ANNUAL RESEARCH REVIEW WORKSHOP 2022-23

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**
Aminul Islam, PhD	CSO & Head	12
Umme Aminun Naher, PhD	PSO	12
Muhammad Sajdur Rahman, PhD[1]	PSO	0
ATM Sakhawat Hossain, PhD	PSO	12
Fahmida Rahman, PhD	SSO	12
Md Mozammel Haque, PhD[1]	SSO	7
Masuda Akter, PhD	SSO	12
S M Mofijul Islam, PhD	SSO	12
Md. Mosud Iqbal, PhD	SSO	12
Md. Nazrul Islam, PhD[2]	SSO	0
M Imran Ullah Sarker, MS[2]	SSO	0
Farjana Alam, MS[2]	SO	0
Afsana Jahan, MS	SO	12
Tanjina Islam, MS	SO	12
Nasima Akhter, B.Sc	SA	12
Abu Taleb, Diploma in Agril.	SA	12
Sahin Sultana	LDA	06
Shakyla Begum	LDA	06
Abu Jabed	LA	12
Md. Rafiqul Hassan	GA	12
Nazma Akter	LA	12

[1] Transferred to and from BRRI RS, [2] Abroad for higher study

Useful Scientific Information

- The optimum nitrogen doses for the submergence tolerant advanced line IR16F1148, drought tolerant advanced lines BR10538-2-1-3 & BR10540-4-1-2-4-1, were 55, 60 and 51 kg N ha$^{-1,}$ respectively for T. Aman season.
- The calculated economically optimum N dose for BRRI dhan95 in T. Aman season was 80 kg ha^{-1} and in Boro season for BRRI dhan92 it was 175 kg ha^{-1}.
- Liquid nano urea might save 33% of the recommended urea fertilizer without sacrificing the rice yield in Boro season at BRRI farm, Gazipur. However, multi-location studies in different seasons are needed to draw a conclusion and confirm the present findings.
- High N dose at potassium deficient conditions adversely affects rice yield, while at N deficient conditions, increasing rates of K fertilizer did not influence rice yield in both T. Aman and Boro seasons. Therefore, maintaining an appropriate N:K ratio is crucial for MV rice production. The optimum N and K rates at BRRI farm Gazipur for achieving the maximum grain yield were 50 and 50 kg/ha, respectively, for BRRI hybrid dhan6 in T. Aman, while for BRRI hybrid dhan3 in Boro season, the rates were 150 kg N and 150 kg K ha^{-1}.
- Rice yield increased sharply due to P fertilizer application as the soil is very deficient in available P. Better grain yield obtained in TSP fertilized plots than DAP fertilizer alone. The combination of TSP and DAP application gave lower grain yield than TSP alone.
- 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 have 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.
- The combinations of 50-75% reduce doses of inorganic fertilizer with PM 1-2 t ha^{-1} showed better growth and yield performance followed by CD 2-3 tha^{-1} with inorganic fertilizer 50-75%. The sole application of 100% inorganic fertilizer or sole application of organic manure using CD and oil cake gave almost similar grain yield.
- 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. Grain yield were non-significant in three BRRI farm irrespective of treatments. But added vermicompost with soil test based fertilizer were performed good in Gazipur and Cumilla; 20% more K with soil test based fertilizer performed good in Rangpur.
- The amount of MWDw was highest with the additions of 0.5 t ha^{-1} vermicompost (VC) with recommended chemical fertilizer (RCF). The highest amounts of SOC were found in different rates of VC application. Therefore, it is concluded that 0.5 t ha^{-1}with RCF fertilization is one of the important tools for improving soil health and rice grain yield.
- As a whole, we have seen that strip tillage can increased about 9-11% net C stock than conventional tillage. Therefore, it is concluded that ST could be one of the important techniques for enhancing net carbon stock under rice-mustard-rice cropping system.
- Application of biochar had positive impact on growth and yield of rice. In this study, single application of 4 t ha^{-1} biochar in Boro-Fallow-T. Aman cropping pattern performed best on rice yield.
- 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 techniques 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.

- Vermicompost (VC) organic fertilizer is good technique for reduced about 18% of global warming potential (GWP), 17% of emission factor (EF) of GHG and 22% of GHG intensity compare to cowdung organic fertilizer during T. Aman season. In Boro rice cultivation, the VC reduce about 14% of GWP, 15% of EF and 17% of GHG intensity compared to cowdung treated plot
- The CO_2 absorption rats were about 1121-4057 kg ha^{-1} under wheat-rice cropping system under different fertilizer management with 11 AEZs.
- About 44-1380 kg CO_2 ha^{-1} are absorbed under Jute-T. Aman cropping system with different fertilizer management. Therefore, we conclude that Jute-T. Aman cropping pattern is one of the important environment friendly cropping patterns.
- Strip tillage can reduce about 20-32% CH_4 emission, 31-55% GWP and 32-58% GHG intensity than conventional tillage depending on growing seasons. Therefore, it is concluded that ST could be one of the important techniques for reducing greenhouse gas emission, GWP, GHG intensity and also to increase crop yields under rice-mustard-rice cropping system.
- Application of BRRI-organic fertilizer 2 t ha^{-1} (dry weight basis) saved 30% N and 100% TSP fertilizer in rice production and improved 8.5 % grain yield over chemical fertilizer in Boro season.
- Bio-Coated Urea Improved N fertilizer use efficiency (NUE) and crop yield in both favorable and unfavorable (saline soil) ecosystem. Application of Bio-coated urea improved yield and saved 25 to 50% prilled urea in rice cultivation.
- *Bacillus* spp. is the dominant bacteria that found in nine tested AEZ's soil. There is a relationship (r^2=0.74) found for soil organic matter and soil biomass C of the tested soil. The expected N use efficient populations were identified as AUS 175, AUS 328, AUS MURALI, BAWOI, BROWN GORA S.B.92, DESHI BORO, DJ 24, KALI AUS, KALI BORO 138-2, KALI BORO 704, LALI BORO, PURANUKA, SAITA BORO, SADA BORO, SONA MUKHI.

SUB-SUB PROGRAM I: SOIL FERTILITY AND PLANT NUTRITION

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

Expt. 1. NITROGEN REQUIREMENT OF DROUGHT TOLERENT ALART MATERIALS IN TRANSPLANTED AMAN SEASON

A.T.M. Sakhawat Hossain, F. Rahman and A. 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 two drought tolerant rice genotypes and two check varieties of T. Aman season.

Materials and Methods

The experiment was conducted in BRRI farm, Gazipur in T. Aman 2022. The soil of the experimental field was clay loam in texture having pH 6.75. The other nutrient status was as follows: organic carbon 1.18%, total N 0.11%, exchangeable K 0.13 meq/100 g soil, available S 12 mg kg^{-1} and available Zn (DTPA extraction) 1.5 mg kg^{-1}. The experiment was conducted in a split-plot design with three replications where fertilizer doses were assigned in main-plot and rice genotypes in sub-plot. The individual main-plot size was 7 m × 6 m. Two drought tolerant rice genotypes viz. BR10538-2-1-3-2 and BR10540-4-1-2-4-1 and two check rice varieties viz. BRRI dhan71 and BRRI dhan75 were evaluated under six N levels e.g., 0, 20, 40, 60, 80 and 100 kgha^{-1}.

All treatments had received a blanket doses of chemical fertilizers P-K-S-Zn @ 10-50-7-1 kg ha^{-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. Twenty-five days old seedlings of each rice genotypes were transplanted on the 1st week of August. 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. N rates to find out optimum N rates for the respective rice genotype.

Results and Discussion

Grain yield and N requirements

Grain yield increased progressively with the increasing of N doses up to 60-80 kg ha^{-1} in most tested rice genotypes and then decreased **(Table 1).** The drought tolerant advanced line BR10538-2-1-3-2 performed better (6.96 t ha^{-1}) than BR 10540-4-1-2-4-1 (6.67 t ha^{-1}) in the same dose of N application (60 kg N ha^{-1}). The tested two drought tolerant rice genotypes also yielded higher than the check varieties in the same doses of N at BRRI farm Gazipur in T. Aman 2022. Between the check varieties, BRRI dhan71 yielded higher (6.77 t ha^{-1}) than BRRI dhan75 (5.33 t ha^{-1}) in the same doses of N application (80 kg N ha^{-1}). The calculated economic optimum doses of N for drought tolerant advanced line BR10538-2-1-3-2 were 60 kg N ha^{-1}, and for BR10540-4-1-2-4-1 the calculated N dose was 51 kg ha^{-1} **(Fig.1).**

Table 1. Effect of nitrogen rates on grain yield (t ha^{-1}) of drought tolerance rice genotypes in T. Aman 2022, BRRI, Gazipur

N doses (kg ha^{-1})	**Rice Genotypes**			
	BR10538-2-1-3-2	**BR10540-4-1-2-4-1**	**BRRI dhan71**	**BRRI dhan75**
0	5.66 d	5.63 c	5.53 d	4.30 d
20	6.07 c	6.26 b	6.01 c	4.65 c
40	6.78 ab	6.56 ab	6.36 b	4.84 bc
60	6.96 a	6.67 a	6.71 a	5.04 ab
80	6.58 b	6.48 ab	6.77 a	5.33 a
100	5.87 cd	5.75 c	6.11 bc	4.72 bc
CV (%) for Treat.		2.50		
CV (%) for Treat. × Var.		2.38		

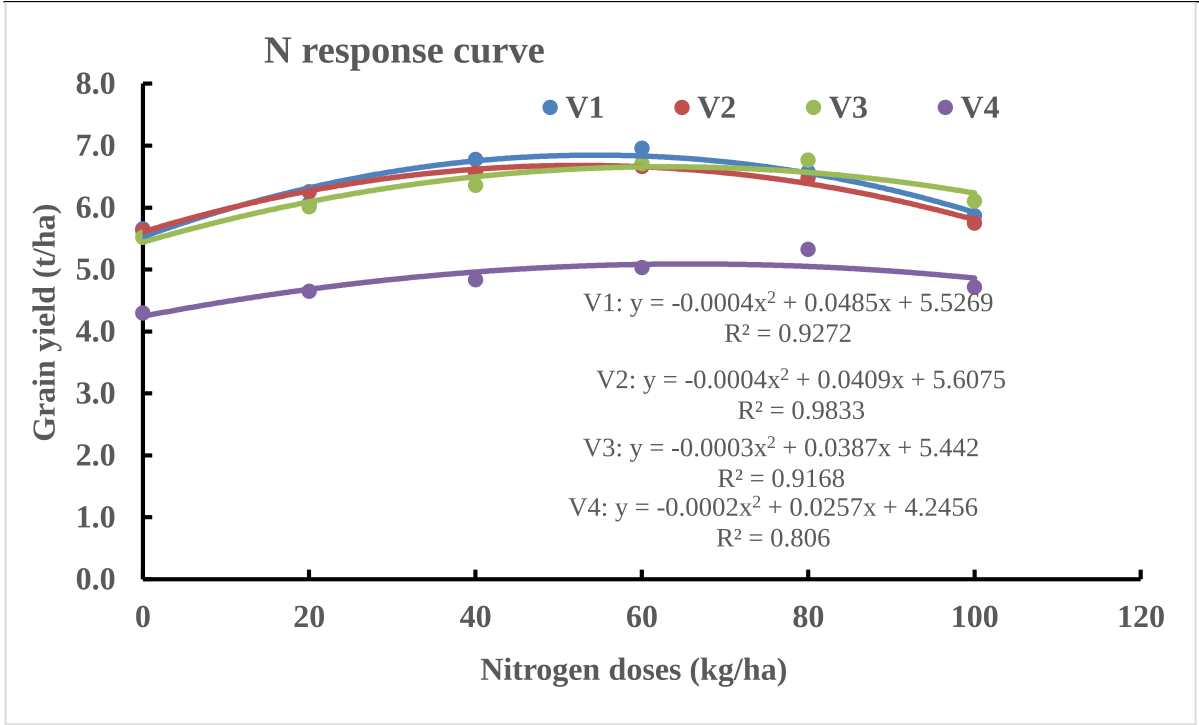

Fig. 1. Nitrogen response curve of drought tolerance ALART materials in T. Aman 2022, BRRI, Gazipur

Drought tolerant ALART materials	**Yield maximizing N doses (kg ha^{-1})**
V1 = BR 10538-2-1-3-2	60
V2 = BR 10540-4-1-2-4-1	51
V3 = BRRI dhan71	65
V4 = BRRI dhan75	64

Conclusion

Nitrogen requirement of drought tolerant advanced line BR10538-2-1-3-2 was 60 kg N ha^{-1}, and for BR10540-4-1-2-4-1 the N dose was 51 kg ha^{-1}. The advanced line BR10538-2-1-3-2 gave higher grain yield than the two check varieties BRRI dhan71 and BRRI dhan75.

Expt. 2. NITROGEN REQUIREMENT OF SUBMERGENCE TOLETANCE ALART MATERIALS IN TRANSPLANTED ANAN SEASON

Tanjina Islam, A.T.M. Sakhawat Hossain and A. 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 submergence tolerant rice genotype and check varieties of T. Aman season.

Materials and Methods

The experiment was conducted in BRRI farm, Gazipur in T. Aman 2022. The soil of the experimental field was clay loam in texture having pH 6.75. The other nutrient status was as follows: organic carbon 1.18%, total N 0.11%, exchangeable K 0.13 meq/100 g soil, available S 12 mg kg^{-1} and available Zn (DTPA extraction) 1.5 mg kg^{-1}. The experiment was conducted in a split-plot design with three replications where fertilizer doses were assigned in main-plot and rice genotypes in sub-plot. The individual main-plot size was 6 m × 6 m. One submergence tolerant rice genotype viz. IR16F1148 and two check rice varieties viz. BRRI dhan71 and BINA dhan11 were evaluated under six N levels e.g., 0, 20, 40, 60, 80 and 100 kg ha^{-1}.

All treatments had received a blanket doses of chemical fertilizers P-K-S-Zn @ 10-50-7-1 kg ha^{-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. Twenty-five days old seedlings of each rice genotypes were transplanted on the 1st week of August. 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. N rates to find out optimum N rates for the respective rice genotype.

Results and Discussion

Grain yield and N requirements

Grain yield increased progressively with the increasing of N doses up to 60-80 kg ha^{-1} in most of the tested rice genotypes and then decreased **(Table 2).** The submergence tolerant advanced line IR16F1148 didn't performed better (4.55 t ha^{-1}) than the check varieties BRRI dhan71 (5.50 t ha^{-1}) and BINA dhan11 (5.26 t ha^{-1}) in the same dose of N application (60 kg N ha^{-1}) at BRRI farm Gazipur in T. Aman 2022. Between the check varieties, BRRI dhan71 yielded higher than BINA dhan11 in the same doses of N. The calculated economic optimum doses of N for submergence tolerant advanced line IR16F1148 was 55 kg N ha^{-1}, and for BRRI dhan71 and BINA dhan11 the calculated N dose were 76 and 60 kg N ha^{-1}, respectively **(Fig.2).**

Table 2. Effect of nitrogen rates on grain yield (t ha^{-1}) of submergence tolerance rice genotypes in T. Aman 2022, BRRI, Gazipur

N doses (kg ha^{-1})	Rice Genotypes		
	IR16F1148	BRRI dhan71	BINA dhan11
0	3.72 c	4.28 d	4.06 c
20	3.95 bc	4.50 d	4.34 c
40	4.25 ab	4.88 c	5.03 ab
60	4.46 a	5.55 a	5.26 a
80	4.55 a	5.35 ab	5.14 ab
100	4.27 ab	5.16 bc	4.90 b
CV (%) for Treat.	3.34		
CV (%) for Treat. X Var.	2.71		

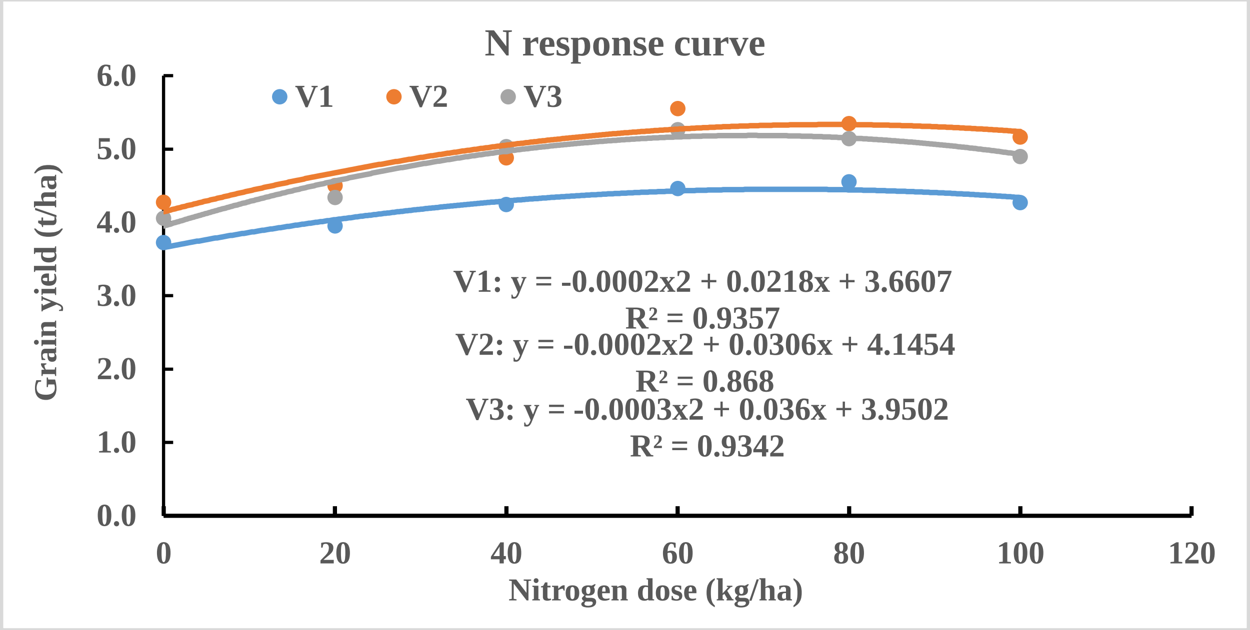

Fig. 2. Nitrogen response curve of submergence tolerance ALART materials in T. Aman 2022, BRRI, Gazipur

Conclusion

Nitrogen influenced positively for increasing the grain yield of the tested rice genotypes. Comparatively lower grain yield obtained with the submergence tolerant rice genotype IR16F1148 than the two check rice varieties BRRI dhan71 and BINA dhan11. The economic optimum N dose for submergence tolerant advanced line IR16F1148 was 55 kg N ha^{-1}.

