducted to determine the effects of the zeolite and nano-urea across different agroecological zones of Bangladesh on rice yield and CH_4 emissions during the Boro (dry) season.

Materials and Methods

The field experiments were conducted in the Bangladesh Rice Research Institute (BRRI) farm, Gazipur, Cumilla, Barishal and Satkhira. BRRI dhan102 was used for conducting the experiment. Six fertilizer treatments were tested: (T1) N control, (T2) 66% of recommended prilled urea (RPU) (33% at basal and 33% at 25 DAT), (T3) 66% of RPU (22% at Basal, 22% at 25 DAT and 22% at before panicle initiation (BPI), (T4) 66% of RPU (22% at Basal, 22% at 25 DAT and 22% at BPI) + Zeolite (4 t/ha), (T5) 66% of RPU (33% at Basal and 33% at 25 DAT) + liquid nano-urea (LNU) (1235 ml/ha; BPI and Flowering), and (T6)100% of RPU (33% at Basal, 33% at 25 DAT and 33% at BPI). Nutrients viz. N, P, K, S & Zn were used as basal at the recommended rate to all plots and the rates were 174 kg N/ha, 18 kg P/ha, 80 kg K/ha, 18 kg S/ha, and 1 kg Zn/ha, respectively. PU was applied in three equal splits. The crop was harvested at full maturity of the crops. After harvest, the plot-wise crop was bundled separately and brought to the threshing floor; threshing was done manually. The rice grains were cleaned and weighed. Then, sundry grain weight was recorded for every plot and the weight in g/plot was adjusted at 14% moisture and finally expressed in t/ha. The sundry weight of straw was also recorded plot-wise and expressed as t/ha.

CH_4 emissions were measured using a closed gas chamber technique and their emission rates were determined from the slope of the linear regression curves of CH_4 concentration against chamber closer time. Cumulative CH_4 and N_2O emissions were estimated by summing up the daily emissions. Emission rates between two sampling days were estimated by linear interpolation of two consecutive measurements. The current report presents CH_4 emissions data from Gazipur and Cumilla, while data analysis for Satkhira and Barishal is still underway.

Results

Rice yield. The application of N significantly increased grain yield compared to the T1 treatment in Gazipur, Cumilla, and Barishal **(Fig. 19).** The highest yield was recorded in the T5 treatment. The lowest was observed in the T1 treatment in Gazipur and Barishal. In contrast, the highest yield in Cumilla was found in the T6 treatment **(Fig. 19).** The variation in yield may be linked to differences in soil properties and climatic conditions. Liquid nano-urea had a notable impact on rice yield in Gazipur and Barishal. However, no additional yield benefit was observed from using Zeolite in any of the locations **(Fig. 19a and b).**

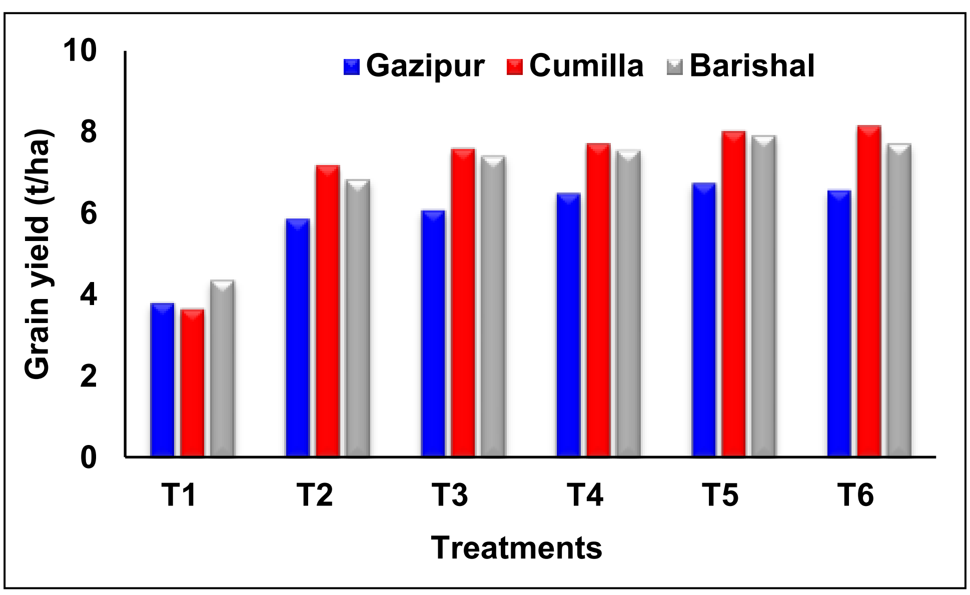


Fig 19. Effects of N fertilizer rates and sources on grain yield during Boro 2024-25 at BRRI farm, Gazipur and Cumilla.

T1, T2, T3, T4, T5, and T6 correspond to N control, 66% of recommended prilled urea (RPU) (33% at basal and 33% at 25 DAT), 66% of RPU (22% at Basal, 22% at 25 DAT and 22% at before panicle initiation (BPI), 66% of RPU (22% at Basal, 22% at 25 DAT and 22% at BPI) + Zeolite (4 t/ha), 66% of RPU (33% at Basal and 33% at 25 DAT) + liquid nano-urea, and 100% of RPU (33% at Basal, 33% at 25 DAT and 33% at BPI), respectively.

Greenhouse gas emissions. The CH_4 emissions were measured at the Gazipur and Barishal sites for six treatments **(Fig. 20).** The highest total CH4 emissions were observed in the T6 treatment, while the lowest were found in T1 at both locations. In Gazipur, nano urea (T5) significantly reduced CH_4 emissions compared to the recommended prilled urea (RPU) (T6), whereas it had no significant effect on CH_4 emissions in Cumilla. The application of zeolite (T4) showed no significant impact on CH_4 emissions at either site in the current study **(Fig. 20).** The data reported here are preliminary and are based on only one Boro season.

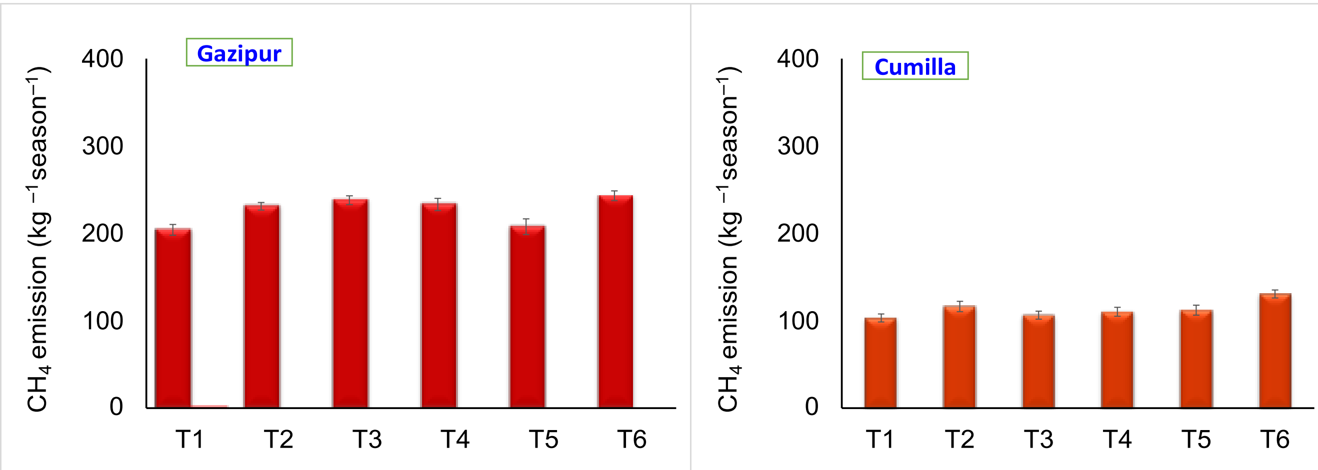


Fig 20. Effects of N fertilizer rates and sources on CH_4 emissions during Boro 2024-25 at BRRI farm, Gazipur and Cumilla.

Conclusion

The CH_4 emissions data presented in this report are preliminary. More research is needed across different agroecological zones with similar soil and environmental conditions to achieve consistent results.

SUB-SUB PROGRAM V: SOIL MICROBIOLOGICAL STUDIES

Project 05: Soil microbiology and bio-fertilizer

Expt. 30. Bio-coated urea: a new approach to improve n fertilizer use efficiency and rice yield

U. A. Naher and Rafiqul Islam

Introduction

Biofertilizers are generally applied to soil, seeds or seedlings, with or without some carriers for the microorganisms. Combination technology of microbial carrier and chemical fertilizer may be termed as Bio-based chemical fertilizer. Bio-inoculant coated with commercial urea, diammonium phosphate (DAP), potassium chloride, or a filler particle or NPK might trigger more fertilizer use efficiency (FUE). Carpenter (2014), reported that the ability of *Bacillus, Pseudomonas,* and *Streptomyces* as a coating for granular NPK. Activity of microbes on coated urea particles show significant nitrification from the coated urea sample indicating activity of the mixed microbial system under realistic use conditions. Organo-zeolitic bio-fertilizer is also developed by Efthimiadou (2010), composed of organic waste and crushed zeolitic rock, containing Clinoptilolite and commonly Mordenite zeolite, functions biologically in sponsoring nitrification, ammonium ions, provided from the degradation of the organic waste, are adsorbed to the zeolite mineral surface thus avoiding a loss to the atmosphere by volatilization. *EMAS* fertilizer is granular-shape biofertilizer first in the world (Patent No ID 0000294S in 1998) and significantly proved to enhance fertilizer use efficiency up to 25% by saving chemical fertilizer dosage and increasing 10% to 30% crops yield depends on crops variety.