Expt. 3. UPDATING OF NITROGEN DOSES FOR MODERN RICE VARIETIES

A. Jahan and A. Islam

Introduction

Among the major nutrient elements required for rice crop growth and yield, nitrogen (N) appeared as the key driving nutrient (Fageria et al., 2008). Different research results revealed that N is the most yield limiting nutrient in Bangladesh soils and N requirement varied with rice genotypes (Kamrunnahar et al. 2016, Islam et al.2016, Haque et al. 2019, Haque et al. 2019a, Jahan et al. 2020). 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 12.59 and 20.88 kg N for each ton of grain yield under N deficient and N optimum condition (Kamrunnahar et al. 2016). Biomass production of irrigated rice is mainly driven by the supply of N (Thein, 2004) and rice yield is positively associated with dry matter production (Islam et al. 2015). Even the demand of the rice plant for other macro-nutrients are also depends on N supply (Islam and Muttaleb 2016). Considering the above reviews, it is necessary to know the N response behavior of newly developed BRRI Modern varieties (MVs) for recommending an appropriate N fertilizer dose. So, this investigation was undertaken to update the N doses for new rice varieties according to response behavior of MVs with different N rates.

Materials and Methods

The experiment was conducted at the experimental field of Bangladesh Rice Research Institute, Gazipur in T. Aman 2022 and Boro, 2022-23 seasons. The soil was silty clay loam in texture having pH - 7, organic C - 1.2%, total N - 0.12%, available P - 8.2 ppm, exchangeable K - 0.10 meq/100g soil, available S - 19 mg/kg and available Zn - 3.7 ppm. The experiment was laid out in a RCB design with three replications. In T. Aman season, six N doses: 0, 30, 60, 90, 120 and 150 kg/ha were tested on BRRI dhan95. In Boro season, six N doses: 0, 40, 80, 120, 160 and 200 kg/ha were tested on BRRI dhan92. Flat doses of PKS were applied @ 10-50-10 in T. Aman and 20-65-10 in Boro season. Urea-N was applied in three 3 equal splits i.e 1/3 N at basal, 1/3 active tillering stage and 1/3 at 5-7 days before PI stage. Phosphorous, K and S fertilizers were applied at the final land preparation. The unit plot size was 7 m × 3.4 m in both seasons. In T. Aman season twenty-five days old seedlings and in Boro season thirty-five days old seedlings were transplanted. All intercultural operations were done as when required. At maturity, the crop was harvested from $5m^2$ areas at the center of each plot and 16 hills were collected for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. Plant samples were analyzed for their nutrient content. The nitrogen and grain yield response function estimated from the regression analysis was quadratic in nature with significant ($P<0.01$) R^2 values.

Results and Discussion

T. Aman 2022

Grain and straw yield

The grain yield of BRRI dhan95 progressively increased with the increased N rates up to 90 kg ha^{-1} then the grain yield declined with the increased N rates. However, the variation in the grain yield with different N rates was statistically similar. In case of straw yield similar result was found **(Table 3).** The calculated optimum nitrogen dose from the quadratic equation that could maximize the grain yield was 84 kg ha^{-1}. However, the economically optimum nitrogen dose appeared as 80 kg ha^{-1} **(Fig.3).**

Total nutrient uptake

The total nutrient uptake by BRRI dhan95 varied significantly with N rates. The highest total N uptake was obtained with 90 kg N ha^{-1} which was statistically similar to that of 60 and 90 kg N ha^{-1}. The total P, S and Zn uptakes were significantly higher with 90 kg N ha^{-1}. The total K uptake did not differ with the N rates **(Table 4).**

Table 3. Grain and straw yield of BRRI dhan95 under different N doses in T. Aman, 2022

N Dose (kg ha^{-1})	Yield (t ha^{-1})	
	Grain	Straw
N_0	3.71 b	4.00 b
N_{30}	4.35 ab	4.99 ab
N_{60}	4.38 ab	5.16 ab
N_{90}	4.72 a	5.86 a
N_{120}	4.24 ab	5.08 ab
N_{150}	3.97 ab	4.73 ab
CV (%)	7.76	10.90

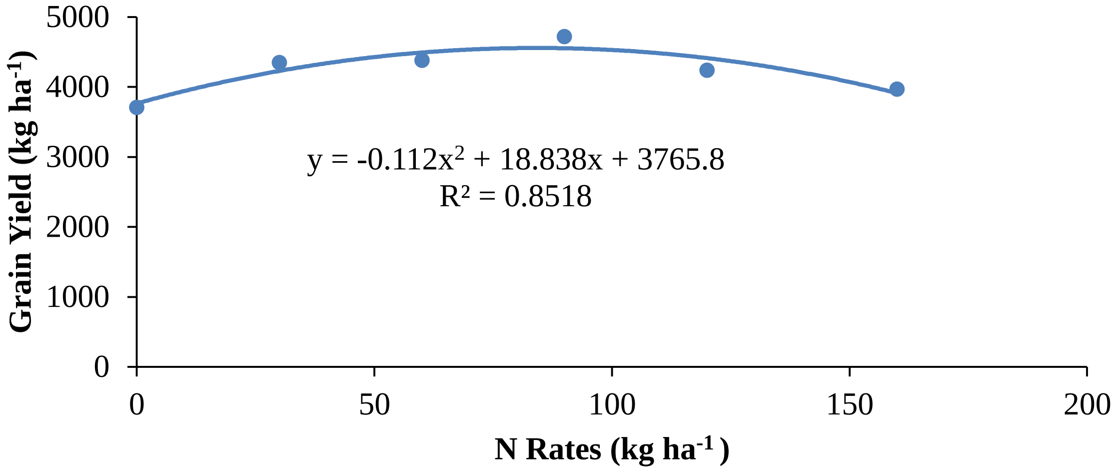

Fig.3. Grain yield response of BRRI dhan95 to added N during T. Aman, 2022

Table 4. Effect of N rates on the total nutrient uptake by rice, T. Aman, 2022, BRRI, Gazipur

Treatments	Total nutrient uptake (kg ha^{-1})				
	N	**P**	**K**	**S**	**Zn**
N_0	56.89 c	10.85 c	86.16	5.34 d	0.23 b
N_{30}	68.72 bc	17.81 abc	103.02	6.67 cd	0.28 b
N_{60}	89.41 ab	20.49 ab	107.13	9.65 ab	0.31 b
N_{90}	103.35 a	23.76 a	118.84	10.57 a	0.48 a
N_{120}	85.08 ab	18.07 abc	103.06	8.78 abc	0.36 ab
N_{150}	78.51bc	15.73 bc	93.09	7.86 bc	0.29 b
CV (%)	9.87	15.54	13.58	10.45	14.06

Boro, 2022-23

Grain and straw yield

The grain and straw yields of BRRI dhan92 showed an increased trend with the increased N rates up to 120 kg N ha^{-1} **(Table 5).** After that the yield difference was insignificant. The nitrogen and grain yield response function derived from the regression analysis was linear in nature with significant ($P<0.01$) R^2 values. The calculated optimum nitrogen dose from the linear equation that maximized the grain yield of BRRI dhan92 was 178 kg ha^{-1}. However, the economically optimum nitrogen dose appeared as 175 kg ha^{-1} **(Fig.4).**

Table 5. Grain and straw yield of BRRI dhan92 under different N doses in Boro, 2022-23

N Dose (kg ha^{-1})	Yield (t ha^{-1})	
	Grain	**Straw**
N_0	2.71 d	2.20 c
N_{40}	3.52 cd	3.03 bc
N_{80}	4.70 bc	4.38 ab
N_{120}	6.15 ab	6.20 a
N_{160}	6.35 a	6.39 a
N_{200}	5.84 ab	5.35 a
CV (%)	10.87	15.67

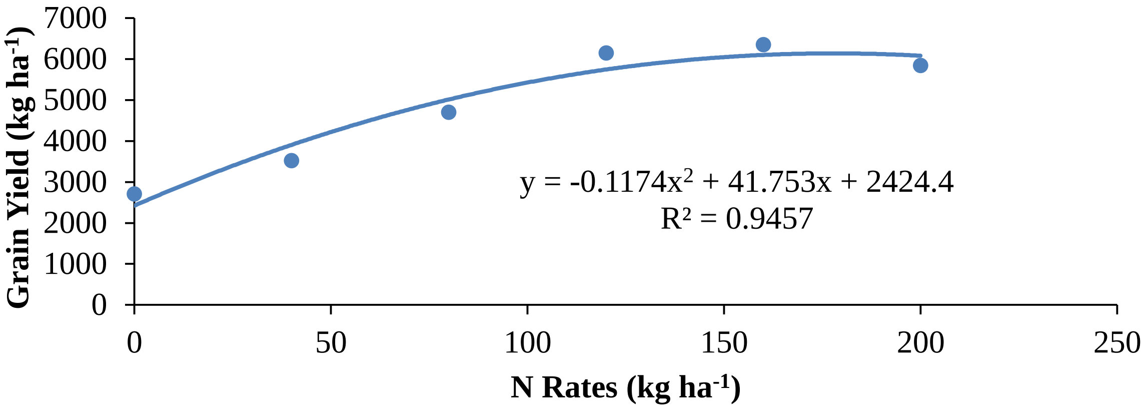

Fig.4. Grain yield response of BRRI dhan92 to added N during Boro, 2022-23

Conclusion

The grain yield of BRRI dhan95 and BRRI dhan92 was significantly influenced by N rates. The calculated economically optimum N dose for BRRI dhan95 in T. Aman season was 80 kg ha^{-1} and in Boro season for BRRI dhan92 it was 175 kg ha^{-1}.

Expt. 4. EFFECTS OF NITROGEN MANAGEMENT ON RICE YIELD AND NITROGEN USE EFFICIENCY

S.M.M. Islam, A. Jahan, T. Islam and A. Islam

Introduction

Rice is the staple food crop in Bangladesh and cultivated in is 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). With the increasing population growth rate, it is projected that the demand for rice by 2050 will be 56% higher compared to the 25.1 million tons production level in 2001 (Mukherjee et al., 2011; Kabir et al., 2015). To meet this demand, rice productivity needs to be increased. One way to do so is by adopting improved agricultural practices including efficient fertilizer management.

Although chemical fertilizers play a critical role in increasing crop productivity. However, inefficient management of nitrogen fertilizer may not only affect crop productivity but also increase N losses through ammonia (NH_3) volatilization, surface runoff, nitrification and denitrification, and leaching and lower nitrogen use efficiency (NUE) (Dong et al., 2012; Islam et al., 2018), which could increase greenhouse gas emissions (Banger et al., 2012; Linquist et al., 2012). In contrast, an efficient and balanced N fertilizer application could substantially improve rice yield and nitrogen use efficiency NUE (Islam et al., 2016, 2018) and reduces GHG emissions (Yao et al., 2017; Islam et al., 2020). This issue is more critical in the current context of increasing fertilizer prices in the global market due to COVID-19 and the Russia-Ukraine conflict. Therefore, fertilizers should be applied judiciously to enhance both crop yield and NUE.

Materials and Methods

The field experiments were conducted in the Bangladesh Rice Research Institute (BRRI) farm, Gazipur. Four rice varieties were tested including BRRI dhan50, BRRI dhan67, BRRI dhan92, and BRRI hybrid dhan3. Six N fertilizer treatments were tested: T1= 3 splits including basal, T2= 3 splits excluding basal, T3= 3 splits including 20% basal, T4= 4 splits including basal, T5= 3 splits excluding basal with DAP, and T6= N control. Recommended N rate @ 150 kg/ha was used for all treatments. The experiment was laid out in factorial RCB with three replications. Nutrients viz. P, K, S & Zn were used as basal at the recommended rate to all plots and the rates were 15 kg P/ha, 70 kg K/ha, 15 kg S/ha, and 1 kg Zn/ha, respectively. For the T5 treatments, urea fertilizer was adjusted with DAP. 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 weight of grain was recorded for every plot and the weight in g plot^{-1} was adjusted at 14% moisture and finally expressed in t ha^{-1}. The sundry weight of straw was also recorded plot-wise and expressed as t ha^{-1}.

Results and Discussion

Rice yield

The application of N fertilizer significantly increased grain and straw yield compared to the control treatment **(Table 6).** Four splits application of N fertilizer significantly increased grain yield compared to three splits application without basal. However, there were no significant variations in rice yield between basal and non-basal as three split applications of N fertilizer. Four split applications of N fertilizer significantly increased agronomic efficiency of N (AE_N) and recovery efficiency of N (RE_N) compared to three split applications **(Table 6).** However, no significant variation in AE_N and RE_N between basal and non-basal applications in the case of three splits of N.

Table 6. Effects of N splits application on rice yield, agronomic efficiency of N (AE_N) and recovery efficiency of N (RE_N) in Boro season at BRRI farm, Gazipur

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	AE_N (kg grain/kg N)	RE_N (%)
3 splits including basal	6.66ab	6.27a	23.30ab	35.99b
3 splits excluding basal	6.44b	6.54a	21.87b	34.04b
3 splits including 20% basal	6.59ab	6.57a	22.88b	41.38b
4 splits including basal	7.14a	6.88a	26.52a	55.02a
3 splits excluding basal with DAP	6.58ab	6.65a	22.79b	43.11b
N control	3.16c	2.88b	-	-
CV (%)	4.22	5.16	6.47	11.56

Conclusion

Since the findings are a one-year experiment it could be continued for another few years to draw conclusive results.

Expt. 5. SCREENING OF N USE EFFICIENT RICE GENOTYPES

U. A. Naher, Masuda Akter, A. A. Rim and A. Islam

Introduction

Rice (Oryza sativa L.) is the staple food crop in Bangladesh and nitrogen (N) is the major yield limiting nutrient in rice production. Farmers apply huge N fertilizer to boost crop growth and yield (Norton et al. 2018). However, N use efficiency is low in rice plant and more than 50% of applied N is not assimilated by the rice plant, and it is lost through different mechanisms including ammonia (NH_3) volatilization, nitrification-denitrification, leaching, and surface runoff (Rochette et al. 2013). Sometimes, low recovery of N by the plant results in poor yield per unit area. Excessive nitrogenous fertilizer application may not result in yield improvement but will lead to serious environmental problems. Hence, to ensure food security and environmental sustainability, agricultural production must be improved by improving land productivity and resource use efficiency. Therefore, breeding for NUE is crucial not only to increase crop yield but also to reduce production costs and environmental pollution. Some parts of Bangladesh and Assam were endowed with a rich source of genetic diversity in Aus rice and bunch of these genotypes named as Bengal Asam Aus Pannel (BAAP) population. Within the global rice germplasms, the BAAP accessions are phenotypically diverse containing the donors of a number of abiotic stress resistance-related traits. There is an enormous opportunity to isolate the outstanding NU efficient cultivars for further breeding high-yielding NU efficient varieties suitable for the rainfed lowland rice ecosystems. Therefore, this study was undertaken to understand the nature and the magnitude of quantitative variation for NUE and related traits and identify high-yielding nitrogen use efficient rice genotypes for low input lowland rice ecosystem that may help in designing effective breeding strategies for the region. Objectives of the present study were to; 1. To find the N use efficient genotypes. 2. To find the agronomic traits related to efficient N management and GWA mapping of selected NUE lines

Materials and Methods

A set of 179 BAAP rice genotypes were grown in BRRI HQ farm, Gazipur to find out the N use efficient traits. BRRI dhan28 was used as check variety. Two N fertilizer doses (kg ha^{-1}); N_{50} and N_{100} were tested among the BAAP populations following split-plot design with four replications, where, N doses were assigned in the main-plot and BAAP populations in the sub-plot. Flat doses of (kg ha^{-1}) of P-K-S-@ 20-50-10 were applied along with N treatment. About 25 days old BAAP populations were grown. Rice seedlings were transplanted at 20 x 20 cm^2 spacing. Nitrogen fertilizer was used as urea and applied in 2 equal splits; one just before transplanting and another at panicle initiation stage. The flooded water level at 5-7 cm depth was maintained during rice cultivation, and then drained 21 days before rice harvesting. Leaf SPAD reading and flowering date were recorded. Crop was harvested at the maturity and grain yield was adjusted at 14% moisture and expressed as g/plant.

Results and Discussion

Grain yield and N efficient populations. Pooled ANOVA (data not shown) revealed significant genotypic differences for all the traits. Principal component analyses were done on the basis of grain yield for each treatment. Study result showed that in the N_{50} treatment 6 distinct clusters and in N_{100} treatment 7 clusters were found **(Fig. 5a and 5b).**

In the N_{50} treatment average grain yield varied from 6.6 to 19.2 g plant^{-1} and formed 6 clusters. The highest population found in the Cluster-3 (57 population) that produced grain average 7 g plant^{-1} followed by Cluster 5 (39 populations) that produced average grain 10.4 g plant^{-1}. The highest grain yield (19.2 g plant^{-1}) obtained in the Cluster-1 that had only 11 populations **(Fig. 5a and 6).** On the other hand in N_{100} treatment 7 distinct Cluster found. In this treatment average grain yield varied 7.80 to 20.54 g plant^{-1}. In the Cluster-1 (18 populations) produced the highest grain yield 20.54 g plant^{-1} followed by Cluster-6 produced 18.34 g plant^{-1} (21 populations) **(Fig.5b and 6).** The expected N use efficient populations were identified as AUS 175, AUS 328, AUS MURALI, BAWOI, BROWN GORA S.B.92, DESHI BORO, DJ 24, KALI AUS, KALI BORO 138-2, KALI BORO 704, LALI BORO, PURANUKA, SAITA BORO, SADA BORO, SONA MUKHI.

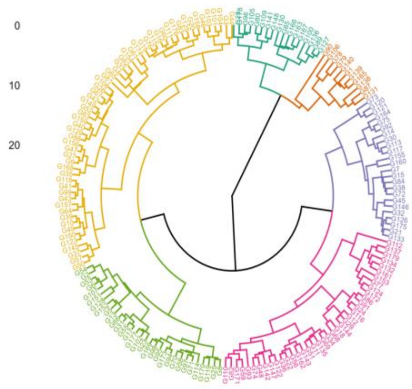

Fig. 5a. PCA analysis generated 6 clusters on the basis of grain yield in the N_{50} treatment

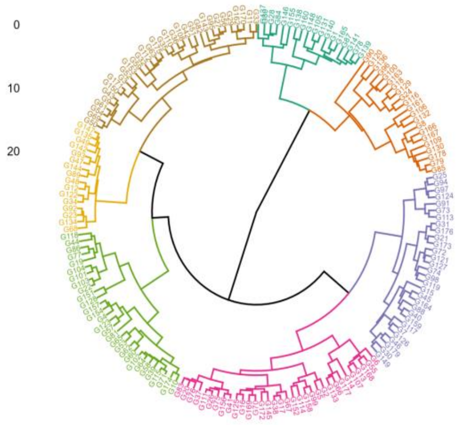

Fig. 5b. PCA analysis generated 7 clusters on the basis of grain yield in the N_{100} treatment

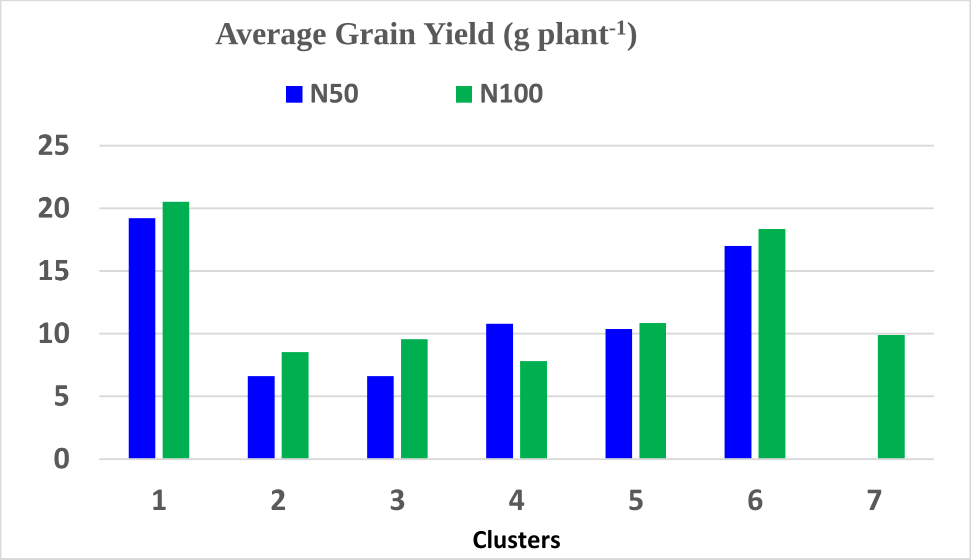

Fig. 6. Average grain yield of (g plant^{-1}) of 189 BAAP populations. Clusters generated using Principal component analyses

Conclusion

The expected N use efficient populations were identified as AUS 175, AUS 328, AUS MURALI, BAWOI, BROWN GORA S.B.92, DESHI BORO, DJ 24, KALI AUS, KALI BORO 138-2, KALI BORO 704, LALI BORO, PURANUKA, SAITA BORO, SADA BORO, SONA MUKHI. These populations can be used in genome wide association (GWAS) study and developed N use efficient modern rice varieties.

Expt. 6. EFFECTS OF LIQUID NANO UREA ON RICE YIELD IN WETLAND CONDITIONS

M.N. Islam, M. Iqbal, M. Akhter and A. Islam

Introduction

The utilization of nanotechnology in agriculture has opened up new avenues for enhancing crop production and addressing the challenges posed by traditional agricultural practices. In this context, one of the notable innovations is the application of nano urea in liquid form, a nanoscale version of conventional nitrogen fertilizer, in rice cultivation. Rice, a staple crop feeding a significant portion of the global population, holds a paramount position in food security considerations. Nitrogen, a crucial nutrient for plant growth, plays a pivotal role in improving crop yield and quality. The introduction of liquid nano urea (LNU) as a novel approach to delivering nitrogen to rice plants has sparked curiosity and debate regarding its potential effects on rice yield. This introduction delves into the evolving landscape of research dedicated to exploring the impacts of LNU on rice agriculture, encompassing its influence on yield outcomes. Spraying nano urea could increase 12–16% rice yield relative to the recommended NPK inorganic fertilizer in Andaman, India (Velmurugan et al., 2021). In another study conducted in Chhattisgarh, India, it was also concluded that 50% of recommended NPK fertilizer along with two sprays of nano urea, performed similarly to the 100% of recommended NPK inorganic fertilizer (Sahu et al., 2022). By examining and synthesizing these effects, we aim to provide insights into the opportunities and challenges associated with incorporating LNU into rice cultivation, ultimately contributing to the ongoing discourse on optimizing agricultural practices for greater food security and environmental stewardship.

Materials and Methods

A field experiment was conducted at BRRI farm, Gazipur, in Boro 2022-23 to test the effectiveness of liquid nano urea (LNU) in increasing the grain yield of BRRI dhan89. Seeds were sown on 5 December 2022 in the seedbed, and seedings of BRRI dhan89 were transplanted on 23 January 2023 in the main field. The unit plot size was 7 m × 6.5 m. Four treatments (T_1, T_2, T_3 and T_4) were assigned in a randomized complete block design (RCBD) with three replications. In T_1 treatment, 66% of the recommended dose of urea (66% RDU, urea @ 105.6 kg N/ha) was applied in 2 equal splits (basal and active tillering), while in T_2 treatment, LNU was applied in addition to 66% RDU (66% RDU+LNU). In T_3 treatment, the recommended dose of urea (100% RDU, urea @ 160 kg N/ha)) was applied in 3 equal splits (basal, active tillering and before 5-7 days of panicle initiation), whereas LNU was applied in addition to the 100% RDU in T_4 treatment (100% RDU+LNU). The blanked dose of PKSZn@20-80-10-1 kg/ha was applied at final land preparation in all treatments. The dose of LNU was 500 ml/acre, which was sprayed (3 ml/L of water) two times (before 5-7 days of panicle initiation and before one week of flowering). Grain yield was recorded from the central 5 m^2 harvest area in each plot at maturity and reported on 14% moisture basis.

Results and Discussion

Application of urea @ 105.6 kg N ha^{-1} (66% RDU, T_1) produced the lowest grain of 5.74 t ha^{-1} compared to other treatments **(Table 7).** Spray of LNU with 66% RDU (T_2) significantly increased the grain yield to 6.55 t ha^{-1}, which was 14% higher than the T_1 treatment. Moreover, application urea @ 160 kg N ha^{-1} (100% RDU, T_3) produced the highest grain of 7.00 t ha^{-1}, which was statistically identical to T_2 treatment (66% RDU+LNU). It indicates that LNU may save 34% Urea without significant yield reduction. Furthermore, the additional use of LNU to 100% RDU (T_4) reduced grain yield by 7% relative to RDU (T_3).

Table 7. Effect of Liquid Nano Urea on the grain yield of BRRI dhan89 at BRRI farm, Gazipur, in Boro 2022-23

Treatment	**GY (t ha^{-1})**
T_1 = 66% RDU	5.74 c
T_2 = 66% RDU+LNU	6.55 ab
T_3 = 100% RDU	7.00 a
T_4 = 100% RDU+LNU	6.48 b
Level of significance	**
CV	3.8

RDU = recommended dose of urea, LNU = liquid nano- urea

Conclusions

The present study reveals that LNU might save one-third of urea fertilizer without sacrificing the rice yield. However, further multi-location studies in different seasons are needed to draw a conclusion and confirm the present findings.

Expt. 7. EFFECT OF NITROGEN AND POTASSIUM RATES ON MODERN RICE CULTIVATION

M.N. Islam, T. Islam, S.M.M. Islam, M. Iqbal and A. Islam

Introduction

Among the major nutrients, nitrogen (N) and potassium (K) are two essential nutrients that play critical roles in plant growth, development, and overall crop yield. The interaction between N and K in crop fertilization is a subject of fundamental importance in modern agriculture (Milford and Johnston, 2007). The way these nutrients interact and influence each other's availability to plants has a profound impact on agricultural productivity and resource management. The form of N fertilizer can affect K availability both on a short- and long-term basis. In reality, the application of NH_4^+ or K^+ to soil may lead to increases as well as decreases in the non-exchangeable pool of the counter ion (Bar-Tal, 2011).

Nitrogen is a primary component of amino acids, proteins, and chlorophyll, making it central to photosynthesis and essential for overall plant growth (Noor, 2017). It promotes vigorous vegetative growth, enhancing the development of leaves, stems, and overall biomass. Adequate nitrogen supply is pivotal for achieving optimal crop yields. On the other hand, potassium is responsible for various physiological processes within plants. It regulates water uptake and transpiration, enhances stress tolerance, and plays a crucial role in nutrient transport and enzyme activation (Hou et al., 2020; Nieves-Cordones et al., 2019). Potassium is a significant contributor to the carbon and nitrogen metabolism in crops (Hu et al., 2015). Understanding the intricate interplay between N and K is essential for achieving the highest crop yields (Ye et al., 2021) while maintaining sustainable agricultural practices. When these nutrients are not in balance, it can lead to nutrient deficiencies or excesses, negatively impacting crop health and productivity.

This exploration delves into the complex dynamics of N and K interactions in rice cultivation, with a focus on their combined effects on rice yield. We aim to unravel the mechanisms by which these two essential nutrients influence each other, as well as their cumulative impact on plant growth, grain production, and overall agricultural sustainability. By gaining deeper insights into these interactions, we hope to provide valuable guidance for farmers and agricultural professionals seeking to optimize nutrient management strategies and achieve higher crop yields while minimizing environmental impacts. Therefore, the present study was undertaken to find out the suitable ratio of N and K for obtaining the maximum yield of MV rice and to study N and K dynamics in soil and plant.

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}. In 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 that of N in the subplots. Soil test-based flat rates of P and S were applied to all the plots. The application rate of K was 0, 50, 100, 150, and 200 kg ha^{-1} both in T. Aman and Boro seasons. Nitrogen was applied @ 0, 50, 75, and 100 kg ha^{-1} in T. Aman season, while in Boro season, the rate of N was 0, 100, 150 and 200 kg ha^{-1}. The tested varieties were BRRI hybrid dhan6 and BRRI hybrid dhan3 in the T. 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 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. While 16 hills from each plot were collected for total straw yield calculation, 125 hills were considered for grain yield calculation. Grain yield was recorded at 14% moisture content, and straw yield was oven dry basis.

Results and Discussion

Grain yield

The interaction effects of K and N on the grain yield of BRRI hybrid dhan6 in T. Aman 2022 and BRRI hybrid dhan3 in Boro 2023 were significant **(Table 8).** In T. Aman 2022, application of 0, 50 and 75 kg N/ha did not show considerable variations in grain yield under K-deficient conditions, but 100 kg N ha^{-1} significantly decreased grain yield of BRRI hybrid dhan6. Furthermore, K rates were not responsible for increased grain yield in N-deficient conditions. Application of N @ 50 kg ha^{-1} with 50 kg K ha^{-1} produced 5.45 t ha^{-1} rice grains, which was statistically identical with the highest grain yield of 5.80 t ha^{-1} achieved with a combination of 100 kg N and 150 kg K ha^{-1} (Table 8). So, the combination of 50 kg K and 50 kg N is suitable for BRRI hybrid dhan6 cultivation to get optimum yield. In Boro 2023, a combination of 200 kg N and 150 kg K ha^{-1} produced the highest grain yield (7.54 t ha^{-1}) of BRRI hybrid dhan3, which was statistically identical to the combination of 150 kg N and 150 kg K ha^{-1}. Therefore, combining 150 kg N and 150 kg K ha^{-1} could be suitable for BRRI hybrid dhan3, achieving optimum grain yield. In N-deficient conditions, increased K rates were not responsible for increasing the grain yield of BRRI hybrid dhan3. On the other hand, in K-deficient conditions, the grain yield of BRRI hybrid dhan3 was increased up to a certain level of N (150 kg ha^{-1}), and then the yield started to decline.

Straw yield

The interaction effect of K and N on the straw yield of MV rice in T. Aman 2022 and Boro 2022-23 was also significant **(Table 9).** Similar to the grain yield of BRRI hybrid dhan6 in T. Aman 2022, a combination of 50 kg N and 50 kg K ha^{-1} was suitable for achieving optimum straw yield. In Boro 2022-23, increasing N rates gradually increased the straw yield of BRRI hybrid dhan3, and the highest straw yield (7.48 t ha^{-1}) was obtained with the combination of 200 kg N and 100 kg K ha^{-1}.

Conclusion

The interaction effect of N and K on rice yield was significant in both T. Aman and Boro seasons. It was observed that a very high N dose at potassium deficient conditions adversely affects rice yield, while at N deficient conditions, increasing rates of K fertilizer did not influence rice yield. Therefore, maintaining an appropriate N: K ratio is crucial for MV rice production. The optimum N and K rates for achieving the maximum grain yield were 50 and 50 kg ha^{-1}, respectively, for BRRI hybrid dhan6 during T. Aman, while for BRRI hybrid dhan3 in Boro season, the rates were 150 kg N and 150 kg K ha^{-1}.

Table 8. Effect of N and K on the grain yield (t ha^{-1}) of MV rice in T. Aman 2022 and Boro 2023 at BRRI farm, Gazipur

K rates (kg ha^{-1})	N rates (kg ha^{-1})							
	0	50	75	100	0	100	150	200
	BRRI hybrid dhan6 (T. Aman)				BRRI hybrid dhan3 (Boro)			
0	4.65aA	4.71bA	4.48cA	3.35cB	2.51aC	4.99bAB	5.39dA	4.72cB
50	4.98aB	**5.45aA**	5.42bA	5.04bB	2.61aB	6.48aA	6.88bcA	6.94bA
100	4.64aB	5.61aA	5.50abA	5.36bA	2.85aC	6.50aB	6.41cB	7.16abA
150	4.72aC	5.34aB	5.80aA	5.80aA	2.87aC	6.65aB	**7.34abA**	7.54aA
200	4.69aB	5.35aA	5.37bA	5.21bA	2.73aC	6.80aB	7.53aA	7.13abAB
ANOVA (p values)								
Nitrogen (N)	<0.001				<0.001			
Potassium (K)	<0.001				<0.001			
N × K	<0.001				<0.001			

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

Table 9. Effect of N and K on the straw yield (t ha^{-1}) of MV rice in T. Aman 2022 and Boro 2023 at BRRI farm, Gazipur

K rates (kg ha^{-1})	N rates (kg ha^{-1})							
	0	50	75	100	0	100	150	200
	BRRI hybrid dhan6 (T. Aman)				BRRI hybrid dhan3 (Boro)			
0	3.60aB	3.52cB	4.59bA	4.06cAB	2.19bC	4.16cB	4.54dAB	4.98cA
50	4.04aB	**4.89aA**	4.98abA	4.83bA	2.09bD	4.79bC	5.56cB	6.60bA
100	4.23aC	4.74abBC	5.42aA	5.09abAB	2.17bD	4.87bC	6.65aB	**7.48aA**
150	3.91aB	4.29abB	5.49aA	5.44abA	2.85aC	5.16abB	6.43abA	7.36aA
200	4.17aB	4.20bB	4.97abA	5.52aA	2.18bC	5.47aB	5.96bcB	7.03abA
ANOVA (p values)								
Nitrogen (N)	<0.001				<0.001			
Potassium (K)	<0.05				<0.001			
N × K	<0.05				<0.001			

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

Expt. 8. RESPONSE OF MODERN RICE VARIETIES UNDER DEFICIENT PHOSPHORUS CONDITION

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

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 dhan4 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 2022 and Boro 2022-23 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 dhan4 in T. Aman and BRRI hybrid dhan3 in Boro season were used as tested rice varieties. Each plot received 90 kg N, 42 kg K 10 kg S and 1 kg Zn ha^{-1} in T. Aman and 160 kg N, 60 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. Thirty- and forty-day old seedlings (2-3 per hill) were transplanted at 15cm×20cm spacing in T. Aman and 20cm×20cm spacing in Boro season. Crops were grown under fully irrigated condition. At maturity the crop was harvested manually from the center of each plot of 5 m^2 area at 15 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. 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 2022

In deficient soil P condition, the P fertilizer has significant effect on grain yield and other yield parameters of BRRI hybrid dhan4 in T. Aman season **(Table 10).** The tiller and panicle number per meter square increased with increasing the P doses up to T_3 (75% STB P) treatments after that tiller and panicle number remain almost same up to T_6 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_4 (100% STB P) treatment and after that the grain yield obtained almost similar up to T_6 (150% STB P) treatment. Although the highest grain yield was obtained with T_6 treatment (5.65 t ha^{-1}), but it was statistically similar with T_4 (5.60 t ha^{-1}) and T_5 (5.63 t ha^{-1}) treatment. The P control plot yielded only 3.36 t ha^{-1}. Similar yield trend was observed for straw production. From the response curve, the economic optimum dose of P for BRRI hybrid dhan4 in P deficient soil was found 29 kg P ha^{-1} **(Fig. 7).**

Table 10. Response of phosphorus on tiller, panicle, grain and straw yield of BRRI hybrid dhan4 in T. Aman 2022 at BRRI farm, Gazipur

Treatment	BRRI hybrid dhan4			
	Tiller m^{-2}	Panicle m^{-2}	GY (t ha^{-1})	SY (t ha^{-1})
T_1 = P control	179 c	164 d	3.36 d	4.39 c
T_2 = 50% STB P	218 b	205 c	4.46 c	5.06 b
T_3 = 75% STB P	230 ab	216 bc	5.15 b	5.44 a
T_4 =100% STB P	237 a	226 ab	5.60 a	5.67 a
T_5 = 125% STB P	241 a	229 ab	5.63 a	5.69 a
T_6 = 150% STB P	245 a	231 a	5.65 a	5.68 a
LSD (0.05)	15	14	0.40	0.33
CV (%)	2.43	2.26	2.84	2.18

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.