Rice production in Bangladesh is chemical fertilizer and pesticide based, which impaired soil quality, ecosystem biodiversity, and environmental pollution. Moreover, the pressure for feeding growing population and the plateau trend of rice yield-imposed stress on rice stakeholders. More cultivable area needs to be under rice production. In this situation boostering rice production in all types of soil including saline soil is an emerging demand. In saline soil crop yield hampered due to excess soluble salts, especially Na^+. Plant root in saline soil, have experienced exo-osmosis of nutrients. Exopolysaccharide (EPS) producing PGPB can play a significant role in alleviating salinity stress. EPS binds with cations, such as Na^+, and decreases bioavailable ions for plant uptake. The formation of biofilm is a common property of microbes under salinity stress. Biofilm is an aggregate of microbes in which they adhere to each other and protect themselves from adverse effects. EPS plays an important role in maintaining the structural stability of the biofilms (Zheng et al., 2016). In these circumstances, such bacterial inoculant may improve rice production in the saline soil. From the previous study report we may have hypothesized that bio-coated zeolite-based urea granule may reduce reactive N loss, improve N and P fertilizer use efficiency along with crop productivity for sustainable rice production in favorable and unfavorable ecosystem. Reduction of chemical fertilizer uses certainly reduced environmental pollution and crop production cost. A bio-based chemical fertilizer may be an environmentally friendly approach. Bio-inoculant coated with urea might trigger more N fertilizer use efficiency (FUE). Hence present study was conducted with the objective; to evaluate the efficacy of formulated Bio-coated urea (BCU) in favorable (AEZ28) and unfavorable (AEZ13) soil plant system

Objective of the study;

1. to evaluate the efficacy of formulated Bio-coated urea (BCU) in favorable (AEZ28) soil plant system

Materials and Methods

A number of 13 plant growth promoting bacteria were added with wheat-flour, zeolite, gypsum and formed Bio-coated urea granule. A field study was conducted in BRRI farm Gaipur (favorable ecosystem) to evaluate the efficacy of formulated BCU over PU. The experimental field soil was clay loam, having pH 6.8 and containing 1.73% organic matter, 0.18% total nitrogen, 29 mg kg^{-1} available phosphorus, 20 mg kg^{-1} available sulphur, 0.17 meq/ 100g soil exchangeable K and 3.2 mg kg^{-1} available zinc (Table 43). Treatment combinations were as; T_1 (fertilizer control), T_2 (N_0+ PKS), T_3 ($N_{100\%}$ PU + PKS), T_4 ($N_{100\%}$ BCU + PKS), T_5 ($N_{60\%}$ PU + PKS) and T_6 ($N_{60\%}$ BCU + PKS). Experiment was designed in RCB with 3 replications. Standard fertilizer doses for N, P, K, S (kg ha^{-1}) were 80-10-30-6 in T. Aman and 170-18-80-10 in Boro season, respectively. BRRI dhan87 and BRRI dhan89 were grown in T. Aman and Boro season respectively. Bio-coated urea (BCU) was applied as N source in the T_4 and T_5 treatments. In the both studies, Prilled urea (PU) and Bio-coated urea (BCU) was applied in 3 equal splits; 1/3 during transplanting, 1/3 at maximum tillering stage and rest of the 1/3rd was applied at panicle initiation stage. Plant was harvested at the maturity stage. Standard agronomic practices were done. Plant height, tiller number, panicle number, straw and grain weight were recorded.

Table 43. Chemical properties of initial soil of the experiment site at BRRI farm Gazipur

Place	Series	pH	OM (%)	Total N (%)	K (meq/100 g soil)	P (mg kg^{-1})	S (mg kg^{-1})	Zn (mg kg^{-1})
BRRI Gazipur	Chhiata	6.82	1.73	0.18	0.17	29	20	3.2

Results and Discussion

Grain yield and N use efficiency in T. Aman season

BRRI dhan87 was cultivated in the T. Aman season. Study result showed that there were no significant grain yield difference obtained due to the reduction of 40% N from Bio-coated urea with 100% (recommended) applied prilled urea. Significantly, the lowest grain yield was recorded in both T_1=N0+ PKS (2.70 t ha^{-1}) and full fertilizer control (T_2) treatment (2.95 t ha^{-1}) **(Fig. 21).** Reduction of 40% N from the standard N fertilizer dose (T_3) reduced 27.36% grain yield in the T_5 treatment. On the other hand, same reduction (40%N) gave 32.58% yield benefit in bio-inoculant coated urea treatment (T_6). Higher agronomic N use efficiency (39%), N recovery efficiency (81%), partial factor productivity of N (89%) and N harvest index (95%) were noticed due to reduction of 40% N in the both PU and BCU treatment compared to Full (100%) dose of N application **(Fig.22).**

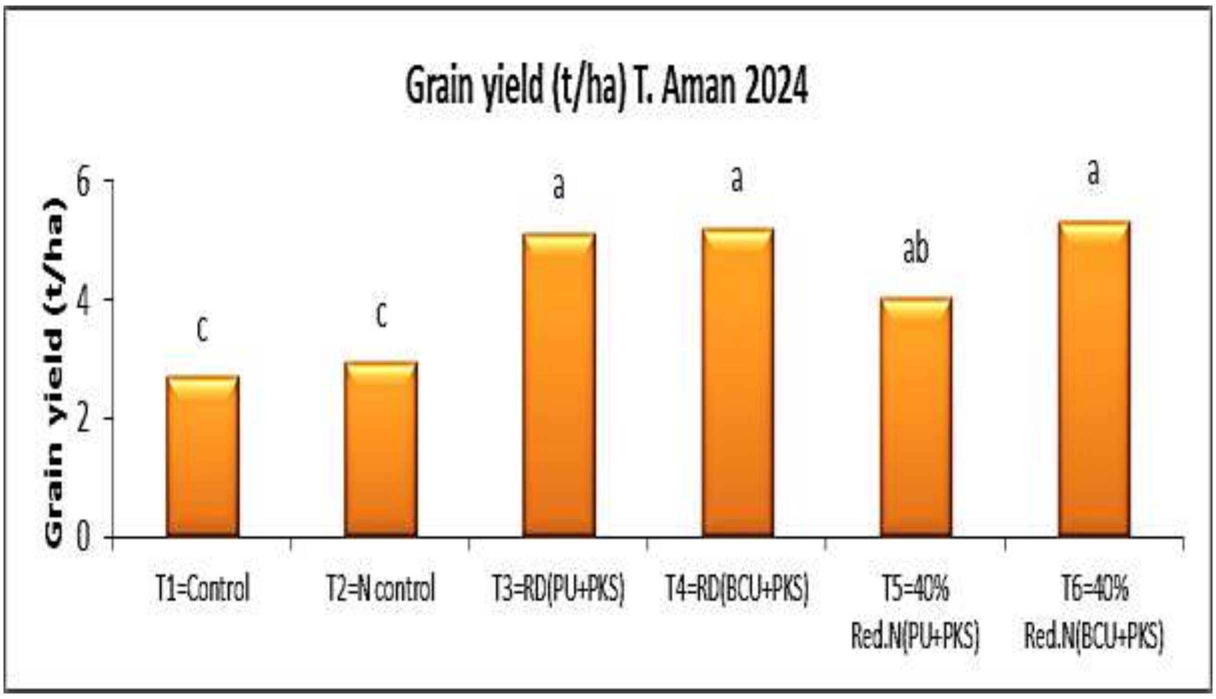


Fig. 21. Effect of Bio-coated urea and Prilled urea on rice grain yield in T. Aman 2024 season at BRRI Gazipur

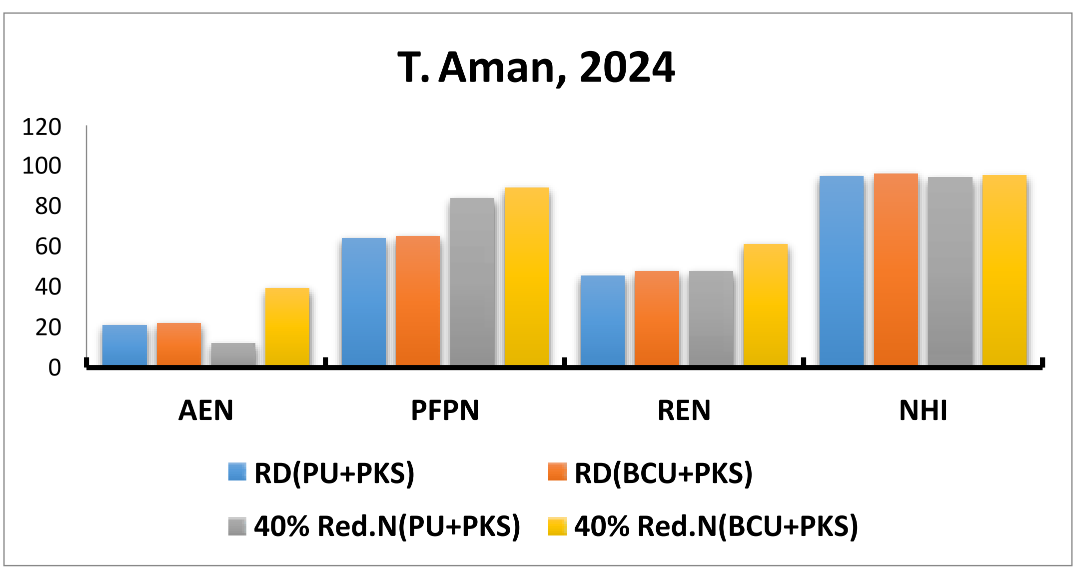


Fig. 22. Effect of Bio-coated urea (BCU) and Prilled urea (PU) on different N use efficiencies AE_N, RE_N, PFP_N and NHI in T. Aman rice at BRRI Gazipur

Grain yield and N use efficiency in the Boro season

In the Boro season BRRI dhan89 was grown. The highest grain yield (6.51 t ha^{-1}) was recorded in the 100% BCU+PKS applied treatment (T_4) and it was statistically similar with 60% BCU+PKS (T_6) and 100% PU+PKS (6.46 t ha^{-1}) treatment (T_3) **(Fig. 23).** The 40% reduction of prilled urea produced 5.84 t ha^{-1} grain yield in T_5 treatment. The lowest 2.46 t ha^{-1}grain yield obtained in the fertilizer control treatment (T_1). Reduction of 40% N from standard N fertilizer dose (T_3) reduced 10.61% grain yield in T_5 treatment. On the other hand, same reduction (40%N) gave 10.21% yield benefit in bio-inoculant coated urea treatment (T_6).

Nitrogen use efficiencies were higher in Boro season compared to T. Aman season. Higher agronomic N use efficiency (35%), N recovery efficiency (45%), partial factor productivity of N (63%) and N harvest index (96%) were noticed in the 40% reduced N (T_6) BCU treatment compared to Full (100%) dose of N application **(Fig.24).**

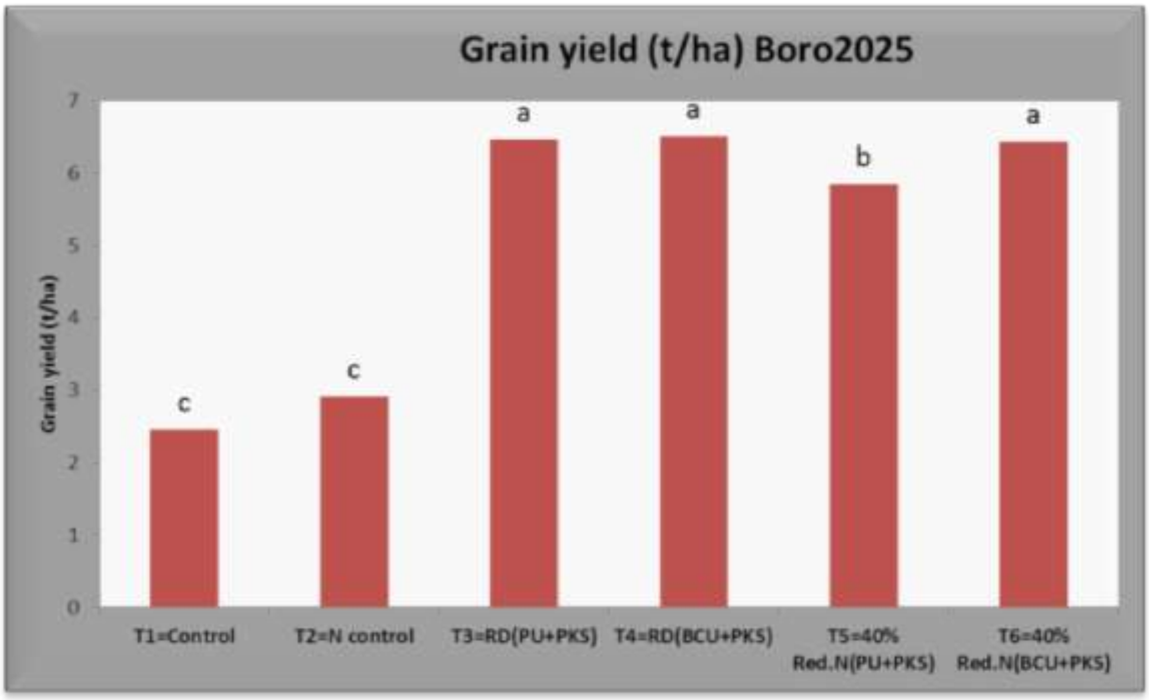


Fig. 23. Effect of Bio-coated urea and Prilled urea on rice grain yield in Boro2024- 2025 season at BRRI Gazipur

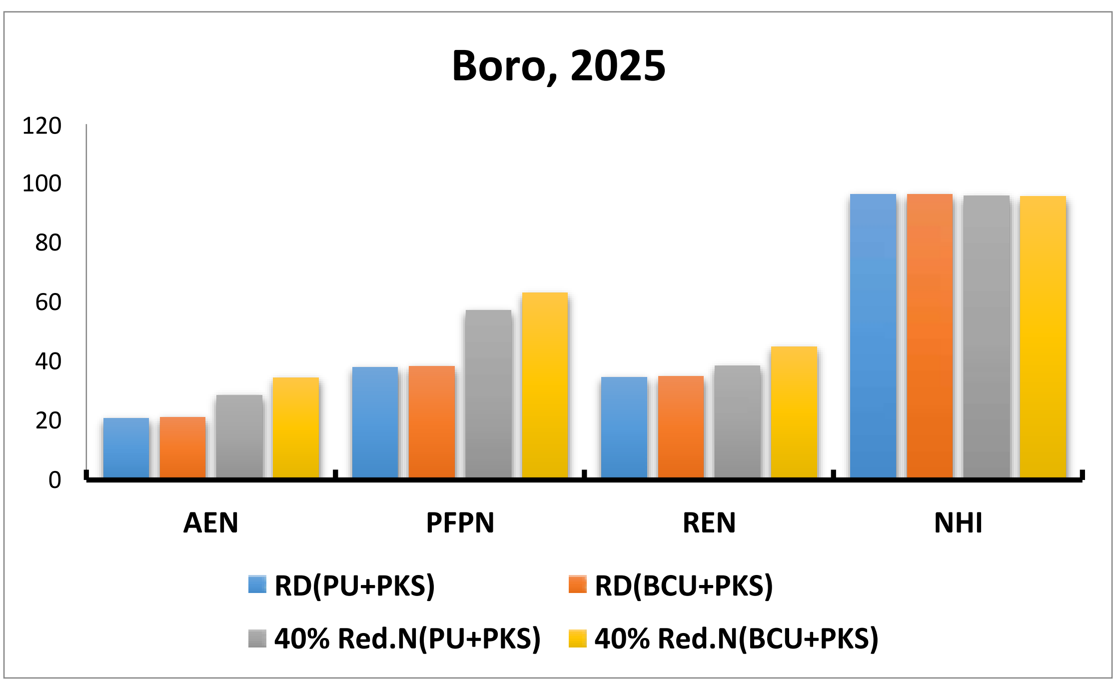


Fig. 24. Effect of Bio-coated urea (BCU) and Prilled urea (PU) on different N use efficiencies AE_N, RE_N, PFP_N and NHI in Boro rice at BRRI Gazipur

Conclusion

At BRRI Gazipur application of Bio-coated urea (BCU) improved rice yield (10 to 40%) and saved 40% N.

Expt. 31. Effect of BRRI-organic fertilizer on rice yield without using Triple super phosphate (TSP) and 30% less use of Urea (N) fertilizer in Boro and T. Aman rice cultivation

Umme Aminun Naher, Aminul Islam and Rafiqul Islam

Introduction

Rice dictates food security in Bangladesh. It covers about 10 m ha of land and requires a lot of chemical fertilizers for its production. Intensive cropping and use of inorganic fertilizers are mostly responsible to reduce soil organic matter content in Bangladesh. Production of chemical fertilizers is energy driven processes and are responsible for emission of greenhouse gases. Besides, use of fertilizers can pollute air, water, soil, and alter ecosystem and biodiversity depending on their use patterns. Nitrogen use efficiency of rice plant is only 30-50%. Most of the applied urea is lost through different processes like ammonia volatilization, N_2O emission and NO_3 leaching. Phosphorus is the second most important nutrient applied as TSP or di-ammonium phosphate (DAP). Rock phosphate (RP) is the natural source for TSP and DAP fertilizer production. Use of RP not only will reduce GHG emission but will also reduce rice production cost. Since P becomes slowly available from RP the use of phosphate solubilizing bacteria (PSB) is very much effective to make it bio-available. It was proved that production of 1 kg urea and 1 kg triple super phosphate (TSP) emitted 6.5 kg of CO_2 in the atmosphere. Moreover, every year the Government has to subsidize a huge amount for urea and TSP fertilizers for crop production.

Waste management is a big issue in Bangladesh, especially house-hold wastes (mostly, kitchen waste) in urban and semi-urban areas because of high population pressure. Wastes are generally dumped on to the road side and make unhealthy environment for the city dwellers. For example, Dhaka city generates around several tons of solid organic waste each day, and at least 80% of which is suitable for composting. About half of it is collected by Dhaka City Corporation and the rest remains on open areas and create environmental pollution. Our preliminary observation indicates that co-composting of these materials with RP (5%) improves P contents and its application can completely eliminate TSP fertilizer requirement for rice production. Co-composting of house-hold waste materials with RP will provide a new era of fertilizer management in rice cultivation in Bangladesh. Considering all of these facts, present study was undertaken with the following objectives:

1. To save about 25-30% urea and omit 100% use of TSP fertilizer for rice cultivation.
2. To improve paddy soil organic matter content by household waste material (kitchen waste) for maintaining soil health and
3. To improve soil biology and soil C stock for ensuring future food security of Bangladesh.