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 11).** 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 1.78 tha^{-1} and with 50% and, or 75% applying of fertilizer P, grain yield increased sharply and significantly up to T_4 (8.15 t ha^{-1}) for BRRI hybrid dhan3 which was significantly higher than T_3 and T_2 treatment. Statistically similar grain yield were obtained in T_4, T_5 and T_6 treatment where, 100%, 125% and 150% STB- P doses were applied, respectively. Similar trend was obtained in case of straw yield of BRRI hybrid dhan3. From the response curve, the economic optimum dose of P for BRRI hybrid dhan3 was found 24.5 kg P ha^{-1} in P deficient soil and in Boro season **(Fig. 8).**

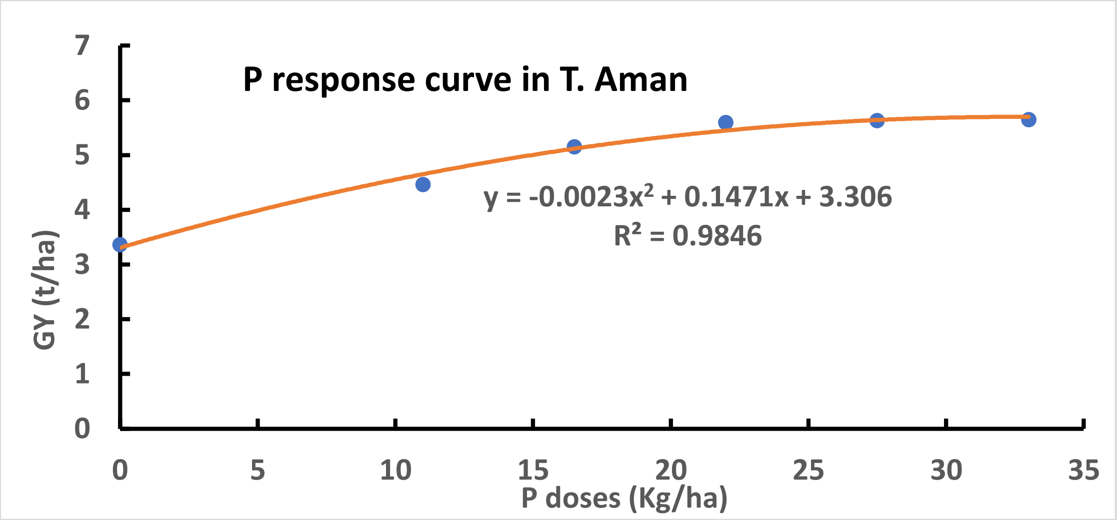

Fig. 7. Phosphorus response curve of BRRI hybrid dhan4 at BRRI, Gazipur in T. Aman 2022

Table 11. Response of phosphorus on grain and straw yield of BRRI hybrid dhan3 in Boro 2022-23 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	151 c	136 b	1.78 d	1.60 d
T_2 = 50% STB P	145 b	235 a	6.67 c	5.85 c
T_3 = 75% STB P	257 ab	246 a	7.38 b	6.35 bc
T_4 =100% STB P	266 ab	255 a	8.15 a	7.09 a
T_5 = 125% STB P	272 ab	260 a	7.96 a	6.83 ab
T_6 = 150% STB P	276 a	262 a	7.91 a	6.81 ab
LSD (0.05)	30	32	0.44	0.65
CV (%)	4.32	4.80	2.32	3.95

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.

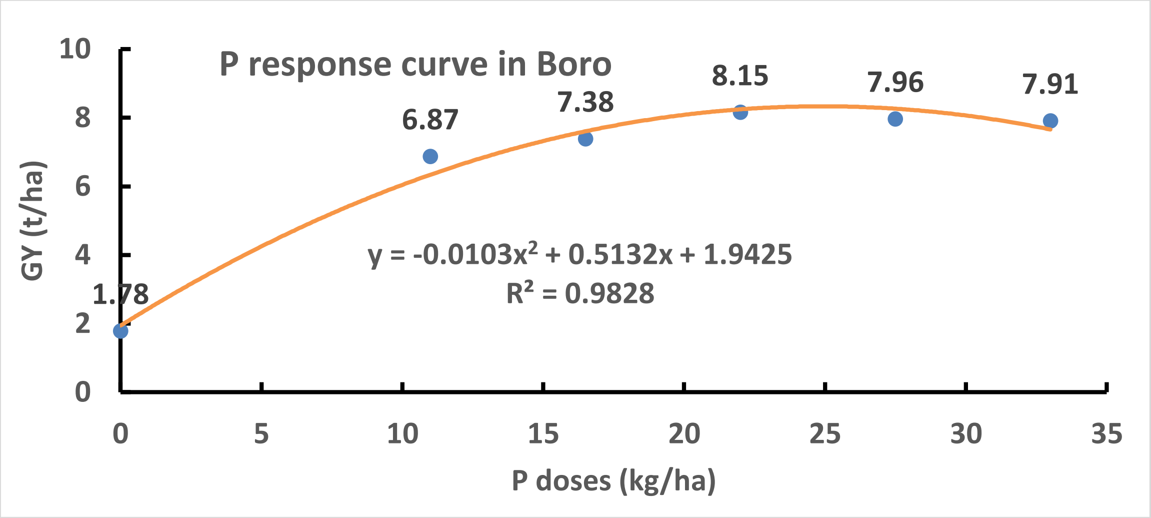

Fig. 8. Phosphorus response curve of BRRI hybrid dhan3 at BRRI, Gazipur in Boro 2022-23

Conclusion

Soil available P levels can be decreased tremendously under wetland rice cultivation 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). The economic optimum dose of P for BRRI hybrid dhan4 in T. Aman was 29 kg P ha^{-1} and for BRRI hybrid dhan3 in Boro was 24.5 kg P ha^{-1}. 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. 9. EFFECT OF PHOSPHATIC FERTILIZERS ON GROWTH AND YIELD OF RICE

A.T.M. Sakhawat Hossain, F. Rahman, MN Islam and A. Islam

Introduction

Phosphorus (P) is second most important plant nutrient after nitrogen. Added inorganic P as water soluble phosphate fertilizer under-goes complex exchanges between various soil-P pools. This is especially true in the tropics where many soils have extremely high P fixation capacity. Phosphorus deficiency in soil extends the lifespan of rice plants, delayed flowering and maturity (Kamrunnahar*et al.*, 2017). 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). Consequently, large amounts of fertilizer P are needed to attain reasonable crop yields. In Bangladesh context, generally triple super phosphate (TSP) used as fertilizer-P and the price of TSP is the highest among the major nutrients. Now a days, TSP is scarce in market of Bangladesh where fertilizer di-ammonium phosphate (DAP) can be used as an alternate source of P and N for plant nutrition. DAP is highly soluble and thus dissolves quickly in soil to release plant-available phosphate and ammonium. Besides, Single super phosphate (SSP) and Rock phosphate (RP) can be used as an alternative source of P fertilizer. Since the recovery efficiency of P is low, there is a need to find the right P source to increase fertilizer use efficiency as well as yield.

Materials and Methods

The experiments were conducted at BRRI farm, Gazipur during Boro 2022-23 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: TSP-P with basal N, T_3: TSP-P without basal N, T_4: DAP-P without basal N, T_5: 50% TSP + 50% DAP + with 50% basal N, T_6: 50% TSP + 50% DAP + without basal N. BRRI hybrid dhan3 in Boro season were used as tested rice varieties. Each plot received 160 kg N, 60 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. Thirty day old seedlings (2 per hill) were transplanted at 20cm × 20cm spacing in Boro season. Crops were grown under fully irrigated condition. At maturity the crop was harvested manually from the center of each plot of 5 m^2 area at 15 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 nutrient content and uptake of phosphorus. 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

Growth and yield of Boro 2022-23

Phosphorus as TSP or DAP fertilizer in have significant effect on growth and yield of BRRI hybrid dhan3 in Boro season **(Table 12).** The tiller and panicle production per meter square increased significantly with application of TSP or DAP fertilizer over P control. Within TSP or DAP application, no significant differences were found regarding tiller and panicle production. Under control P condition (T_1), grain yield was only 2.78 tha^{-1} and with application of P fertilizer as TSP or DAP or the combination of TSP and DAP grain yield increased significantly over P control. The highest grain yield was obtained in T_2 (7.42 t ha^{-1}) treatment where, TSP-P was applied with basal N followed by TSP-P without basal N (T_3: 7.01 t ha^{-1}). The DAP-P without basal N (T_4: 6.58 t ha^{-1})) gave significantly lower yield than T_2 and T_3 **(Table 12).** The combination of TSP-P and DAP-P with and without basal N i.e., T_5 (6.74 t ha^{-1}) and T_6 (6.67 t ha^{-1}) treatment also gave significantly lower grain yield than TSP-P alone (T_2 and T_3). Similar trend was observed in straw yield in both TSP or DAP application of BRRI hybrid dhan3 in Boro season.

Table 12. Efficacy of TSP and DAP fertilizer on growth and yield of BRRI hybrid dhan3, Boro 2022-23 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	172 b	157 b	2.78 c	2.14 c
T_2 : TSP-P with basal N	259 a	245 a	7.42 a	6.57 a
T_3 : TSP-P without basal N	251 a	237 a	7.01 ab	5.97 ab
T_4 : DAP-P without basal N	233 a	218 a	6.58 b	5.50 b
T_5 : 50% TSP+ 50% DAP+ with 50% basal N	237 a	225 a	6.74 b	5.69 b
T_6 : 50% TSP+ 50% DAP+ without basal N	236 a	221 a	6.67 b	5.62 b
LSD (0.05)	40	36	0.58	0.73
CV (%)	6.11	5.92	3.33	4.87

N.B. 100% STB- P = 22 kg Pha^{-1} irrespective of P sources in P deficient soil

Conclusion

Phosphorous availability in soil may varied with sources of P which reflected on rice yield and other parameters. Same doses of TSP fertilizer performed better than DAP fertilizer or the combinations of TSP and DAP fertilizer. Regardless this, basal application of N fertilizer has some yield advantage in all cases. Further studies should be needed to verify this result.

Expt. 10. RESPONSE OF ADDED ZINC ON BRRI ZINC ENRICHED RICE VARIETIES

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

Introduction

Zinc is a most vital micronutrient, deficiency of which adversely affects children's natural growth and immune system. In Bangladesh, over 40% children under five are stunted while an estimated 44 percent children of the same age group are at risk of zinc deficiency. Though fruits, vegetables and animal products are rich in micronutrients, these are often not available for the poor in Bangladesh as well as in many other Asian countries where the poor's daily diet consists mostly of relatively much inexpensive low-zinc staple -- rice. Micronutrients provided by soils are crucial for plant development and growth. Nutrient mining occurs when crops take out a high proportion of the nutrients available in the soil, leaving a nutrient imbalance that threatens the sustained provision of food and ecosystem services. Exploring different soil management practices can help increase the nutritional content of crops, as many are directly affected by the nutritional status of the soil. Zinc fertilization is an important factor for rice growth and yield and also rice quality. There are several ways for Zn fertilization like broadcasting or band placement in soil, foliar spray, seedling root dip, seed dressing etc. The study was therefore undertaken to compare the performance of fortified rice var. BRRI dhan74 with BRRI dhan89 and to determine the suitable Zn fertilizer management.

Materials and Methods

The experiment was conducted in BRRI farm, Gazipur in Boro 2022-23. The soil of the experimental field was clay loam in texture having pH 6.75. The other nutrient status was as follows: organic carbon 1.18%, total N 0.11%, exchangeable K 0.13 meq/100 g soil, available S 12 mg kg^{-1} and available Zn (DTPA extraction) 1.0 mg kg^{-1}. The experiment was conducted in a split-plot design with three replications where Zn fertilizer doses were assigned in main-plot and rice varieties in sub-plot. The individual main-plot size was 6 m × 6 m. Two rice genotypes viz. BRRI dhan74 (Zn rice) and BRRI dhan89 (non-Zn rice) were evaluated under six different levels of Zn application. The treatments were T_1: No Zn fertilizer (control), T_2: Zn @ 2.0 kg/ha as basal, T_3: Zn @ 3.0 kg/ha as basal, T4: Zn @ 2.0 kg/ha as basal + One-time $ZnSO_4$ spray (0.5%) at PI stage, T5: Zn @ 3.0 kg/ha as basal + One-time $ZnSO_4$ spray (0.5%) at panicle initiation (PI) stage and T_6: $ZnSO_4$ spray (0.5%) two times at active tillering and PI stage of rice. All treatments had received a blanket dose of N-P-K and S @ 150-20-60-15 kg ha^{-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. Zinc fertilizer was applied according to treatment combinations. Thirty-five days old seedlings of each rice variety was transplanted on the 2nd week of December. 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 also recorded. Data were analyzed statistically using software STAR.

Results and Discussion

Grain yield of BRRI dhan74

Effect of added Zn as basal or spray or basal and spray at different stages of BRRI dhan74 have great impact on grain yield in Boro season **(Table 13).** Without application of Zn fertilizer, grain yield attained more than seven ton per hectare. When applied Zn fertilizer as basal @ 2 or 3 kg/ha, grain yield decreased significantly. When applied Zn fertilizer in basal (2 or 3 kg/ha) and with spray at panicle initiation stage (@ 0.5%), grain yield increased significantly over basal application of Zn. Spray of Zn fertilizer at two times one at active tillering and another in PI stage also increased grain yield significantly over control.

Grain yield of BRRI dhan89

The Zn fertilizer apply as basal or spray or basal and spray at different growth stages have great influence on grain yield of BRRI dhan89 in Boro season **(Table 13).** Application of Zn fertilizer as basal and basal with spray increased grain yield significantly over control. Only two times Zn fertilizer spray (@0.5%) didn’t increased grain yield significantly over basal application in BRRI dhan89.

Table 13. Effect of added Zn on grain yield of BRRI dhan74 and BRRI dhan89 in Boro 2022-23, BRRI, Gazipur

Treatment	Grain yield (t ha^{-1})	
	BRRI dhan74	BRRI dhan89
T$_1$: No Zn fertilizer (control)	7.13 bc	6.82 b
T$_2$: Zn @ 2.0 kgha^{-1} as basal	6.95 c	7.31 a
T$_3$: Zn @ 3.0 kgha^{-1} as basal	6.94 c	7.40 a
T$_4$: Zn @ 2.0 kgha^{-1} as basal + $ZnSO_4$ spray (0.5%)	7.65 a	7.10 ab
T$_5$: Zn @ 3.0 kgha^{-1} as basal + $ZnSO_4$ spray (0.5%)	7.55 a	7.35 a
T$_6$: Two times $ZnSO_4$ spray (0.5%)	7.43 ab	6.87 b
CV (%) : Treatment	2.10	
CV (%) : T X V	1.54	

Conclusion

Application of Zn has great influence on grain yield. The Zn enriched rice BRRI dhan74 performed well with Zn spraying but the non Zn enriched rice BRRI dhan89 showed better grain yield in basal application of Zn in grey terrace soil of AEZ 28. Zinc uptake at different growth stages may define clearly these findings. Further experiments in different calcareous and non-calcareous soil should conduct to verify this result.

Expt. 11. EFFECTS OF POTASSIUM FERTILIZATION AT DIFFERENT GROWTH STAGES ON GROWTH AND YIELD OF RICE

A. Islam and M. Iqbal

Introduction

Potassium (K) is an essential nutrient for plant growth and development. It is known as nutrient of quality and so far, there is no report of adverse effects due to its excess use. Plant absorbs huge amount of potassium from soil. Farmers apply low dose of potassium for their crops and removes all of crop residues from the field. As a result, potassium is mining from the soil day by day. Potassium management is crucial for disease free, insect free and other biotic and abiotic stress-free healthy crop cultivation with higher crop yield. Now a days researchers and other relvant sources claiming that split application and additional K with recommended K dose is beneficial for crop growth and yield. Considering these information Soil Science Division undertaken an experiment to confirm the benefits of split K application.

Materials and Methods

The experiment was conducted T. Aman 2021, 2022, 2023 and Boro 2021-22, 2022-23 seasons in RCB design with three applications at Paba, Rajshahi; Dumuria, Khulna and Amtoli, Borguna.The objective was to find out the effect of potassium fertilization at different growth stages of rice.

Treatments:

Rajshahi

$T_1 = K_0$ (No Potassium)

$T_2 = K_{Basal(RD)}$ (Recommended dose as basal)

$T_3 = T_{2+}K_{20}$15 DAT (20kg k/ha at tillering stage)

$T_4 = T_{2+}$ K_{20}15 DAT $_+K_{20}$ 30 DAT (20kg k/ha at max. tillering stage)

$T_5 = T_{2+}$ K_{20}15 DAT $_+K_{20}$30DAT $_+K_{20}$ 50 DAT (20kg k/ha at panicle initiation stage)

$T_6 = T_2 + K_{20}$ MTS + K_{20}PIS

$T_7 = T_2 + K_{20}$MTS

$T_8 = T_2 + K_{20}$PIS

T_9 = Two-third of RD as basal + K_{20}PIS

Khulna and Borguna

T. aman season:

T_1= K application @ 60 kg/ha as basal.
T_2= K application @ 40 kg/ha as basal + 20 kg/ha at tillering stage.
T_3= K application @ 40 kg/ha as basal + 20 kg/ha at Maximum tillering stage.
T_4= K application @ 40 kg/ha as basal + 20 kg/ha at Panicle initiation stage.
T_5= K application @ 20 kg/ha as basal +20 kg/ha at Maximum tillering + 20 kg/ha at PI stage.

Boro season:

T_1= K application @ 75 kg/ha as basal.
T_2= K application @ 50 kg/ha as basal + 25 kg/ha at tillering stage.
T_3= K application @ 50 kg/ha as basal + 25 kg/ha at Maximum tillering stage.
T_4= K application @ 50 kg/ha as basal + 25 kg/ha at Panicle initiation stage.
T_5= K application @ 25 kg/ha as basal +25 kg/ha at Maximum tillering + 25 kg/ha at PI stage.

Results and Discussion

Paba, Rajshahi

In T. Aman and Boro season, 2/3 basal application and 20 kg at PI stage performed better than other treatments **(Fig. 9).** Extra 20 kg ha^{-1} K application at different growth stages yielded more than basal application alone. However, extra 20 kg K ha^{-1} (T_2 to T_8) did not show any positive effects compared to the split application of recommended dose (T_9)

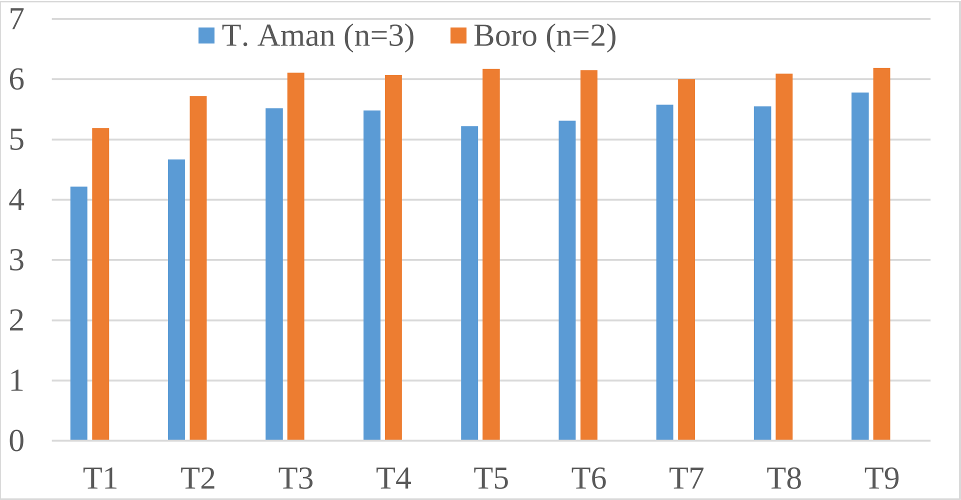

Fig. 9. Grain yield (t/ha) under different K management, Paba, Rajshahi, 2021-2023

Khulna and Borguna

Effect of split application of potassium on grain yield is shown in **Fig. 10.** The highest grain yield is found with two split application of Potassium which was significantly different from full dose basal application. Three splits application of K (T_5) showed no significant benefit regarding grain yield of T. Aman and Boro rice compared to two split applications (basal and PI stage, T_4).