Materials and Methods

Two field experiments were conducted in T. Aman 2023 and Boro 2023-24 at BRRI farm Gazipur. Soil nutrient content was given below (Table 44). The treatment combinations were T_1 = 100% Recommended chemical fertilizer, T_2 = 70% N + 0% P+ 100% other recommended fertilizers (K & S), T_3 = 70% N + 0% P+ 100% K & S + BRRI-organic fertilizer @ 500 kg/ha), T_4 = 70% N + 0% P+ 100% K & S + BRRI-organic fertilizer@750 kg/ha), T_5 = 70% N + 0% P+ 100% K & S + BRRI-organic fertilizer@1000 kg/ha), T_6 = BRRI-organic fertilizer@2000 kg/ha T_7 = Native fertilizer (Control). Recommended rates of chemical fertilizers for T. Aman and Boro were N-P-K-S @ 80-12-50-10 kg ha^{-1} and 170-20-50-10 kg ha^{-1}respectively. BRRI dhan92 in T. Aman and BRRI dhan89 was grown in Boro season. Each treatment was assigned in 4 x 5 m^2 sized plot in a randomized complete block design with three replications. Rice seedlings were transplanted at 20 x 20 cm^2 spacing. During final land preparation, BRRI-organic fertilizer was applied along with chemical fertilizers. The flooded water level at 5-7 cm depth was maintained during rice cultivation, and then drained 21 days before rice harvesting. At maturity, the crop was harvested manually from an area of 5 m^2 at 15 cm above ground level at the center of each plot for grain yield and 16 hills from each plot at ground level for straw yield data. Grain yield was recorded at 14% moisture content and the straw yield was on an oven dry basis (72ºC, for 72 hours).

Table 44. Chemical properties of initial soil of the experiment site at BRRI farm Gazipur

Soil Series	Chemical properties	pH	Organic matter (%)	Total N (%)	Available P (%)	Exchangeable K
Chhiata	Clay loam	6.82	1.45	0.13	26	0.19

Grain yield in T. Aman season

The effect of different dosages of BRRI-organic and chemical fertilizer significantly affected grain and straw yield of BRRI dhan92 **(Table 45).** The highest grain yield (4.5 t/ha) produced in the BRRI organic applied treatments (T_3 and T_4), however it is statistically similar with (T_1) treatment where full chemical fertilizer was applied. The significant lowest grain yield was obtained in the T_7treatment. The result proved that omission of TSP along with 30% reduction of urea fertilizer did not impact negatively on grain yield (T_3 and T_4 treatment) as BRRI organic fertilizer has ability to supplement substantial amount of P and 30% N nutrient for rice production. Improved plant growth and phosphate uptake have been reported in many crop species as a result of bacterial inoculants e.g., *Pseudomonas aeruginosa* in rice (Singh et al., 2013) [10], *Bacillus sp.* in maize (Canbolat *et al.,* 2006) and *B. amyloliquefaciens* in wheat, maize and cotton (Egamberdiyeva *et al.,* 2003).

Grain yield in Boro season

In the Boro season, different dosages of BRRI-organic and chemical fertilizer also affected grain and straw yield of BRRI dhan89. The highest grain yield 7.64 t ha^{-1} was obtained in the 0.5 t ha^{-1} BRRI organic applied treatment (T_3), and it was statistically similar with full dose application of chemical fertilizer (7.56 t ha^{-1}), T_1 and 1.0 t ha^{-1} BRRI organic treatment (T_5). The lowest grain yield obtained in the control plot. The result proved that omission of TSP along with 30% reduction of urea fertilizer did not impact grain yield. In conclusion we found application of 0.5 t ha^{-1} BRRI organic fertilizer saved 100% TSP/DAP and 30% urea in rice cultivation with financial benefit.

Table 45. Effects of BRRI-organic and chemical fertilizer application on grain yield of BRRI dhan 92 and BRRI dhan 89 at BRRI, Gazipur

Treatments	Grain yield (t/ha)	
	T. Aman	Boro
T_1: 100% Recommended chemical fertilizer	4.20a	7.6a
T_2:70% N + 0% P+ 100% K & S	3.47b	5.6b
T_3:70% N + 0% P+ 100% K & S+ BRRI-organic fertilizer@500kg ha^{-1}	4.50a	7.6a
T_4:70% N + 0% P+ 100% K & S+ BRRI-organic fertilizer@750 kg ha^{-1}	4.51a	7.5a
T_5:70% N + 0% P+ 100% K & S+ BRRI-organic fertilizer@1000 kg ha^{-1}	4.50a	7.2a
T_6: BRRI- organic fertilizer@ 2000 kg ha^{-1}	3.68b	3.8c
T_7: Native fertilizer (Control)	2.49bc	2.3d
($p \leq 0.05$)	***	***
CV (%)	13.65	14.00

Similar letters for mean values of the treatment within a column were not significantly different at 5% level of significance ($p \leq 0.05$).

Nitrogen use efficiencies

Application of BRRI organic fertilizer improves N use efficiencies compared to use of sole synthetic fertilizers. Though 30% N reduced in the BRRI organic applied treatments (T_3, T_4, T_5, and T_6) higher N use efficiencies (AE_N, RE_N, PFP_N) were noticed **(Fig.25a and 25b).** At Boro season, N use efficiencies were also higher in the BRRI organic fertilizer applied treatment.

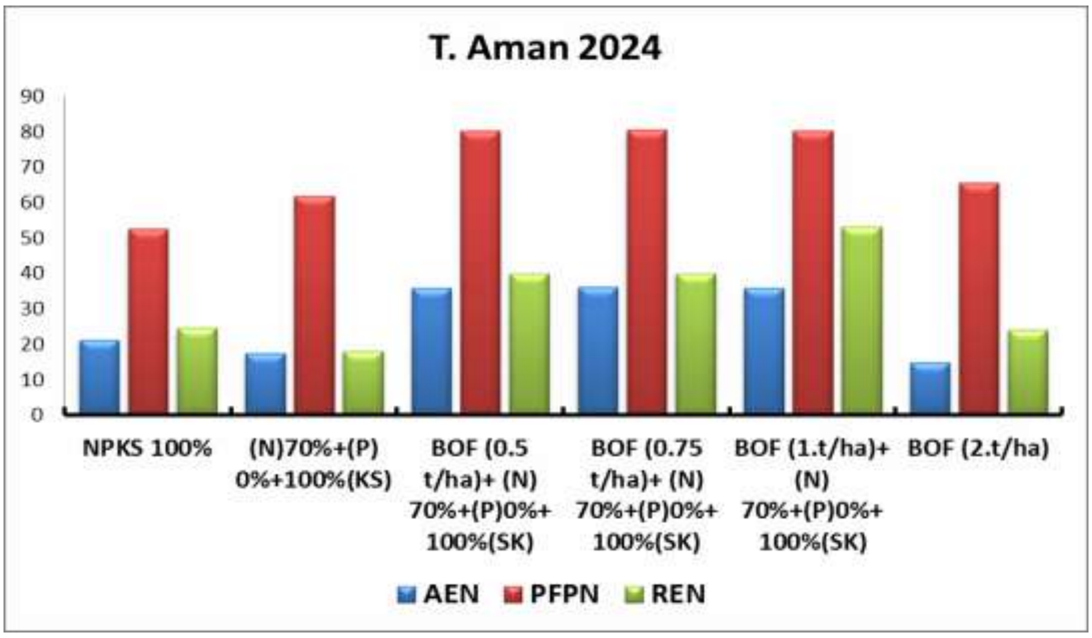


Fig. 25a. Effect of BRRI organic and synthetic fertilizer on different N use efficiencies (AE_N, RE_N, and PFP_N) in the T. Aman rice at BRRI Gazipur

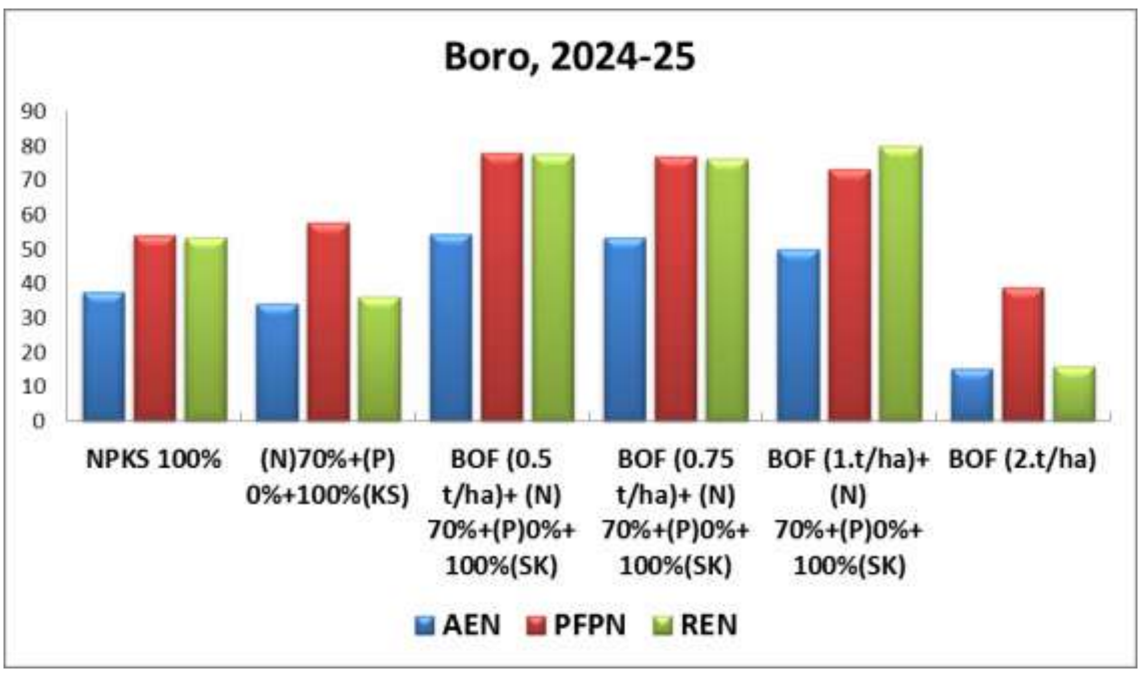


Fig. 25b. Effect of BRRI organic and synthetic fertilizer on different N use efficiencies (AE_N, RE_N, and PFP_N) in the Boro rice at BRRI Gazipur