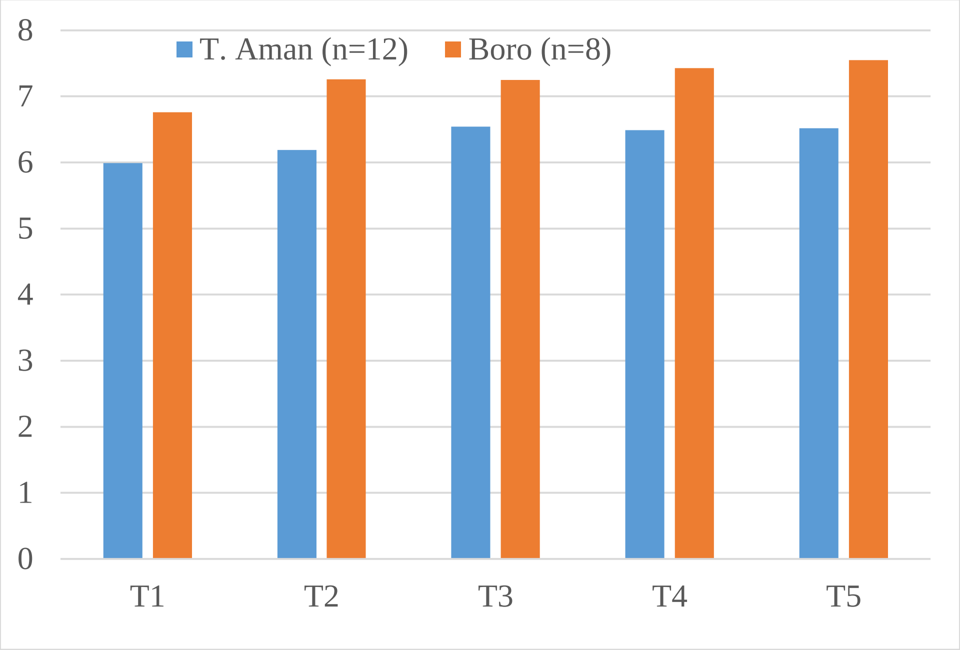

Fig. 10. Grain Yield (t/ha) under K management, Khulna T. Aman 2021-2023

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

Project 2. Nutritional Problems in Soil

Expt. 12. LONG-TERM EFFECT OF ORGANIC AND INORGANIC NUTRIENTS ON YIELD AND YIELD TREND OF LOWLAND RICE

F. Rahman, A.T.M. Sakhawat Hossain, M. R. Islam and A. 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 14).** 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 kg ha^{-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 kg ha^{-1} and 100-10-80-5 kg ha^{-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 t ha^{-1}), saw dust (SD, 3 t ha^{-1}), cow dung (CD, 3 t ha^{-1}), mixed manure (CD: PM: SD: OC= 1:1:1:0.5) and poultry manure (PM, 2 t ha^{-1}) in T_{10}, T_9, T_5, T_{11} and T_8 treatment, respectively. Only N @ 138 kg ha^{-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 kg ha^{-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 t ha^{-1}), PM (2 t ha^{-1}) and VC (2 t ha^{-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 100-10-80-5-2 kg ha^{-1} for Boro and T. Aman, respectively. In T. Aman 2022, the variety was BRRI dhan87 and in Boro 2022-23, it was BRRI dhan89.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 14. Treatment details of the long-term missing element experiments, 1985-2023

Treat.	Original (1985)	Reverse (2000)	Treatment (2009-10)	Treatment (2011-23- Boro/T. Aman)
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@ 160/100-12/10-40-5-2 kg ha^{-1}
T_{12}	All missing	+ NPKSZn	Control	Control (native nutrients)

Results and Discussion

T. Aman 2022 (Grain and straw yield)

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 15).** The fertilizer control treatment gave the lowest grain yield (3.52 t ha^{-1}). Among the applied organic materials, although PM+IPNS (5.71 t ha^{-1}) gave higher grain yield but the result was statistically similar in compared to complete fertilizer (5.63 t ha^{-1}), CD+ IPNS (5.54 t ha^{-1}) and VC+ IPNS (5.57 t ha^{-1}. The omission of sulphur (5.38 t ha^{-1}) and zinc (5.51 t ha^{-1}) also gave statistically similar grain yield compared to full dose of chemical fertilizer. Moreover, significant yield difference was found in reduce K dose (40 kg ha^{-1}) but no yield penalty observed in K 60 kg ha^{-1} compared with full K fertilizer treatment (K 80 kg ha^{-1}). Similar trend was obtained for straw production in different treatment combinations.

Table 15. Effect of organic and inorganic amendments on rice grain and straw yield of BRRIdhan87 in T. Aman 2022 at BRRI HQ, Gazipur

Treatments	**T. Aman season** **GY (t ha^{-1})**	 **SY (t ha^{-1})**
T_1=NPKSZn@100-10-80-5-2 kgha^{-1}	5.63 ab	5.48 ab
T_2 = NPSZn (-K)	4.63 c	4.38 c
T_3 = NKSZn (-P)	4.26 c	4.19 c
T_4 = PKSZn (-N)	4.28 c	4.08 c
T_5 = CD (3 t ha^{-1}) + IPNS fert.	5.54 ab	5.39 ab
T_6 = NPKS (-Zn)	5.51 ab	5.41 ab
T_7 = NPKZn (-S)	5.38 ab	5.23 ab
T_8 = PM (2 t ha^{-1}) + IPNS fert.	5.71 a	5.58 a
T_9=NPKSZn@100-10-60-5-2 kgha^{-1}	5.54 ab	5.41 ab
T_{10} = VC (2 t ha^{-1}) + IPNS fert.	5.57 ab	5.47 ab
T_{11}=NPKSZn@100-10-40-5-2 kgha^{-1}	5.19 b	5.01 b
T_{12} = Control (native nutrients)	3.52 d	3.39 d
CV (%)	3.73	4.01

Boro 2022-23 (Grain and straw yield)

In the Boro season, the complete fertilizer treatment gave around 7.00 t ha^{-1} grain yield, which was decreased significantly due to omission of N, P and K @ 2.54, 2.47 and 4.17 t ha^{-1}, respectively **(Table 16)**. Like N, P and K omission, sulfur and Zn omission gave statistically similar grain yield to complete fertilizer. The highest grain yield 7.36 t ha^{-1} was obtained from PM+IPNS, which was statistical identical with complete fertilizer (7.00 t ha^{-1}) and CD +IPNS (7.31 t ha^{-1}) and VC + IPNS (7.30 t ha^{-1}). Moreover, significant yield difference was found among reduce K doses (K 40 and K 60 kg ha^{-1}) in compared to complete K dose (K 80 kg ha^{-1}) **(Table 16).** Similar yield trend was found in straw production.

Annual yield trend of organic treatments

The annual yield trend of IPNS based treatment compared with complete chemical fertilizer and control treatment were showed in **Figure 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.

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 have no yield reduction in these seasons. Application of IPNS based fertilizers have 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.

Table 16. Effect of organic and inorganic amendments on rice grain and straw yield of BRRI dhan89 in Boro 2022-23 at BRRI, Gazipur

Treatments	GY (t ha^{-1})	SY (t ha^{-1})
T_1 = NPKSZn@150-12-80-5-2 kgha^{-1}	7.00 abc	6.78 abc
T_2 = NPSZn (-K)	4.17 d	4.29 e
T_3 = NKSZn (-P)	2.47 e	2.48 f
T_4 = PKSZn (-N)	2.54 e	2.38 f
T_5 = CD (3 t ha^{-1}) + IPNS fert.	7.31 a	6.84 abc
T_6 = NPKS (-Zn)	7.30 a	7.07 a
T_7 = NPKZn (-S)	7.15 ab	6.81 abc
T_8 = PM (2 t ha^{-1}) + IPNS fert.	7.36 a	6.97 ab
T_9 = NPKSZn @140-12-60-5-2 kgha^{-1}	6.88 bc	6.65 bc
T_{10} = VC (2 t ha^{-1}) + IPNS fert.	7.30 a	6.61 cd
T_{11} = NPKSZn@140-12-40-5-2 kgha^{-1}	6.70 c	6.26 d
T_{12} = Control (native nutrients)	1.37 f	1.25 g
CV (%)	3.01	2.65

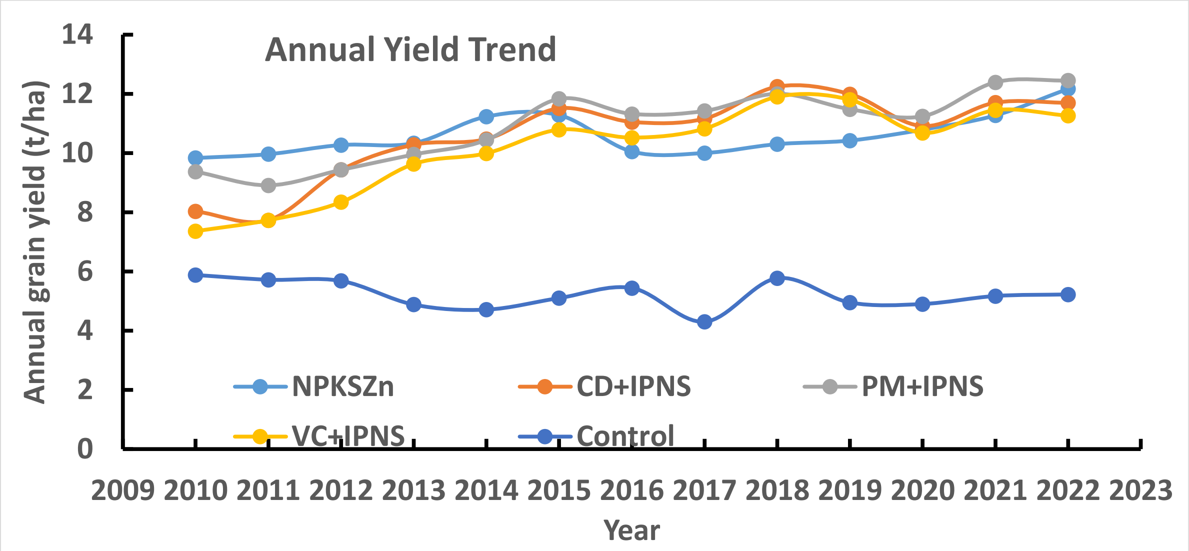

Fig. 11. Annual yield trend of IPNS based treatment compared with complete chemical fertilizer and control treatment, 2022-23, BRRI, Gazipur

Expt. 13. LONG-TERM MISSING ELEMENT TRIAL AT BRRI REGIONAL STATION RANGPUR

A.T.M. Sakhawat Hossain, M. R. Hasan and A. Islam

Introduction

Nitrogen, P, K, S and Zn are five essential plant nutrients of which the first three are the most important in terms of their deficiencies in soils and potential to increase or decrease crop yield (Shah et al., 2008). Nitrogen is the most yield limiting nutrient elements in the many paddy soils (Savant and Datta, 1982) including Bangladesh. Many rice soils of Bangladesh are also becoming deficient in P, K, S and Zn (BARC, 2018). To study the effect of long-term nutrient omission on rice yield, a long-term missing element trial has been conducted at BRRI regional station farm, Rangpur.

Materials and Methods

The experiment was initiated in a permanent layout at BRRI farm Rangpur during Boro, 2014-15 combining 7 treatments **(Table 17)** in RCB design with 3 replicates. Fertilizer nutrients i.e., N-P-K-S-Zn rate was 95-8-40-12-1 kg ha^{-1} and 145-10-60-15-2 kg ha^{-1} in T. Aman and Boro seasons, respectively. 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. BRRI dhan87 in T. Aman and BRRI dhan89 in Boro seasons were cultivated as test rice varieties. The tiller and panicle number per meter square and grain and straw yield data were obtained. Grain yield was recorded from 5 m^2 areas at the center of each plot and 16 hills were collected for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis. Data were analyzed statistically by the software STAR.

Table 17. Treatment's combination in the long-term missing element trial at BRRI, Rangpur

T_1	Control (No fertilizer)	T_5	NPSZn (-K)
T_2	NPKSZn	T_6	NPKZn (-S)
T_3	PKSZn (-N)	T_7	NPKS (-Zn)
T_4	NKSZn (-P)		

Results and Discussion

T. Aman 2022 (Tiller, Panicle, Grain and Straw yield)

In T. Aman 2022 season, the omission of nutrients significantly reduced the yield and yield contributing parameters of rice **(Table 18).** The highest tiller (267) and panicle (254) production per meter square were observed in complete fertilized plot followed by Zn and S omitted plot. The fertilizer control (176 & 166) and N (203 & 195) control treatments produced significantly lowest tiller and panicle number than other treatments, respectively. The N and P omission from complete fertilizer significantly reduced the grain yield of BRRI dhan87 by 32% and 4% respectively. The highest grain yield reduction was found in T_3, which was N omission plot from complete fertilizer. The omission of P, K, S and Zn gave statistically similar grain yield like complete fertilizer treatment in T. Aman season. Similar trend was found in straw yield.

Table 18. Effect of long-term missing element on the tiller, panicle, grain and straw yield of BRRI dhan87 at BRRI farm, Rangpur in T. Aman, 2022

Treatments	Tiller per m^2	Panicle per m^2	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	(%) Grain yield decreased due to nutrient omission
T_1	176 b	166 b	3.37 c	3.10 c	-
T_2	267 a	254 a	5.82 a	6.05 a	-
T_3	203 b	195 b	3.95 b	4.36 b	32
T_4	257 a	240 a	5.59 a	5.94 a	4
T_5	261 a	245 a	5.70 a	5.99 a	2
T_6	262 a	249 a	5.65 a	6.04 a	3
T_7	265 a	252 a	5.74 a	6.10 a	1.5
CV (%)	6.7	6.71	2.72	3.45	

N.B. T_1= Control, T_2= NPKSZn, T_3= PKSZn (-N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn)

Boro 2022-23 (Tiller, Panicle, Grain and Straw yield)

In Boro 2022-23 season, omissions of different nutrient from complete fertilizer have significant influence on tiller-panicle production and grain-straw yield of BRRI dhan89 **(Table 19).** Except the fertilizer control plot and N control plot, the tiller and panicle number per meter square increased significantly in all treatments. The highest tiller (224) and panicle (214) production were found in complete fertilizer treatment and the lowest tiller (126) and panicle (120) production were recorded in fertilizer control treatment. Omission of P, K, S and Zn produced statistically similar tiller and panicle per meter square. The omission of N, P, K and S from complete fertilizer significantly reduced the grain yield of BRRI dhan89 by 47%, 24%, 6% and 3% respectively in Boro season. The omission of K (6%) and S (3%) have less yield reduction compared to N and P omission, although slightly lower yield obtained in K (6.32 t ha^{-1}) and S (6.51 t ha^{-1}) omission plots than complete treatment (6.71 t ha^{-1}). Like K and S, the Zn omission have no significant effect on yield reduction in BRRI Rangpur farm yet. Similar result was found in case of straw yield.

Conclusion

The omission of N in T. Aman and omission of N and P in Boro season from complete fertilizer significantly reduced the grain yield of rice at BRRI Rangpur 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 both seasons. The S and Zn omission have no significant effect on yield reduction at BRRI regional station Rangpur farm yet.

Table 19. Effect of long-term missing element on the tiller, panicle, grain and straw yield of BRRI dhan89 at BRRI farm, Rangpur in Boro, 2022-23

Treatments	Tiller/m^2	Panicle/m^2	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	(%) Grain yield decreased due to nutrient omission
T_1	126 b	120 b	3.04 c	2.75 c	-
T_2	224 a	214 a	6.71 a	6.18 a	-
T_3	141 b	135 b	3.54 c	3.22 c	47
T_4	199 a	189 a	5.10 b	4.65 b	24
T_5	206 a	191 a	6.32 a	5.88 a	6
T_6	208 a	198 a	6.51 a	6.06 a	3
T_7	209 a	199 a	6.53 a	6.10 a	2.5
CV (%)	*5.77*	*5.91*	*5.3*	*3.39*	

N.B. T_1= Control, T_2= NPKSZn, T_3= PKSZn (-N), T_4= NKSZn (-P), T_5= NPSZn (-K), T_6= NPKZn (-S), T_7=NPKS (-Zn)

Expt. 14. EFFECT OF INTENSIVE RICE CROPPING ON RICE YIELD UNDER CONTINUOUS WETLAND CONDITION

A. Jahan and A. 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

This experiment was initiated in 1971 in a permanent layout with an objective to grow three rice crops (Boro, T. Aus and T. Aman) annually with NPK fertilizer application. In 1982, the field was divided into two sub-plots, one part receiving NPK dose and the other one no fertilizer. In 1984, NPK treatment was modified with the inclusion of S as gypsum because of its deficiency was confirmed through soil-plant analysis. In 1991, the plot was again divided into five sub-plots to accommodate two N levels with and without S fertilizer comprising 4 treatments with an absolute control. Since Boro 2000, the experiment was modified to accommodate six treatments viz. control (native nutrient), reverse control (NPKSZnCu), NPK, NPKS, NPKSZn and NPKSZnCu. 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. This was a non-replicated trial.