Phosphorus use efficiencies

BRRI organic fertilizer is a special type of organic fertilizer that capable to supply available P. In the study different P use efficiencies (AE_P, RE_P, PFP_P) were determined. It was observed that in the T. Aman season, AEp and PFPp were higher in the BRRI organic treatments (T_3, T_4 and T_5) compared to TSP application (T_1). However, REp was slightly higher BRRI organic treatments **(Fig.26a).** At the Boro season P use efficiencies were higher than T. Aman season. The values obtained were similar for both of the TSP and BRRI organic fertilizer application except T_6 treatments **(Fig. 26b).**

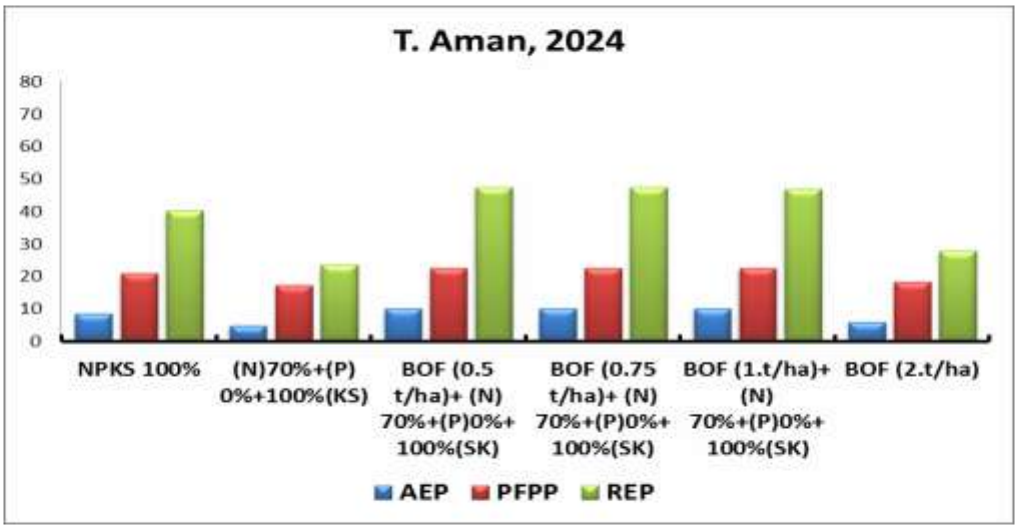


Fig. 26a. Effect of BRRI organic and synthetic fertilizer on different P use efficiencies (AE_P, RE_P, and PFP_P) in the T. Aman rice at BRRI Gazipur.

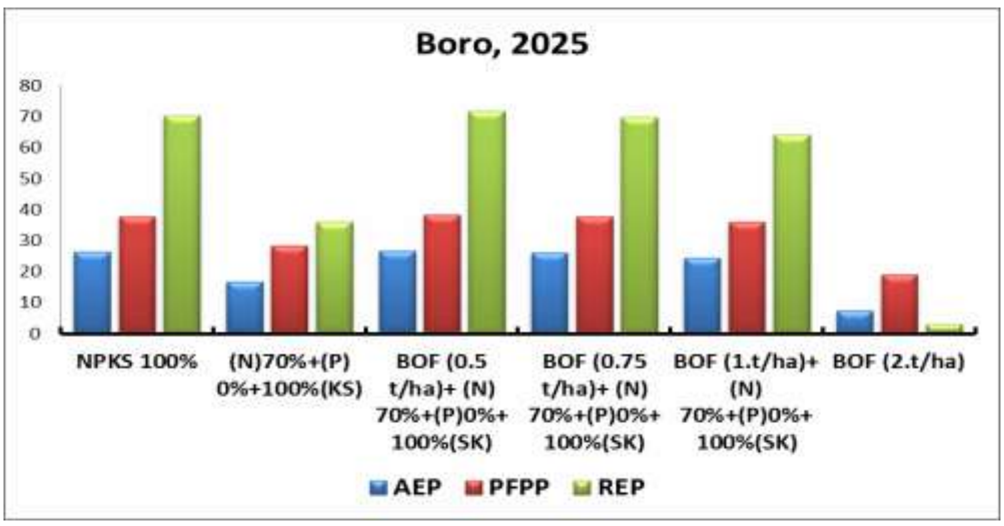


Fig. 26b. Effect of BRRI organic and synthetic fertilizer on different N use efficiencies (AE_P, RE_P, and PFP_P) in the Boro rice at BRRI Gazipur.

Conclusion

Study results proved BRRI organic fertilizer (0.5 t ha^{-1} to 1 t ha^{-1}) has the potential to supplement 30% N and 100% P requirement for HYV rice without sacrificing yield.

Expt. 32. Study on hill soil biodiversity

Umme Aminun Naher, Mehedi Hasan Khan and Rafiqul Islam

Introduction

Bangladesh is a riverine country including long coast areas and hills. Less than one fourth area of Bangladesh in the north, north-east, east, and south-east consists of hills, hillocks and high ground which supported mega biodiversity from the time immemorial. Essential foods, vegetable oils and fats, fiber, forage, wood products and other agricultural products are dependent entirely on the soil conditions. Vast areas of hill districts of Bangladesh have been so damaged due to soil erosion that they no longer can be used to grow anything of value to human beings. Much of the good conditioned land that remains is in danger, from overuse and improper use. In our country, people are becoming aware of the importance of keeping their land permanently productive and restore topographic situation for their betterment.

Rice is the staple food crop of all over the Bangladesh including hilly people. Usually rice is grown in the valley or nearly flat land with water facility. System redundancies (i.e. different species with similar functions), are available in ecosystems at low altitudes of hill area and that land are prone to crop production, especially suitable for rice. Such redundancies usually provide stability to ecosystems. The absence of these redundancies renders hill ecosystem particularly vulnerable to the impacts of global climate change. Generally, people are unaware of the threats to hill ecosystems and the services of mountains provide to the humanity. Hill ecosystems sequester CO_2, clean water and air, regulate climate, provide biomedical resources, and regulate floods.

Hill ecosystem consists of terrace and valley. Application of any agricultural inputs at terrace or slightly upper portion such as fertilizer or pesticides may washout with water and dumped at the valley or more down that causes ecological hazard including soil and water pollution. Moreover improper nutrient management badly affected soil health, increase soil erosion and crop production. The impact of human interventions in hill area may represent graphically as below which finally disrupted soil biodiversity, ecosystem services and soil health, particularly impacted human wellbeing. Due to improper soil nutrient management at hill, soils are losing biodiversity and polluting soil-water environment, causing land erosion. The in-depth study of soil physical, chemical and biological properties of Alikadam, Sitakundo, Kaptai and Matiranga were not well documented, especially information of soil biology and biodiversity that related to soil health. Baseline survey needed to select soil management options for higher rice production and improve soil health. Specific objectives of the study was

1. to study the agricultural soil health (physical, chemical and biological properties of hill soil ecosystem) of Alikadam, Kaptai, Sitakundu and Matiranga upazilla

Materials and Methods

Soils from rice /non rice crop cropping pattern was collected from Matiranga upazilas maintaining 0-15 cm depth using global positioning system (GPS) record along with plot history. Soil was collected from about 500 locations of each upazila (Matiranga Sadar, Baranala, Belchhari, Amtoli, Gumti, Tubalchhari, Taindang) of Matiranga. After collection of soil, samples were kept at -80ºC temperature until biological analyses. Bacterial DNA was purified using DNA kit and metagenomics done by 16S rRNA gene (V3-V4 region) for all bacteria identification in culture free method using F515 (5′-GTGCCAGCMGCCGCGGTAA-3′) and R806 (5′-GGACTACVSGGGTATCTAAT-3′) primers. All PCR reactions were carried out with 15 µL of Phusion High - Fidelity PCR Master Mix; 0.2 µM of forward and reverse primers, and produce 10ng template DNA. Thermal cycling consisted of initial denaturation at 98ºC for 1 min, followed by 30 cycles of denaturation at 98 ºC for 10 s, annealing at 50ºC for 30 s, and elongation at 72 ºC for 30 s and 72 ºC for 5 min. Sequencing libraries were generated and checked with Qubit and real-time PCR for quantification and bio-analyzer for size distribution detection. Quantified libraries were pooled and sequenced on Illumina platforms, according to effective library concentration and amount of data required. Paired-end reads were merged using FLASH (V1.2. 1 1, http://ccb.jhu.edu/software/FLASH/). Quality filtering on the raw tags were performed using the fastp (Version 0.23.1) software to obtain high-quality Clean Tags (Bokulich NA et al.,2012). Species annotation was performed using QIIME2 software. A heat map (35 genera) and hundred genera with the highest abundance in the samples were selected and performed sequence alignment to draw the phylogenetic tree in perl with SVG function. Chemical analysis such as soil pH, total N and organic C were measured following standard protocol.

Soil chemical properties

Average values of the soil organic matter (OM), pH and total N content (%) were given in **Table 46.** In general, soils of the Matiranga were red in color and acidic in nature (pH 4.7 to 6.1) and have low to medium total N (0.07% to 0.25%) and OM (1.0% to 2.6%) content. In the Tubalchhari union soil samples were collected from double rice cropping pattern and Lichi garden. In this area, soil pH was 4.8 to 5.2, OM content was 1.6% to 2.4% and total N range was 0.11 to 0.0.21%. Soil Samples of Taindang union were collected form double rice cropping, wheat, mustard and banana garden, where soil pH ranged 4.7 to 5.2, OM content 1.6% to 2.6% and total N content was 0.18% to 0.25%. Soil pH of Matiranga Sadar varied from 5.0 to 5.7, total N content 0.09% to 0.19% and OM content was 1.2% to 1.9%. Compared to Tubalchhari and Tindang union soil OM and total N content was lower in the Matiranga Sadar. Notably soil samples of Matiranga Sadar were collected from rice, vegetables and mango orchard. Soil pH of Gumti and Bornala were ranged from 4.9 to 5.4, having OM content 1.6% to 2.4% and total N content was 0.15% to 0.24%. In these two unions, soil samples were collected from mango, tobacco, segun tree (forest) and rice field. Compared to above unions, soil OM (1.2% to 1.7%) and total N (0.07% to 0.14%) content were lower in the Belchhari and Amtoli union. In this place, soil samples were collected from rice, fruit, vegetables and forest tree (Segun).

Table 46: Chemical properties of Matiranga soil

Unions	Cropping pattern	pH	%N	OM (%)
Tubalchhari	Fallow-Aus-T. Aman	5.2	0.18	2.4
Tubalchhari	Fallow-Aus-T. Aman	5.2	0.11	2.0
Tubalchhari	Lichi Garden	4.8	0.21	1.6
Taindang	Fallow-Aus-T. Aman	4.7	0.20	2.6
Taindang	Fallow-Aus-T. Aman	5.2	0.25	2.5
Taindang	Mustard- Wheat-Papaya	5.2	0.18	2.4
Taindang	Fallow-Aus-T. Aman	4.7	0.18	1.7
Taindang	Banana	4.8	0.21	1.6
Matiranga Sadar	Tomato-Potato-Brinjal	5.2	0.19	1.9
Matiranga Sadar	Banana	5.7	0.18	1.9
Matiranga Sadar	Fallow-Aus-T. Aman	5.0	0.14	1.8
Matiranga Sadar	Boro-Aus-T. Aman	5.0	0.18	1.4
Matiranga Sadar	Fallow-Aus-T. Aman	5.1	0.09	1.3
Matiranga Sadar	Mango Garden	5.1	0.09	1.2
Gumti	Boro-Aus-T. Aman	5.1	0.25	2.4
Gumti	Boro-Aus-T. Aman	5.1	0.14	1.8
Gumti	Segun Garden	5.0	0.14	1.7
Bornala	Boro-Aus-T. Aman	5.4	0.18	2.0
Bornala	Mango Garden	4.9	0.12	1.8
Bornala	Tobacco-Fallow	5.0	0.15	1.8
Belchhari	Segun Garden	5.2	0.09	1.4
Belchhari	Mango Garden	6.1	0.08	1.2
Belchhari	Banana-Vegetable	5.4	0.09	1.0
Amtoli	Fallow-Aus-T. Aman	4.9	0.14	1.7
Amtoli	Mustard-Vegetable-T. Aman	5.1	0.07	1.3

Soil micro-biodiversity (Classes of bacteria and archea)

Soil samples were collected from diverse group of cropping patterns and analyzed for biodiversity. Result showed a diverse group of bacteria present in the alpha and meta-analysis (Fig. 27). Among them top 15 class were *Alphaproteobacteria, Gammaproteobacteria, Acidobacteriae, Bacteroidia, Vicinamibacteria, Verrucomicrobiia, Actinobacteria, Acidimicrobiia, Myxococcia, Polyangiia, Bathyarchaeia, Anaerolineae, Parcubacteria, Desulfuromonadia, Gemmatimonadia*. Relative abundance of the top 10 classes was shown in **Fig. 1.**

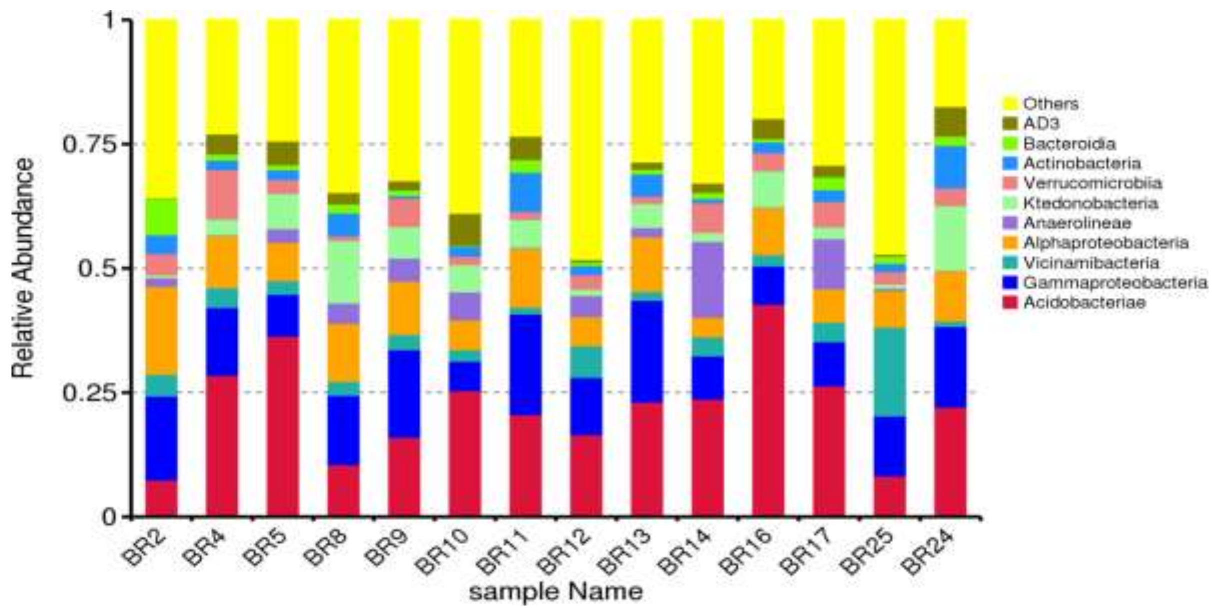


Fig.27. Relative abundance of top 10 classes of bacteria from different field sample. Here, sample Id- BR2: Belchhari (Bana garden), BR4: Gumti (Segun- pineapple garden), BR5: Amtoli (Mustard- Vegetable-T. Aman), BR8: Gumti (Boro-Aus-Aman), BR9: Matiranga Sadar (Boro-Aus-Aman), BR10: Matiranga Sadar (Fallow-Aus-T. Aman), BR11: Bornala (Mango garden with short term vegtables/pineapple), BR12: Bornala (Boro-Aus-Aman), BR13: Bornala (Tobacco), BR14: Tubalchhari (Fallow-Aus-T.Aman), BR16: Tubalchhari (Lichi garden), BR17: Taindang (Fallow-Aus-T. Aman), BR25: Matiranga Sadar (Banana) and BR24: Matiranga Sadar (Mango- pineapple garden).

Among the cropping pattern and crops, soil samples can be subdivided by 5 major groups namely; triple rice crop (RG3), double rice cropping (RG2), medium high land (VMH) where vegetable crops (tobacco, tomato, brinjal etc, wheat, mustard grown), Banana field (BGU), Fruit orchard (mango, lichi, pineapple etc. and segun forest (FOU). According to the cropping pattern and crops, relative abundance of the bacteria phylum were shown in the **Fig. 28.** The higher number of *Acidobacteriae* were belongs to the BGU (vegetables and cereal crop) and FOU group (fruits and segun tree) followed by triple rice growing cropping pattern (RG2 and RG3). The lowest abundance of *Acidobacteriae* was found in the banana garden. The relative abundance of *Gammaproteobacteria* was similar to all cropping patterns except RG2. The abundance of *Vicinamibacteria* was high in the BGU compared to others. Low abundance of *Alphaproteobacteria* was recorded in the RG2 pattern. The other bacteria including some uncalssified group were highest in the banana and lowest in the forest and fruit crop.

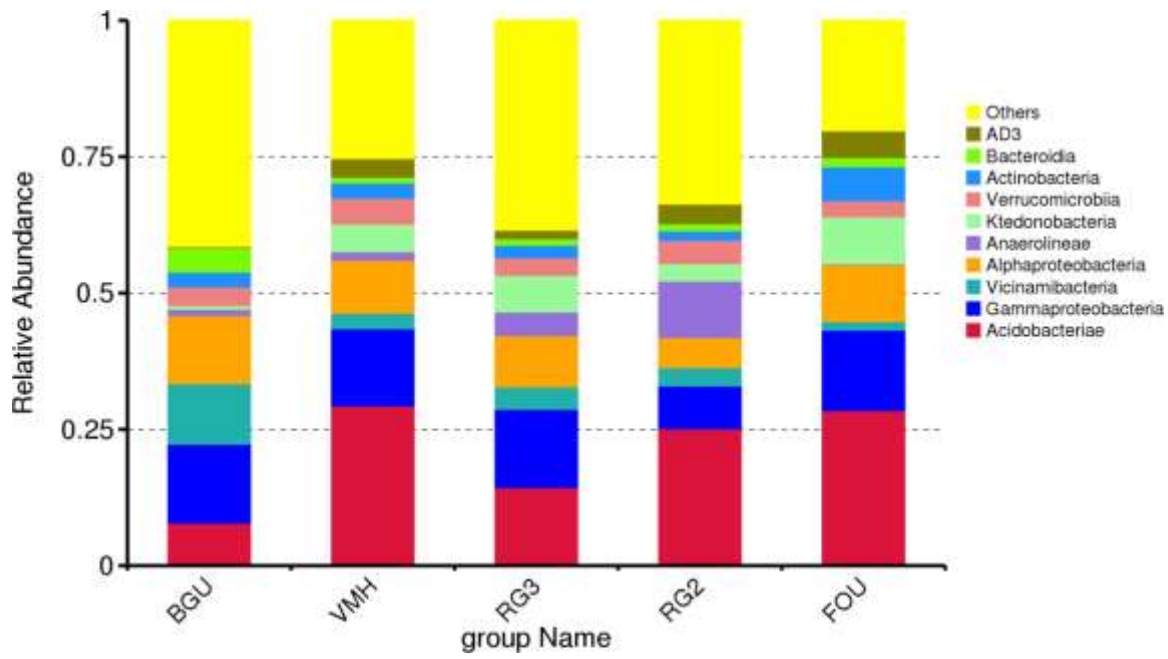


Fig.28. Relative abundance of the bacteria class according to the cropping pattern.