Results and Discussion

Grain yield and yield trend

Annual rice production decreased from 6.41 t ha^{-1} in 1981 to less than 2.0 t ha^{-1} in 2008 because of continuous rice cultivation without fertilizer application. However, grain yield in this treatment showed somewhat increasing trend during 2008-2012 and then again declined. Moreover, from 2001 the reverse control treatment produced grain yield almost similar to complete fertilized treatment **(Fig. 12).**

The continuous rice cultivation in a triple rice cropping pattern (Boro-T. Aus-T. Aman) with different fertilizers influenced rice yield. Grain yield in control plot was 0.96-2.64 t ha^{-1} irrespective of season in 2022. In 2022, annual rice production in control plot was 5.33 t ha^{1}. However, its reversed management (addition of NPKSZnCu fertilizer) resulted in 13.35 t ha^{-1} yr^{-1} grain production, which was close to complete fertilizer treatment (12.27 t ha^{-1} yr^{-1}). It indicates that complete fertilization can recuperate soil productivity even after a long period of rice cultivation. The results indicated that additional use of Zn and Cu once in a year with NPKS increased annual grain yield by more than 1.0 t ha^{-1} than the application of NPKS alone **(Table 20).**

Table 20. Effect of NPKSZnCu on yield of triple rice crop, 2021-22 at BRRI, Gazipur

Treatment	Grain yield (t ha^{-1})			
	Boro, 2021-22	T. Aus, 2022	T. Aman, 2022	Annual
Control	0.96 c	1.73 d	2.64 b	5.33
Reverse control	4.35 ab	3.24 ab	4.68 a	12.27
NPK	3.43 b	2.35 c	4.50 a	10.28
NPKS	3.88 ab	2.76 bc	4.74 a	11.38
NPKSZn	3.95 ab	2.99 ab	4.79 a	11.73
NPKSZnCu	5.02 a	3.46 a	4.81 a	13.29

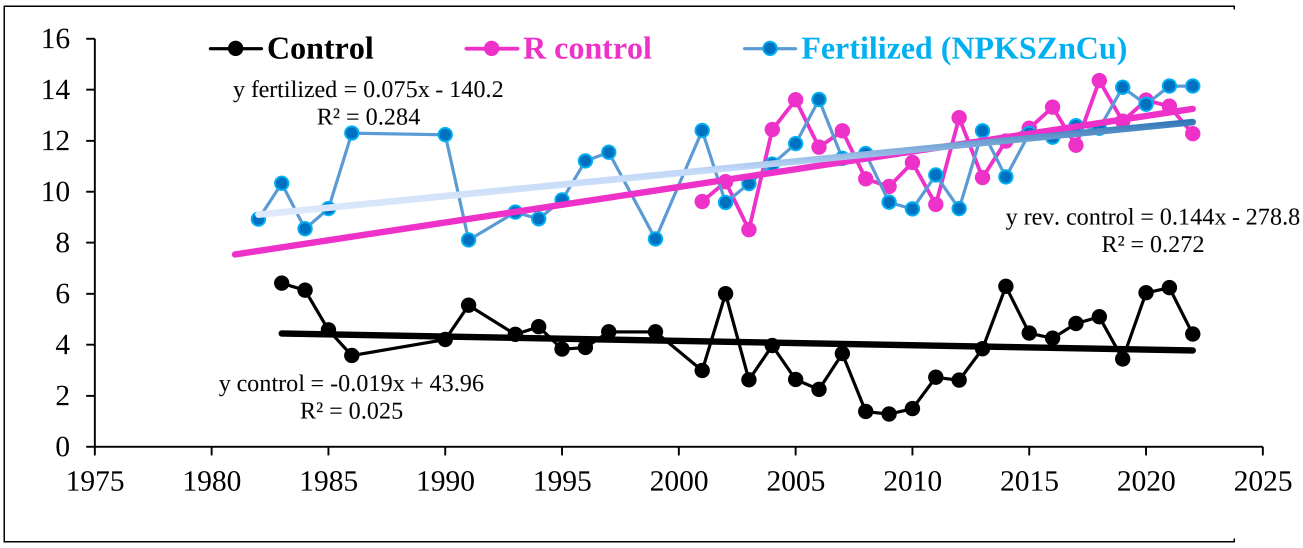

Fig. 12. Annual rice production trend under intensive wetland conditions in BRRI

In Boro, 2022-23 season, rice grain yield was significantly higher (5.92 t ha^{-1}) with complete fertilizer (NPKSZnCu) treatment compared to NPK fertilizer and control treatments. However, this was statistically similar with other treatments **(Table 21).**

Table 21. Effect of NPKSZnCu on yield of Boro rice, 2022-23 at BRRI, Gazipur

Treatment	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
Control	0.98 c	0.91 b
Reverse control	5.48 ab	4.95 a
NPK	5.41 b	4.90 a
NPKS	5.52 ab	5.05 a
NPKSZn	5.87 ab	5.22 a
NPKSZnCu	5.92 a	5.43 a
CV (%)	3.67	9.36

Annual total nutrient uptake

The highest annual total uptake of N (301.71 kg ha^{-1}), P (65.78 kg ha^{-1}), K (303.63 kg ha^{-1}) and S (29.60 kg ha^{-1}) were observed in reverse management treatment. The lowest nutrients uptake was found with the control treatment **(Table 22).** It is noteworthy that the application of Zn and Cu significantly increased the uptake of major nutrients even under continuous wetland condition.

Table 22. Effect of different nutrient managements on annual total nutrient uptake of triple rice in 2021-22 at BRRI, Gazipur

Treatment	**Annual total nutrient uptake (kg ha^{-1})**			
	N	**P**	**K**	**S**
Control	69.84 c	15.14 bd	76.05 c	6.59 d
Reverse control	248.75 ab	56.20 ab	261.67 ab	23.47 b
NPK	200.28 b	40.54 c	221.82 b	17.48 c
NPKS	226.51 b	47.98 bc	228.08 b	20.27 bc
NPKSZn	242.96 ab	51.91 b	254.35 ab	23.22 bc
NPKSZnCu	301.71 a	65.78 a	303.63 a	29.60 a
CV (%)	10.02	7.71	8.87	10.21

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.

Expt. 15. DEPTH DISTRIBUTION OF SOIL PHYSICAL AND CHEMICAL PROPERTIES WITH CROP RESIDUES RETENTION AFTER SIX CYCLES OF FOUR CROPS CROPPING.

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

Introduction

Increased cropping intensity growing four crops per year with two/three rice crops may impair soil fertility which should appropriately handle via inclusion of non-cereal/legume crops in the pattern and application of harvested crop residues. Grain yield stagnation or declination is a fact due to intensive use of lands (Bhuiyan et al., 1991; Pagiola, 1995; Islam and Dowlah, 1998). When three or four crops are grown per year, no scope is left for natural safeguarding of soil through mobilization of inherited soil nutrients or addition from other sources. Therefore, the whole amount of nutrients remove by the crop harvest should replenish through adding chemical and organic nutrient sources to sustain crop production in the long run. Initiatives must also be taken to add available organic sources with balance chemical fertilizers to maintain soil health and sustainable production. One of the potentials to add organic matter in soil is to include suitable leguminous crop in the cropping pattern, and incorporate the crop residues after harvest. There is some information available on nutrient management for growing double or triple rice crops per year, but little or no information is available on nutrient management for growing four crops per year including two or three rice crops in the pattern. So, it is indispensable to explore appropriate integrated nutrient management packages for growing four crops per year including two or three rice crops in the patterns. Therefore, this experiment was designed to assess total productivity and changes in soil properties for cropping patterns growing four crops per year.

Materials and Methods

The experiment was initiated during T. Aus season 2016 in a permanent layout of Soil Science Division’s field at BRRI, Gazipur and continued till Boro or Mungbean 2022, then terminated after completing 6 crop cycles. The soil samples were collected from two depths (0-15, 16-30cm) after harvesting Boro or Mungbean, 2022 and analyzed to evaluate the changes in soil physicochemical properties (pH_2O:1:2.5, soil OC, total N and available K) with crop residues retention after six cycles of four crops cropping. Throughout all cropping cycles, three fertilizer treatments viz. Soil test based (STB) fertilizer (T_1), crop residues (CR) + STB fertilizer (T_2) and fertilizer control i.e. native soil nutrients (T_3) were tested under Mustard-Boro-T. Aus-T. Aman (CP-1) and Mustard-Mungbean-T. Aus-T. Aman (CP-2) patterns. Experimental design was RCB with three replicates. All plots were surrounded by 50 cm soil levee to avoid fertilizers movement between the plots. Standard cultural practices were followed to raise every crop in both pattern. In T_2, the whole amount of crop residues of every crop during whole 6 crop cycles were incorporated. Statistical tests were performed with IBM SPSS statistics 16.0 (SPSS Inc., USA). One-way ANOVA was carried out within each cropping pattern per depth to detect the differences in soil properties between the fertilizer treatments.

Results and Discussion

Comparison of two cropping patterns in terms of rice equivalent yield (REY)

In view of rice equivalent yield (REY), CP-1 performed better than CP-2 in each year of 2019-20, 2020-21 and 2021-22 **(Fig.13).** This difference may be due to the inclusion of HYV Boro rice in CP-1 while it was mungbean in CP-2.

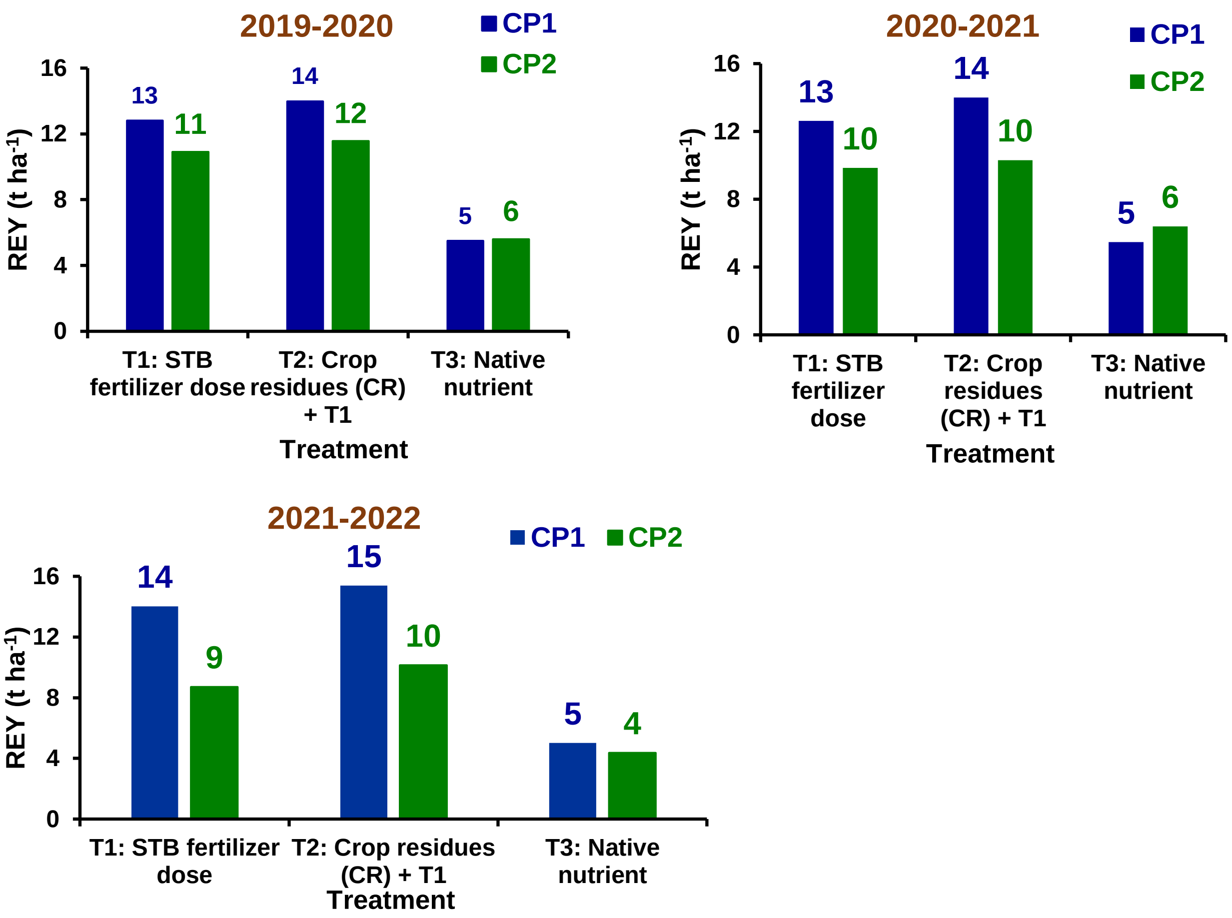

Fig.13. Rice equivalent yield (REY) of both cropping patterns during the year 2019-20, 2020-21 and 2021-22

Soil water pH (pH_2O: 1:2.5)

Irrespective of cropping patterns and depths, the overall soil pH was increased by ~1.0 to 2.0 units after six crop cycles over initial surface soil pH **(Fig. 14a and 14b).** The extent of soil pH rise was greater in sub soil than that in surface soil layer. Within each cropping pattern, the soil pH did not differ significantly between the treatments per depth (p=0.122 to 0.506).

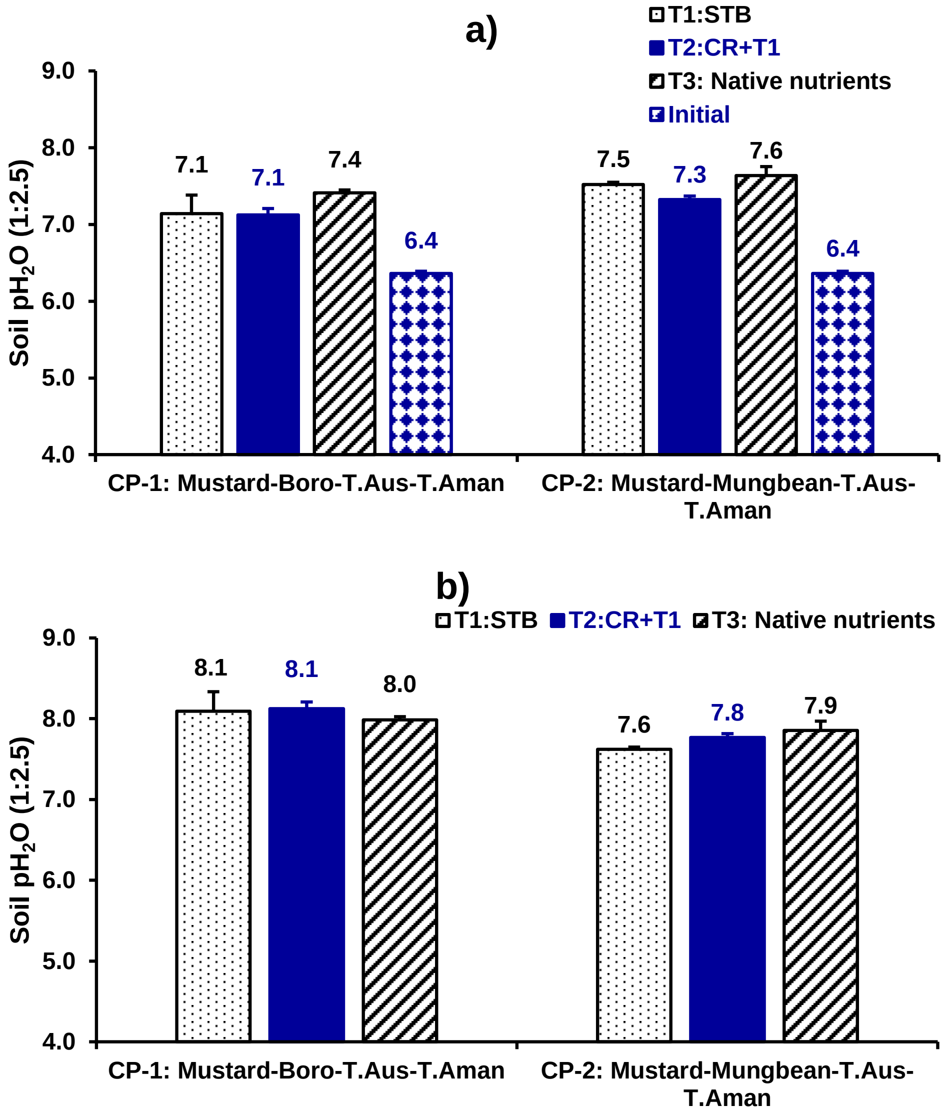

Fig. 14. Changes in surface (0-15cm) (a) and sub (16-30cm) (b) soil pH$_2$O (1:2.5) after six crop cycles (after Boro or Mungbean, 2022)

Soil organic C (SOC) and total N (TN)

In both cropping pattern, the overall soil organic C (SOC) and total N (TN) contents were greater in surface (0-15cm) than sub (16-30cm) soil layer **(Fig. 15 and Fig. 16).** The significant differences in SOC and TN contents between the fertilizer treatments only existed in surface soil layer. In case of CP-1 growing three rice crops and mustard, surface SOC increased by 0.18 to 0.41% in all three fertilizer treatments over initial surface SOC **(Fig. 15a).** While in CP-2, the surface SOC increased (by 0.33%) in crop residues incorporated treatment, T$_2$ only than initial surface SOC **(Fig. 15a).** In both cropping pattern, the surface SOC was significantly ($p<0.01$ to <0.05) greater in crop residues incorporated treatment (T$_2$) than that in the treatment without fertilizer application (T$_3$). Alike SOC, the surface soil TN increased by 0.01 to 0.06% in all three fertilizer treatments of CP-1 over initial surface soil TN **(Fig. 16a)**. While this was the case for crop residues incorporated treatment, T$_2$ in CP-2 **(Fig. 15a).** The surface soil TN in crop residues incorporated treatment (T$_2$) was significantly ($p<0.01$) greater than that in T$_3$ (in both CP-1 and CP-2) and T$_1$ (in CP-1).

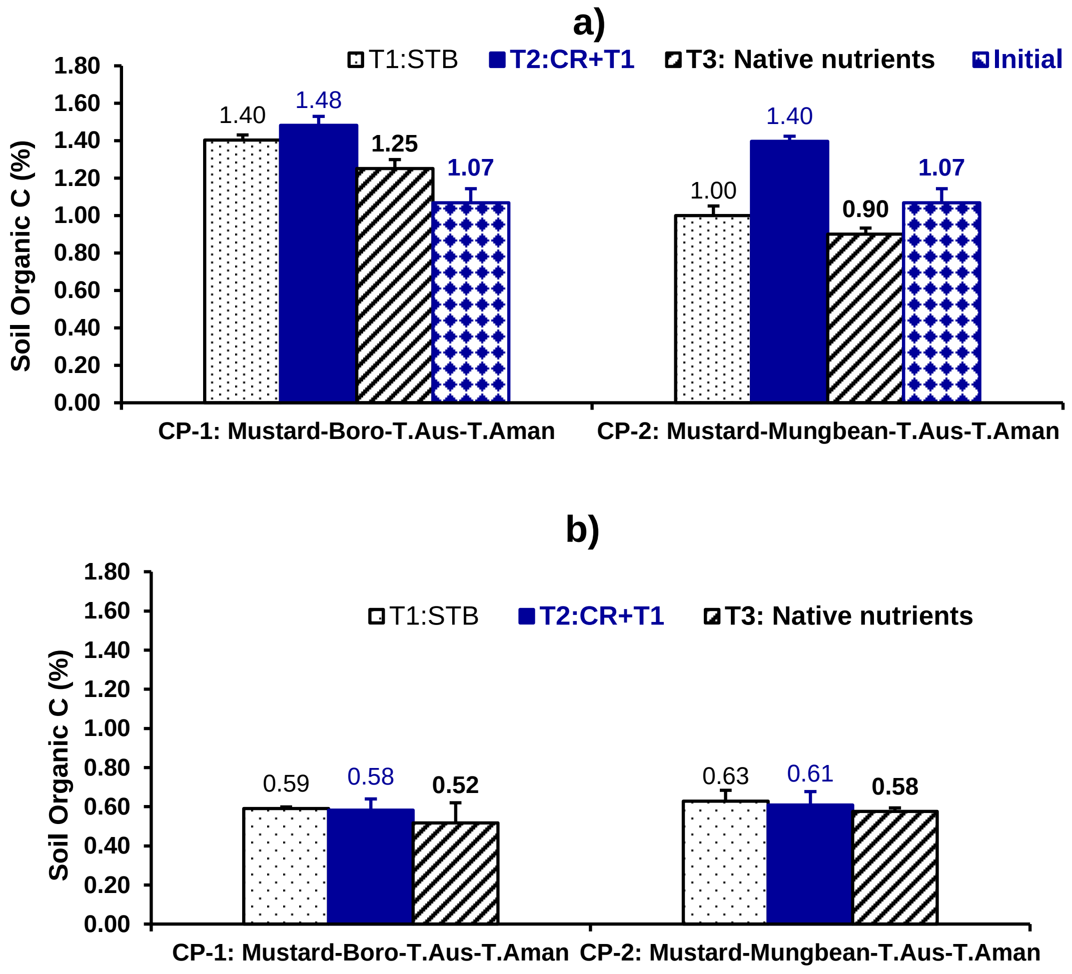

Fig. 15. Changes in surface (0-15cm) (a) and sub (16-30cm) (b) soil organic C after six crop cycles (after Boro or Mungbean, 2022)

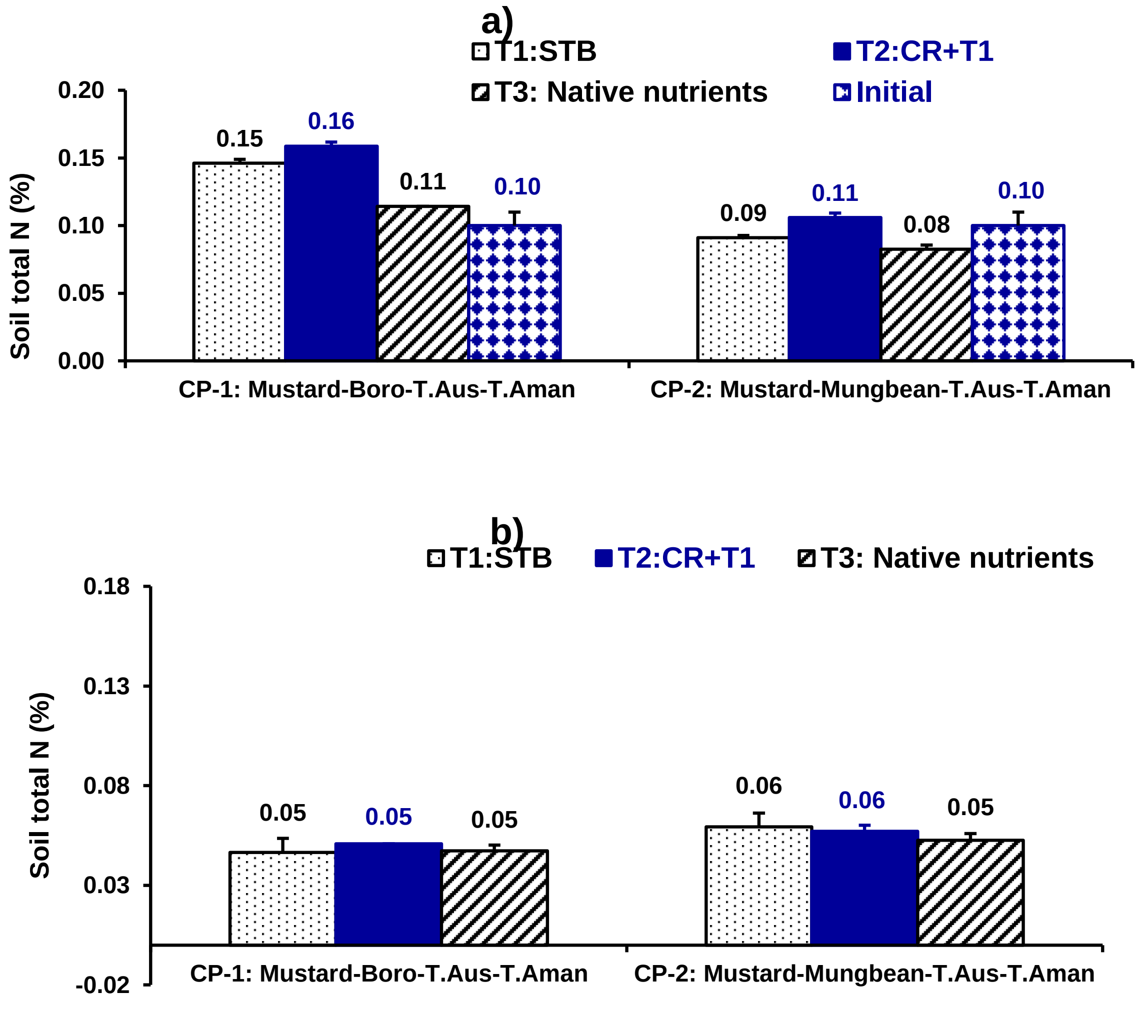

Fig. 16. Changes in surface (0-15cm) (a) and sub (16-30cm) (b) soil total N after six crop cycles (after Boro or Mungbean, 2022)

Soil exchangeable K

In contrast to soil OC and TN, the exchangeable K content was greater in sub soil (16-30cm) than in surface (0-15cm) soil **(Fig. 17a and 17b).** The extent of sub soil exchangeable K rise over surface soil was greater in CP-1 (0.08 to 0.13 meq 100g^{-1} soil) than that in CP-2 (0.01 to 0.03 meq 100g^{-1} soil). Irrespective of cropping pattern, the soil exchangeable e K did not differ significantly between the treatments in all depths (p=0.422 to 0.952), except at 0-15cm depth of CP-1, where the soil available K in crop residues incorporated treatment (T_2) was significantly ($p<0.05$) greater than that in T_3.

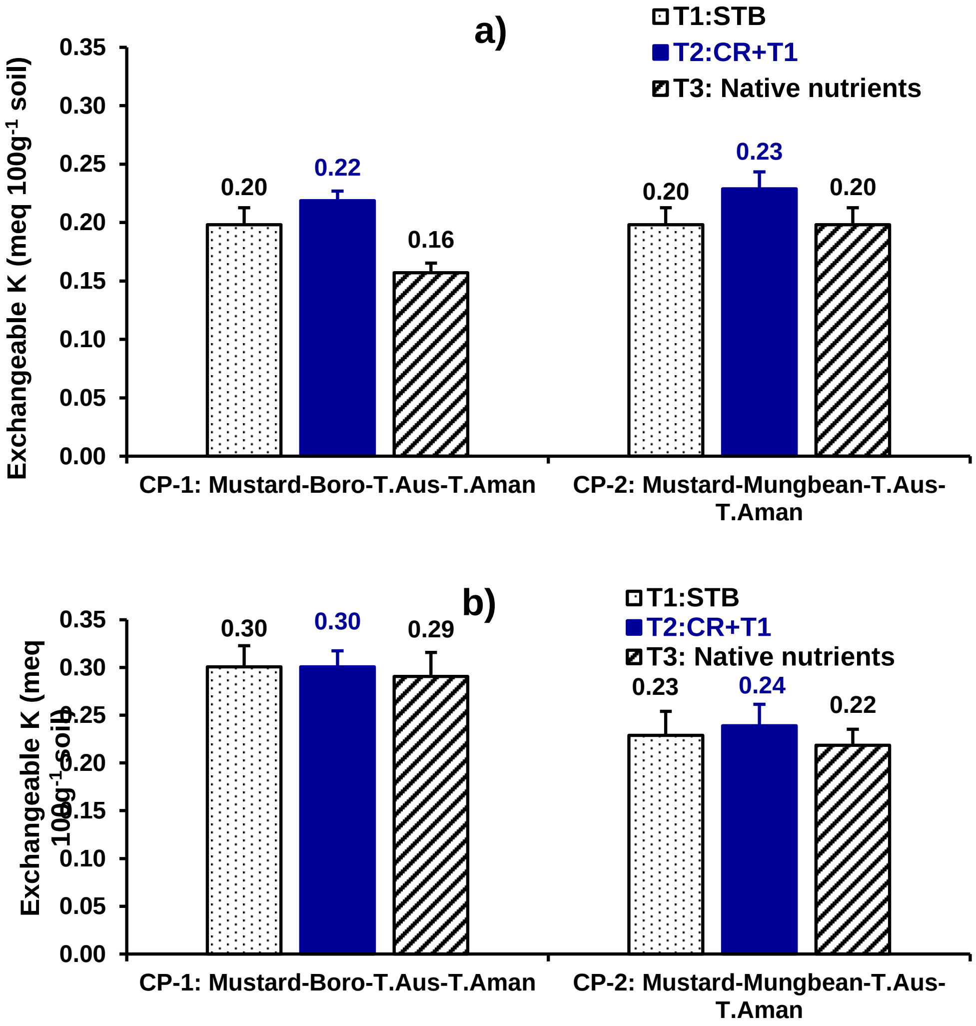

Fig. 17. Changes in surface (0-15cm) (a) and sub (16-30cm) (b) soil exchangeable K after six crop cycles (after Boro or Mungbean, 2022)

Conclusion

In most cases, incorporation of crop residues with AEZ based or STB chemical fertilizers had positive influence on REY, soil OC, TN and available K than chemical fertilizer and no fertilizer applied treatments. This efficacious control was more prominent in CP-1 than CP-2, hence indicating that growing three rice crops and mustard essentially with AEZ based or STB chemical fertilizers and incorporation of crop residues may propose to sustain productivity and maintain soil fertility in terrace paddy field of Gazipur, Bangladesh.

SUB-SUB PROGRAM III: INTEGRATED NUTRIENT MANAGEMENT

Project 3: Integrated Nutrient Management for Intensive Rice Cropping

Expt. 16. INTEGRATED NUTRIENT MANAGEMENT FOR DOUBLE AND TRIPLE RICE CROPPING FOR MAXIMIZING PRODUCTIVITY

M. Iqbal, M. I. U. Sarker, M. N. Islam, M. N. Ahmed and A. 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

Figure18 present the annual grain yield of double rice cropping pattern from 2008 to 2022. Parallel increasing trend of grain yield of 100% STB fertilization and 50% STB with mixed manure were observed from the beginning to upto date. But Control and Farmers Practices (FP) showed decreasing trend with the increment of time. Almost similar pattern was observed in triple rice cropping pattern except FP shown in **Fig.19**. Cumulative yield of triple cropping was always higher than double rice cropping pattern irrespective of treatments. Soil chemical properties were changes after certain period of time **(Table 23).** Percentage of soil organic carbon, available P and S were increased in 100% STB and 50% STB with mixed manure application plot. Increasing trend was more in 50% STB with mixed manure application plot.

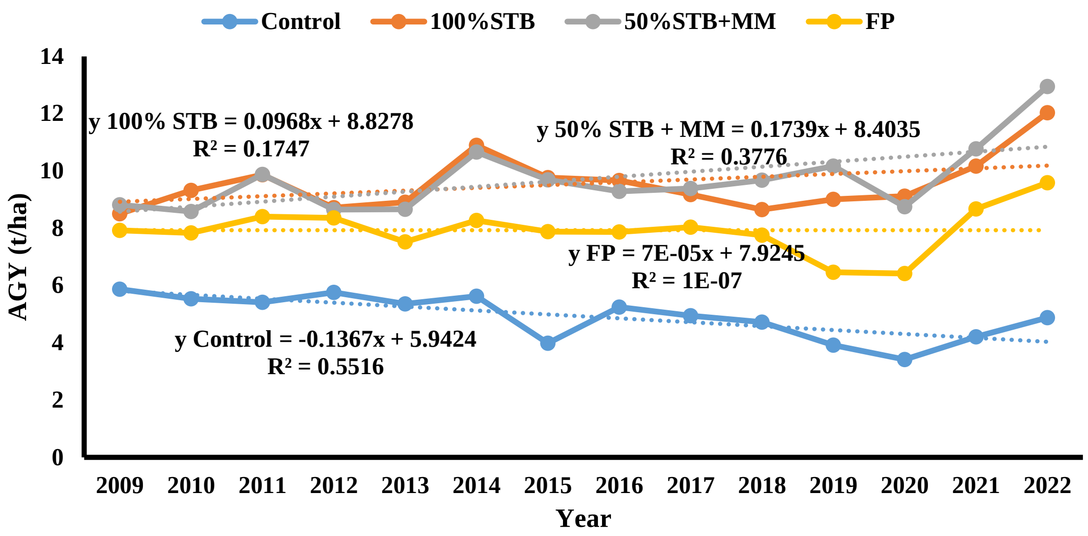

Fig.18. Annual rice production trend under integrated nutrient management for double rice cropping for maximizing productivity during 2009-2021 in BRRI, Gazipur

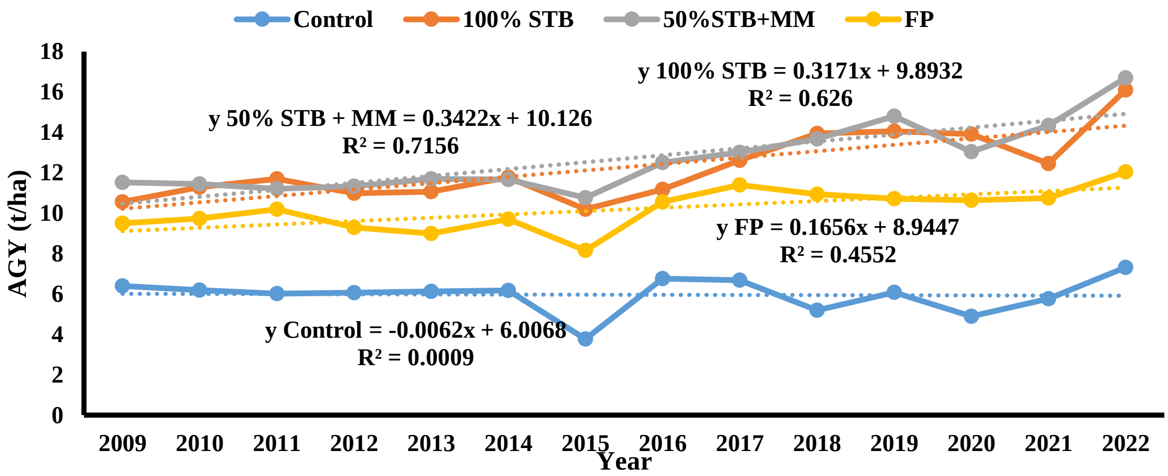

Fig.19. Annual rice production trend under integrated nutrient management for triple rice cropping for maximizing productivity during 2009-2021 in BRRI, Gazipur

Table 23. 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. 17. DIFFERENT RATES OF VERMICOMPOST APPLICATION AS INFLUENCED OF AGGREGATE STABILITY AND CARBON STORAGE IN RICE SOIL

Md Mozammel Haque and A. Islam

Introduction

Paddy soils are manipulated in different ways to increase crop yields for maintaining food requirement of growing population around the globe. Different nutrient sources such as fertilizers (Haynes et al., 1998) and organic manures are mostly used for crop yield improvement (Haque et al., 2015). Organic amendments improve SOC content, physical properties and biological activity (Hati et al., 2007; Kundu et al., 2001; Manna et al., 2005; Reeder et al., 1998; Lal, R. 2003; Lal, 2006; Komatsuzaki and Ohta, 2007). Agricultural management practices that enhance SOC content, reduce greenhouse gas emissions and lower the farming carbon foot print are generally adopted for crop culture (Haque et al., 2017; Lal, 2004; Jarecki et al., 2003). Organic manures such as green manure, cover crop biomass, farmyard manure, poultry litter, mustard oil cake, etc not only supply plant available nutrients but also affect soil physical properties such as improve organic carbon (Haque et al., 2015), aggregate stability (Aminiyanet al., 2015; Barzegar et al., 2002; Duiker et al., 1999; McVay et al., 2006; Pernes-Debuyser et al., 2004; Rachman et al., 2003), decrease volume of micropores, increase macropores (Hati et al., 2006), improve water holding capacity (Hati et al., 2007; Zhang et al., 2007; Pernes-Debuyser et al., 2004; Rasool et al., 2007; Sharma et al., 2001; Zhang et al., 2006), porosity, increase infiltration rate (Bhattacharyya et al., 2007), increase saturated hydraulic conductivity and decrease bulk density (Haque et al., 2015; Ndiaye et al., 2007; Anderson et al., 1990; Bhattacharyya et al., 2007). Fertilizer additions, on the other hand, also affect soil chemical composition that can be responsible for dispersion/flocculation of clay particles and thus affecting the soil aggregation stability (Haynes et al., 1998). Valuable effects of increasing SOC content on enhancing soil structural stability, total porosity and water infiltration rate have been reported by Barzegaret al., 1997; Sharma et al., 2003, Ndiaye et al., 2007. Reduce of SOC can increase bulk density and reduce soil fertility and health resulting in reduced crop productivity (Haque et al., 2015; Sharma et al., 2003).

The SOC levels depend upon cover crop biomass addition, crop rotation, and tillage management practices (Haque et al., 2015, 2017; Purakayasthaet al., 2008). Continuous cultivation of crops has resulted in the reduction in SOC and soil physical properties in general (Bhattacharyya et al., 2007). Maintaining SOC content above the threshold level is critical for improving soil quality (Aune et al., 1997). Fertilizer applications and crop rotation can regulate C cycling dynamics and soil C storage through its effects on soil biological activity and the amount and quality of residue returned (Gregorich et al., 2001). Long-term study can be more useful for studying the changes in soil properties over time for developing future strategies to maintain soil health and crop productivity (Haynes et al., 1998). Therefore, the objectives of this study were to assess the effect of organic and inorganic nutrients sources after continuous eight years use in a rice-fallow-rice rotation on soil physical and chemical properties, carbon storage and crop yields.

Materials and Methods

Experimental site

To investigate the long-term organic and inorganic nutrients effects on rice yields and soil physio-chemical properties, paddy soil was prepared at Bangladesh Rice Research Institute (BRRI) (23˚85.9`N and 90˚82.4`E, elevation 12m), Gazipur, Bangladesh in 2015-2022.