Here, VMH-vegetable cropping pattern (tobacco, tomato, brinjal etc, wheat, mustard grown) in medium high land, RG3 -triple rice crop, RG2-double rice cropping, BGU- banana field, FOU-fruit orchard (mango, lichi, pineapple etc. and segun tree).

Relative abundance of the bacteria classes according to the specific crops

Bacteria abundance may vary according to the crops **(Fig. 29).** Besides soil physico-chemical properties, root exudates specific carbon compounds have important role to harbour microbial diversity. In the study we found *Acidobacteriace* class was significantly high in the lichi crop followed by segun tree. The lowest abundance was in the banana crop. The relative abundance of *Gammaprotobacteria* class was comperable in the tobacco and mango tree,while lowest was in the lichi garden. The relative abundance of this class of bacteria were notable in the rice field. *Alfaprotobacteria* abundance was slighly lower in the rice compared to other forest, fruit and vegetable crop. The relative abundance of unclassified bacteria were high in the banana crop. which proved some variation among the species.

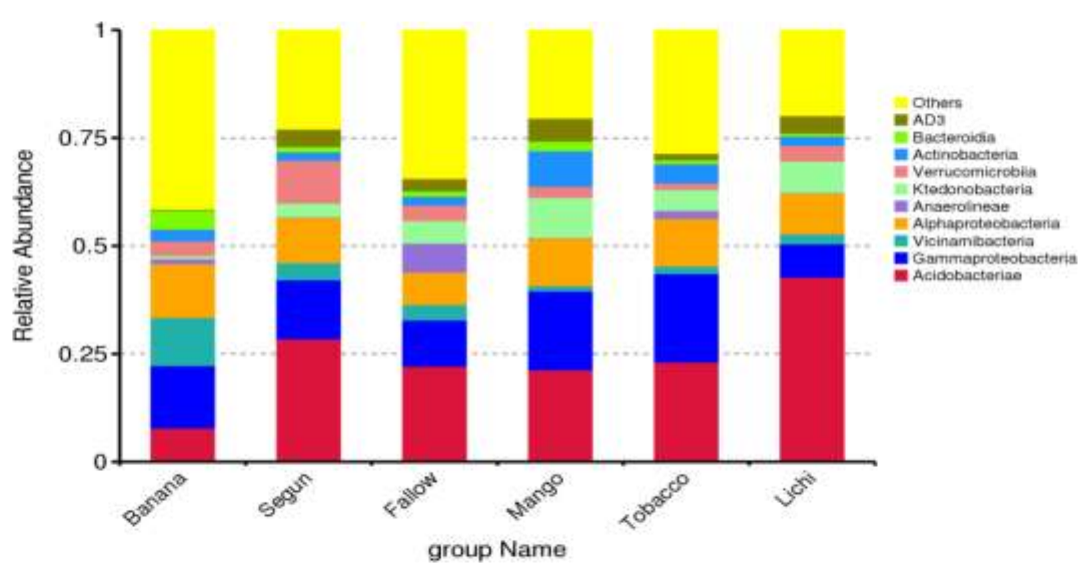


Fig. 29. Relative abundance of bacterial class according to the crops.

Here, VMH-vegetable cropping pattern (tobacco, tomato, brinjal etc, wheat, mustard grown) in medium high land, RG3 -triple rice crop, RG2-double rice cropping, BGU- banana field, FOU-fruit orchard (mango, lichi, pineapple etc. and segun tree).

Bacterial community diversity and phylogenetic tree map analysis

The Shannon diversity index is a measure of biodiversity within a community and Simpson index measures the probability that two randomly selected individuals belong to different species. Visualizations and ecological interpretations proved that BGU exhibited the highest microbial diversity and richness. RG3 showed similarly high diversity, ranking second overall. VMH and RG2 displayed moderate diversity, with lower evenness. FOU harbored the least diverse community. Ranking: BGU » RG3 > VMH » RG2 > FOU **(Table 47).**

Table 47. Shannon and Simpsion diversity index of the bacterial community

Cropping pattern/crop	Shannon index	Simpson index	Richness	Evenness
BGU	4.70	0.97	643	0.72
VMH	4.18	0.95	576	0.65
RG3	4.37	0.96	576	0.69
RG2	4.12	0.96	529	0.65
FOU	3.9	0.95	368	0.67

Here, VMH-vegetable cropping pattern (tobacco, tomato, brinjal etc, wheat, mustard grown) in medium high land, RG3 -triple rice crop, RG2-double rice cropping, BGU- banana field, FOU- fruit orchard (mango, lichi, pineapple etc. and segun tree).

In order to study phylogenetic relationship of each amplicon sequence variants (ASV) and the differences of the dominant species among different samples (groups), multiple sequence alignment was performed using QIIME2 software (Fig. 30). The phylogenetic tree reveals 24 phyla overall, but 7 major groups dominate across cropping patterns: *Acidobacteriota, Actinomycetota, Bacteroidota, Proteobacteria, Chloroflexota, Planctomycetota, and Verrucomicrobiota.* BGU and FOU contained oligotrophic communities. Whereas, VMH and RG3 have diverse, nutrient responsive communities. RG2 have high niche specific and unique microbial communities. Phylogenetic tree is given in the Fig. 4.

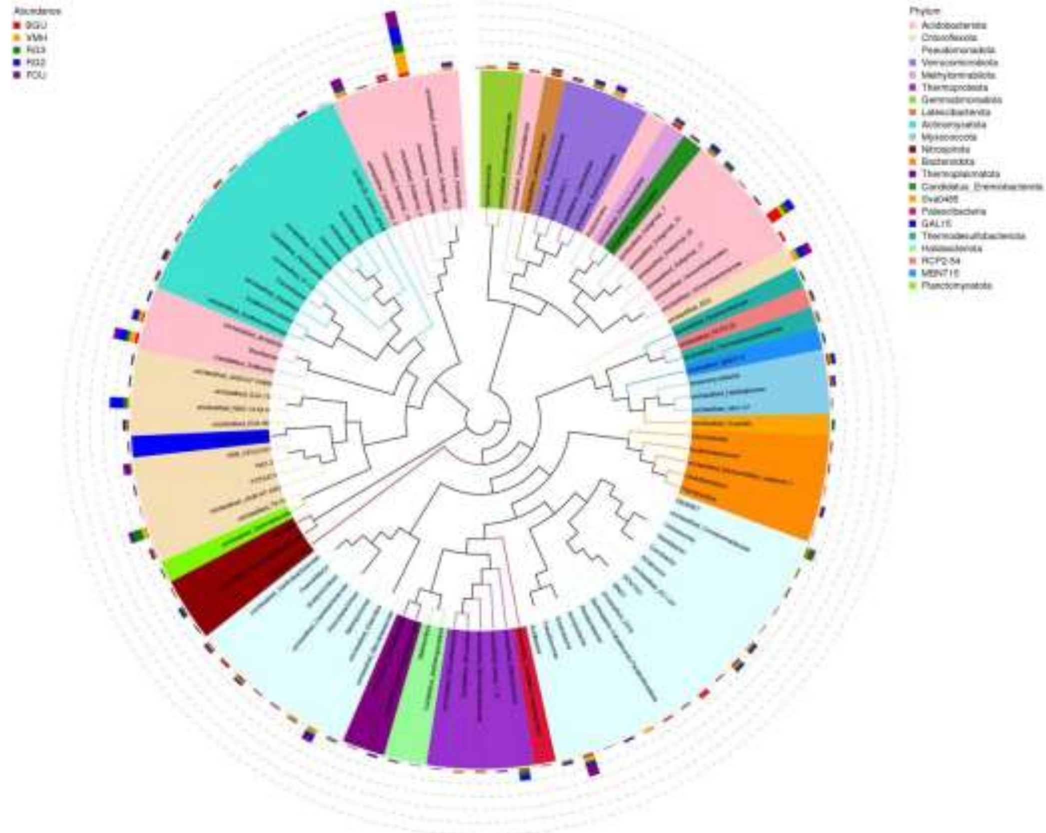


Fig. 30. Bacterial community diversity and phylogenetic tree map.

Here, VMH-vegetable cropping pattern (tobacco, tomato, brinjal etc, wheat, mustard grown) in medium high land, RG3 -triple rice crop, RG2-double rice cropping, BGU- banana field, FOU-fruit orchard (mango, lichi, pineapple etc. and segun tree).

Principal component analysis (PCA)

Principal component analysis was done to explain bacterial variability across the cropping pattern. PC1 explains the largest portion of variation (11.61) in bacterial communities across cropping patterns. PC2 explains the second largest portion of variation (10.46%). Together explain ~22% of the total variability in bacterial biodiversity. BGU (banana) was strongly separated from all other cropping patterns along PC1 and PC2. This means the banana cropping system has a very distinct bacterial community composition compared to the others. Also shows high spread points are distant, indicating variability among banana replicates. VMH (vegetables/tobacco- maize), RG3 (Rice-Rice-Rice), RG2 (Rice-Fallow-Rice) and FOU (Mango and forest showed clusters closely near the center which indicates their bacterial communities were more similar to each other and have less variability compared to banana **(Fig. 31).**

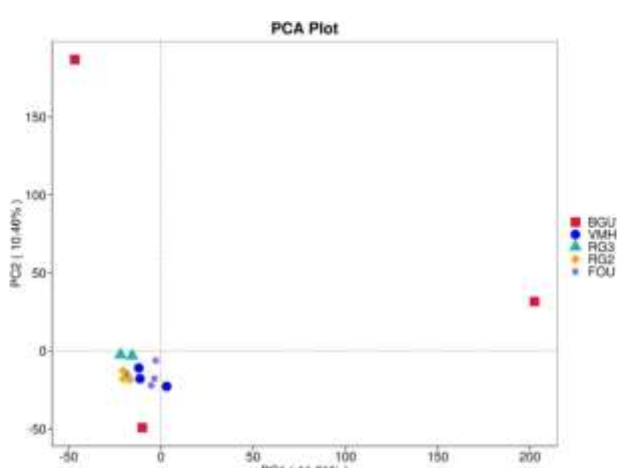


Fig. 31. Principal component analysis of bacterial biodiversity according to the cropping pattern. Here, VMH-vegetable cropping pattern (tobacco, tomato, brinjal etc, wheat, mustard grown) in medium high land, RG3 -triple rice crop, RG2-double rice cropping, BGU- banana field, FOU-fruit orchard (mango, lichi, pineapple etc. and segun tree).

Heatmap and Flower Diagram

The abundance information of top 35 taxa of samples at each taxonomic ranks were used to drawn the heatmap, which visually display different abundance and taxa clustering. This was achieved in R through the pheatmap function. Visual map showed FOU have lower relative abundance for many taxa compared to other systems **(Fig. 32)**. BGU showed strong red blocks, especially for *Acinetobacter* and *Bryobacter,* and several unclassified groups. VMH also showed dominance in a few taxa e.g., *Rhodanobacter*, some unclassified_JG30-KF-AS9, but less widespread than BGU. RG3 and RG2 have more balanced color distribution (fewer extreme red/blue) which indicates greater evenness and possibly higher biodiversity. *Anaeromyxobacter* and some unclassified groups (e.g., Subgroup_7, *Rokubacteriales*) were abundant in RG2 and RG3. *Pseudomonas* and *Bradyrhizobium* are present but not dominant, suggesting they are background members across systems. In conclusion, biodiversity patterns BGU possesses lower biodiversity, dominated by a few strong genera. VMH showed moderate biodiversity, some dominance but not as strong as BGU. RG2 and RG3 have higher biodiversity, more even distribution, less dominance. Generally, lower abundance across most taxa recorded in FOU, possibly reflecting nutrient-limited or less favorable conditions. *Rhodanobacter* showed strong cropping-pattern-specific dominance. *Chloroflexota* and *Verrucomicrobiota* also present but less dominant, likely contributing to diversity in RG2/RG3.

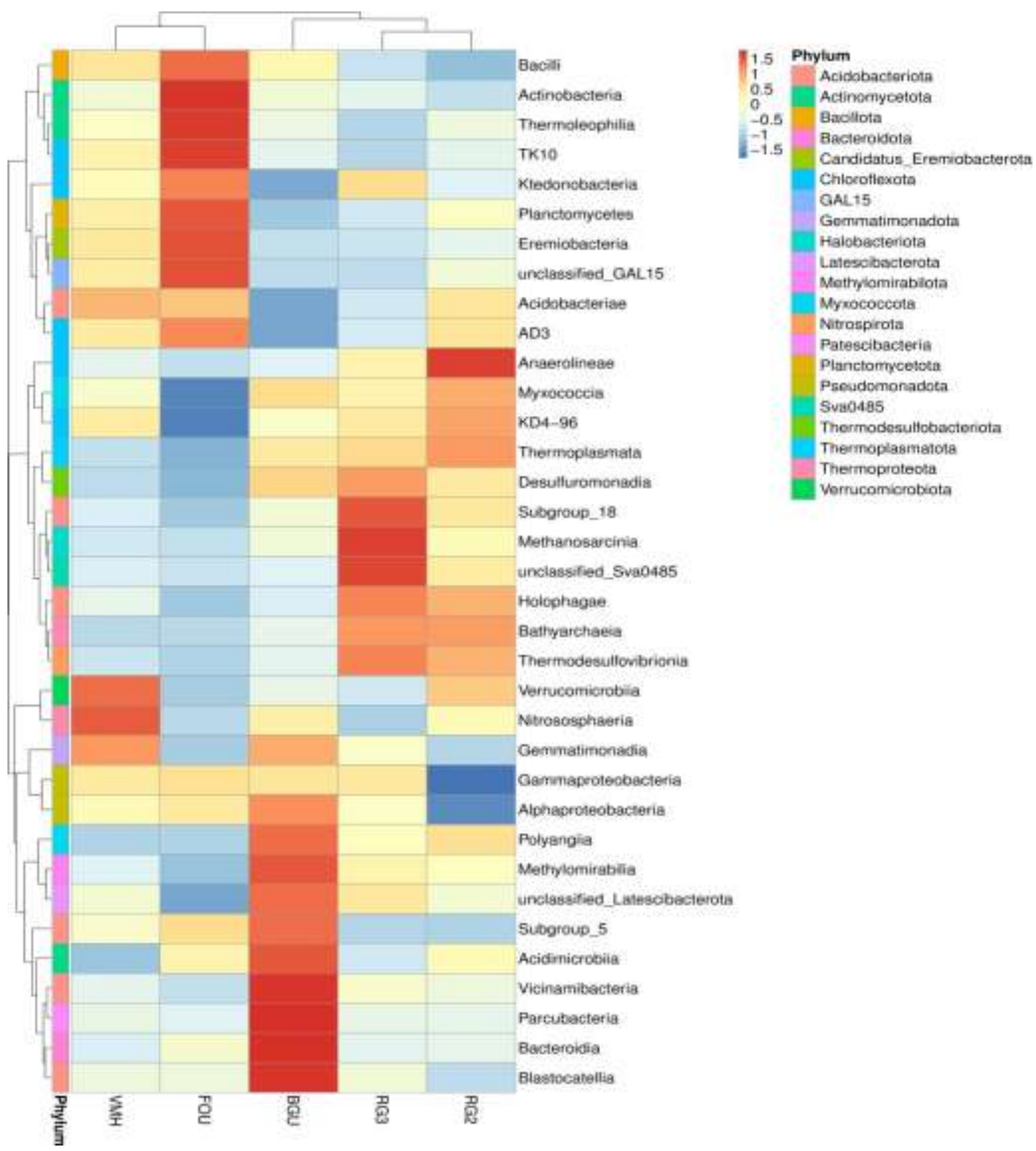


Fig. 32. Heat map with clustering analysis (variable clustering on the vertical axis), the distribution of gates in different crops and cropping pattern is shown. The relative abundances for microbial phyla are indicated by the depth of color.

Flower Diagram

About 38 taxa are shared across all cropping systems (RG2, RG3, BGU, FOU, VMH) and reflected as core microbiome. Also represents resilient, generalist bacteria that persist regardless of crop type or fallow conditions. The highest diversity (10,553 unique taxa) recorded in the RG2 and RG3 that is in rice cropping pattern. The second highest 4,969 unique taxa found in the

BGU (banana) crop. In the FOU have collectively moderate to low diversity (mango:1,747 taxa, segun:1,450 taxa and lichi:1,159 taxa) indicating strong microbial filtering. VMH have moderate diversity of 1,545 unique taxa **(Fig. 33).**

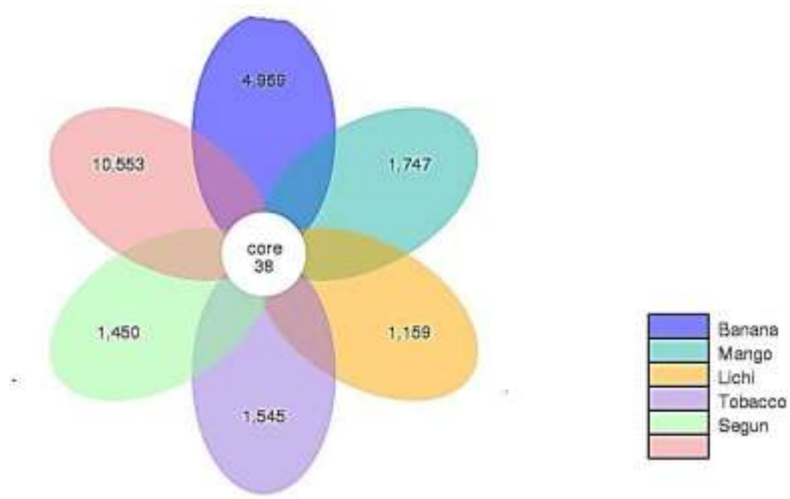


Fig. 33: Floral diagram of unique texa according to crops and cropping pattern

Conclusion

Matiranga soils are acidic and pH ranged from 4.7 to 6.1. Soil organic matter is low to medium (1.2% to 2.5%) and having 0.07% to 2.5% total N. Soil samples were collected from rice (double and triple rice) mostly medium low land, fruit orchard (mango, lichi, pineapple) and forest (segun tree); high land, and vegetables (brinjal, mustard, wheat, tobacco etc.) medium high land. Soil samples were also collected from banana crop as there were many old and new banana gardens in medium high land. In the Matiranga, top 15 phylum/genera identified were *Alphaproteobacteria, Gammaproteobacteria, Acidobacteriae, Bacteroidia, Vicinamibacteria, Verrucomicrobiia, Actinobacteria, Acidimicrobiia, Myxococcia, Polyangiia, Bathyarchaeia, Anaerolineae, Parcubacteria, Desulfuromonadia, Gemmatimonadia.* Among the crops and cropping pattern, BGU and VMH are dominated by a few genera showing lower diversity, higher specialization. On the other hand RG2 and RG3 showed more even bacterial communities with higher biodiversity. FOU shows overall lower abundances with possibly due to less microbiome activity. Core taxa 38 bacterial community were present across all the systems. Further analysis for fungus and actinomycetes are in progress.