Experimental design and fertilization

VC was used @ 0.5, 1.0, 1.5, 2.0 t ha^{-1} in each season with full doses of recommended chemical fertilizer (RCF) and compared with sole RCF. Unit plot size was 3-x 5-m with three replications in a randomized block design. Thirty-five-day-old (BRRI dhan29) and 25-day-old (BRRIdhan49) seedlings were transplanted at 20- x 20-cm spacing during Boro and T. Aman rice season, respectively. The RCFs were 140-10-80-5-5 and 100-10-80-5-5 kg ha^{-1} of N, P, K, S, Zn for Boro and T. Aman season, respectively. The whole amounts of fertilizers were applied one day before rice transplanting except urea. Urea was applied in three equal splits at final land preparation before rice transplanting, active tillering and one week before panicle initiation stages. Paddy field water level was maintained at 5-7 cm depth and drained 21 days before harvesting the crops.

Chemical analysis

Soil samples were collected from the surface layer (0-15cm) before the test in the 1st year and after harvest in the 7th year after the installation, and air-dried. The sieved soils (<2 mm) were analyzed for pH (1:2.5 water extraction), and organic carbon content (Walkley and Black method; Allison 1965). Total nitrogen (Kjeldahl methods), available P was Olsen methods, available sulfur was extracted by 0.16 M $Ca(H_2PO_4)_2$ (Fox et al., 1964). Available zinc was determined by DTPA extraction method (Olsen and Ellis, 1982).

Soil aggregate analysis

Determination of Soil Physical Properties: Bulk density (bd) was determined using the core method. Total porosity (TP) was obtained from bulk density value with assumed particle density (pd) value of 2.65 g cm as follows: Tp = 100 (1-bd/pd). Soil samples from 0–15 cm depth were used for aggregate analysis by the wet sieving method. The classical procedure described by Kemper and Rosenau (1986) was used to separate water-stable aggregates. In brief, 20 g of 4 mm air–dried soil samples were put on the topmost sieve of a nest of three sieves of 2, 0.59, 0.30, 0.149 and 0.074-mm mesh sizes and pre-soaked in distilled water for 30 min. Then, the nest of sieves was oscillated vertically in water 20 times, using 4-cm amplitude at the rate of one oscillation per second. Care was taken to ensure that soil particles on the topmost sieve were always below the water surface during each oscillation. After wet sieving, the water-stable soil materials left in each sieve were quantitatively transferred into beakers, dried in the oven at 50^{o}C for 48 h, weighed, and stored for later analysis. OC content in each fraction was measured by Walkley and Black (1934) method. MWDw was calculated by the following equation: MWDw=Xi×Wi where Xi is the mean diameter of the ith sieve, and Wi is the amount of total aggregates in ith fraction.

Soil organic carbon balance

Soil organic carbon stock (SOCS) was determined according to following formula:

SOCS = Soil organic C (%)*depth*Bulk density.

Statistical analysis

Statistical analyses were conducted using SAS software (SAS Institute, 1995). Fisher's protected least significant difference (LSD) was calculated at the 0.05 probability level for making treatment and year mean comparisons.

Results and Discussion

Yield of rice

Use of VC at variable rates significantly influenced grain yield compared to RCF in both the seasons, although VC at 0.5 t ha^{-1} along with RCF treated plots showed higher grain yield in T. Aman season. Sole RCF treatment had the lowest grain yield of about 3.22 t ha^{-1} and 5.19 t ha^{-1} during T. Aman and Boro season, respectively. In T. Aman, grain yield was 3.7-4.06 t ha-1 under different rates of VC application. In Boro season, grain yield was 6.3-6.4 t ha^{-1} under VC application. Incorporation of VC increased 18-35% grain yield compared to sole RCF depending on growing season.

Net carbon stock and selected soil parameters

Organic carbon, available N-P-K, mean weight diameter of soil, bulk density, total soil carbon stock and net carbon stock were significantly affected by VC incorporations for eight years compared to sole RCF **(Table 24).** Total and net soil carbon stocks increased with greater VC incorporation rates. Available soil N and P were statistically similar among VC incorporation rates. Incorporation of VC at 0.5 t ha^{-1} + RCF showed significantly higher mean weight diameter of soil, especially with the highest VC rate, than other treatments. Total soil carbon stock varied from 2137 to 2554 kg C ha^{-1} after eight years of imposed treatments. Net carbon stock or balances were -57 to 360 kg C ha^{-1} depending on treatments **(Table 24).** A study for eight years with VC incorporations rate for growing rice reveals that higher VC rates were responsible for increased about 20-386% of net carbon balance, 2-13% of total soil carbon stock and other soil nutrient elements in Boro-Fallow-T Aman rice cropping system, the dominant one in Bangladesh. Among the tested rates of VC incorporation, use of 0.5 t ha^{-1} VC + RCF was the best one for reducing GHG emission and grain yield improvement.

Table 24. Some soil parameters and carbon stock as influenced by VC incorporation rates after seven years

Parameters	Treatments				
	RCF (NPKSZn)	$VC_{0.5\ t\ ha^{-1}}$ +RCF	$VC_{1.0\ t\ ha^{-1}}$ +RCF	$VC_{1.5\ t\ ha^{-1}}$ +RCF	$VC_{2.0\ t\ ha^{-1}}$ +RCF
Organic carbon (g kg^{-1})	10.4c	11.2b	12.2a	12.5a	12.9a
Available N (g kg^{-1})	1.0b	1.2a	1.3a	1.3a	1.3a
Available P (mg kg^{-1})	18b	19.2a	19.3a	19.5a	19.6a
Available K (mg kg^{-1})	70c	72b	75a	77a	78a
Mean weight diameter (mm)	15.23c	19.62a	17.46ab	16.60b	16.78b
Bulk density (g cm^{-3})	1.37a	1.35b	1.33c	1.33c	1.32c
Total soil carbon stock (kg ha^{-1})	2137c	2268b	2434a	2494a	2554a
Net carbon balance (kg ha^{-1})	-57e	74d	240c	300b	360a

Small letters in a column compare means significant at P≤ 0.05% level by Tukey's HSD test.

Conclusion

Aggregation process in soil is important, and it plays a considerable role in improving soil physical characteristics such as carbon sequestration, hydraulic conductivity, infiltration, ventilation, etc. This report shows the amount of MWDw was highest with the additions of 0.5 t ha^{-1} VC with RCF. The highest amounts of SOC were found in different rates of VC application. Therefore, it is concluded that 0.5 t ha^{-1}with RCF fertilization is one of the important tools for improving soil health and rice grain yield.

Expt. 18. TILLAGE SYSTEM ENHANCED CARBON SEQUESTRATION UNDER RICE-MUSTARD-RICE CROPPING SYSTEM

Md Mozammel Haque and A. Islam

Introduction

Conventional tillage (CT) and no-tillage can also significantly influence GHG emission and soil properties depending on production environments (Kong et al., 2009; Mangalassery et al., 2014). Conservation agriculture, such as strip and zero tillage along with use of mulch (Gupta et al., 2016; Yadav et al., 2018), cover crop or residue (Haque et al., 2020b) and diverse crop rotations, is the best way of maintaining nature sustainably (Kassam et al., 2009). Generally, strip or zero tillage aims to conserve, improve and make efficient use of natural wealth through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhance and to sustain agricultural production and to minimize soil carbon loss (Lal et al., 2003). The CT practice is dominant in Bangladesh, although some changes are taking place gradually because of mechanization and enhanced knowledge of the farmers. Such practice negatively influences soil properties and its productivity, damages macro-aggregates and increases soil erosion (Borie et al., 2006; Palm et al., 2014). Therefore, now a day, strip or zero tillage practice is being adopting all over the world because it can also save time and energy, improve soil organic C (SOC), improve soil structure (Abdalla et al., 2013), control soil erosion effectively and minimize labor costs, but no data are available on soil C stock as affected by tillage operations under rice-mustard-rice system. Therefore, the aim of this research was to determine above mentioned parameters and to identify the influencing factors of increasing carbon sequestration under CT and ST with similar fertilization under rice-mustard-rice cropping system.

Materials and Methods

The experiment was initiated at farmers field Kushtia during 2021-2023. The treatments were conventional tillage (CT) and strip tillage (ST) under recommended of NPKSZn fertilization for rice and NPKSZnB for mustard crop cultivation. The unit experimental plot area was 7.0 m × 5.0 m. The design of the experiment was RCBD with three replications. Rice seedlings were transplanted in the first week of August and harvested in second week of November for wet season (Monsoon season). Dry season irrigated rice (Boro rice) was transplanted in the second week of February and harvested in the fourth week of May. Two to three seedlings (25-35 day-old in wet season, and 35-40 day-old in dry season) were transplanted at 0.2 m x 0.2 m spacing. Rice crops were grown under fully anaerobic conditions but mustard in aerobic environment. After the harvests of crops, root biomass was incorporated into field soil. Synthetic fertilizers (NPKSZn) used were: 100-10-80-5-5 kg ha^{-1} for wet season and 138-10-80-5-5 kg ha^{-1} for dry season rice as N from urea, P from triple super phosphate, K from muriate of potash, S form gypsum and Zn from zinc sulphate. One third of N, total P, K, S and Zn were applied as basal fertilizers before rice transplanting. The rest of N fertilizer was applied in two equal splits at active tillering stage and one week before panicle initiation stage. BRRI dhan75 and BRRI dhan58 were used as indicator crop variety in wet and dry seasons, respectively.

Mustard seeds were sown on 16th November 2021 and 15th November 2022 at 30 cm row spacing in a continuous line. The rates of synthetic fertilizers (NPKSZNB) used were 102-22-54-10-1-0.5 kg ha^{-1} for mustard. Half dose of N and whole amounts of other the fertilizers were applied as basal dose and the remaining half of N as urea was applied at 25 days after sowing (DAS). Weeds were cleaned by hand at 24th DAS only. No soil pulverization occurred in ST practice during weeding. Strip tillage was done by power tiller operated seeder (PTOS) with one pass, whereas conventional tillage was accomplished by power tiller with two-three passes followed by two laddering.

Net ecosystem C balance

Net C balance was calculated according to Ma et al. (2010); Zhang et al. (2017); Haque et al. (2020a, b, 2021a)

$$\text{NECB} = \text{NPP} - R_h - \text{Harvest} - CH_4 + \text{Fertilizer}$$

The NPP was estimated according to Smith et al., 2010.

Where, NPP and R_h represent net primary production (above and below ground biomass, litter and rhizodiposit) and heterotrophic respiration, respectively. The harvest includes straw/stover and grains and fertilizer C inputs were calculated from urea rates.

The relative ability of measured gases were expressed in terms of CO_2 equivalent according to Robertson et al. 2000, and GWP was calculated considering 28 for CH_4, and 265 for N_2O (IPCC, 2014): The net GWP was estimated according to Ma et al. 2013 and Haque et al. 2015.

$$\text{Net GWP (kg } CO_2 \text{ eq. ha}^{-1}) = CH_4\times28 + N_2O\times265 - \text{NECB}\times44/12\times1$$

Soil organic carbon stock (SOCS) was determined according to following formula:

$$\text{SOCS} = \text{Soil organic C (\%)}*\text{depth}*\text{Bulk density.}$$

Results and Discussion

Annual net carbon stock

Two techniques were used for estimating annual net carbon balance during study period. First method, carbon stock as determined based on carbon input and output source. The input C was about 11.90 and 12.20 t ha^{-1}, respectively for CT and ST **(Table 25);** while output C was about 10.22 t ha^{-1} and 10.36 t ha^{-1} for CT and ST system, respectively. After completion of two year cycle of tested cropping system, net carbon stocks were 1.68-1.85 t C ha^{-1} depending tillage systems. The ST showed significantly higher net C stock in ST system compared to CT. Second methods, soil organic C stock as determined based on soil bulk density and soil organic C content after two years of cropping also higher in ST (1.94-1.96 t C ha^{-1}) than CT **(Table 26).** The ST increased about 9-11% net C stock after two years of cropping cycle based on two techniques.

Table 25. Net carbon stock as influence by tillage operations under rice-mustard-rice cropping patterns.

Year	Treatments	Input C (t ha^{-1})	Output C (t ha^{-1})	Yearly net C stock (t C ha^{-1})
2018	Conventional tillage	11.90	10.21	1.68
	Strip tillage	12.21	10.37	1.84
2019	Conventional tillage	11.91	10.22	1.69
	Strip tillage	12.18	10.34	1.85
Statistical analysis				
Treatments (A)		***	***	***
Year (B)		**ns**	**ns**	**ns**
A×B		**ns**	**ns**	**ns**

Table 26. Changes in soil organic carbon stock based on tillage system under rice-mustard-rice system

Year	Treatments	Organic C (g kg^{-1})	Bulk density (g cm^{-3})	SOCS (t C ha^{-1})
2018	Conventional tillage	8.70	1.36	1.78
	Strip tillage	9.50	1.36	1.94
2019	Conventional tillage	8.62	1.36	1.76
	Strip tillage	9.60	1.36	1.96
Statistical analysis				
Treatments (A)		***	***	***
Year (B)		**ns**	**ns**	**ns**
A×B		**ns**	**ns**	**ns**

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Conclusion

As a whole, we have seen that strip tillage can increased about 9-11% net C stock than conventional tillage. Therefore, it is concluded that ST could be one of the important techniques for enhancing net carbon stock under rice-mustard-rice cropping system.

Expt. 19. SOIL MANAGEMENT TO MAXIMIZE THE YIELD OF NEWLY RELEASED RICE VARIETIES

M. Iqbal, M. N. Ahmed, U. Aminun Naher and A. Islam

Introduction

Soil management is the application of operations, practices, and treatments to enhance soil fertility. It includes soil conservation, soil amendment, and optimal soil health. In agriculture, some amount of soil management is needed both in inorganic and organic types to prevent agricultural land from becoming poorly productive over decades. Organic farming in particular emphasizes optimal soil management, because it uses soil health as the exclusive or nearly exclusive source of its fertilization and pest control. The first step in managing soil fertility is testing the soil. A soil test provides very important information about nutrient levels in the soil, including phosphorus, potassium, calcium and magnesium as well as the pH (or acidity). We can also test for organic matter. Nitrogen, a very important nutrient and one that is frequently deficient, is not included directly in most soil tests. This is because nitrogen forms and amounts change in response to temperature, soil moisture, and biological activity, so a one-time test doesn't provide very useful information.

Considerable yield gap exists between potential yield and attainable yield of most of the rice varieties, which may be due to lack of appropriate soil and crop management practices. We know soil and crop management can contribute 60% for getting potential yield of a variety. Hence, the present study was carried out to explored soil management practices that maximizes rice yield.

Materials and Methods

The experiment was initiated in T.Aman 2022 at BRRI farm Cumilla and Sonagazi to find the best soil management to maximize rice yield with organic and inorganic amendment with maintaining soil health. Treatments were assigned in split plot design with three replications. Main plot treatments were T_1= soil test based fertilizer application, T_2= soil test based fertilizer plus 20% more nitrogen T_3= soil test based fertilizer plus 20% more potassium and T_4= soil test based fertilizer with available organic matter (2 t/ha). Sub plot treatments were three rice varieties; V_1= BRRI dhan87, V_2 = BRRI dhan94, V_3 = BRRI dhan95 for T.Aman season and V_1 = BRRI dhan89, V_2 = BRRI dhan92, V_3 = BRRI dhan96 for Boro season. Before the initiation of the experiment, soil samples from the top layer (20 cm) were collected, analyzed for calculating soil test based fertilizer recommendation in each sites. Vermicompost and cowdung were available in Cumilla and Sonagazi respectively. Soil test based nutrient recommendation in Cumilla and Sonagazi were 96:12:52:10 and 88:15:54:6 kg/ha for T.Aman season 173:18:61:12:1.5 and 178:24:82:10:1.7 kg/ha for Boro season respectively. The N was applied as urea in three equal splits: the first one at the time of final land preparation, the second at maximum tillering stage and the third at the time of panicle initiation. The unit sub plot size was 5 m × 4 m. The data were analyzed using analysis of variance. The mean comparison among the treatments was done following Least Significance Difference Test (LSD) at 5% level of significance. The analyses were carried out using the Statistix software.

Results and Discussion

T. Aman 2022

Insignificant grain yield was found among the soil management treatments in both locations. But BRRI dhan94 produced significant grain yield when 20% nitrogenous fertilizer application in addition with soil test based fertilization compared with cowdung application in Sonagazi farm **(Table 27).** Soil test based fertilizer management were enough for both locations, although Cumilla farm were required organic matter in addition with STB dose **(Table 28).**

Table 27. Grain yield under different soil management practices for double rice cropping for maximizing productivity of newly released BRRI rice varieties in BRRI farm, Sonagazi, T. Aman 2022

Treatments	BRRI dhan87	BRRI dhan94	BRRI dhan95	Mean
STB	6.00	7.20	6.01	6.41
STB+20%N	5.44	7.51	6.18	6.38
STB+20% K	5.55	7.10	6.08	6.24
STB+CD	5.27	6.97	5.68	5.97
Mean	5.56	7.19	5.99	
CV (%)		8.19		
LSD 0.05	Treatment : NS	Variety: 0.44	Interaction: NS	

Table 28. Grain yield under different soil management practices for double rice cropping for maximizing productivity of newly released BRRI rice varieties in BRRI farm, Cumilla, T. Aman 2022

Treatments	BRRI dhan87	BRRI dhan93	BRRI dhan95	Mean
STB	5.57	5.44	5.09	5.37
STB+20% more N	4.92	5.34	5.32	5.19
STB+20% more K	5.01	5.68	5.46	5.38
STB+VC	5.69	5.75	5.19	5.54
Mean	5.29	5.55	5.26	
CV (%)		6.67		
LSD 0.05	Treatment :NS	Variety: NS	Interaction: NS	

Boro 2022-23

BRRI dhan92 and BRRI dhan96 produced significant highest grain yield when 20% more nitrogenous fertilizer application in addition with soil test based fertilization but BRRI dhan89 produced insignificant grain yield in Sonagazi farm **(Table 29).** Varietal difference among the treatments were recorded in Cumilla farm where BRRI dhan96 produced highest grain yield at soil test based fertilization. Soil test based fertilizer management were enough for both locations **(Table 30).**

Table 29. Grain yield under different soil management practices for double rice cropping for maximizing productivity of newly released BRRI rice varieties in BRRI farm, Sonagazi, Boro 2022-23

Treatments	BRRI dhan89	BRRI dhan92	BRRI dhan96	Mean
STB	7.64	7.42	5.27	6.78
STB+20%N	7.93	7.94	6.66	7.51
STB+20% K	7.61	7.60	5.67	6.96
STB+CD	7.74	7.80	5.96	7.16
Mean	7.73	7.69	5.89	
CV (%)		7.10		
LSD 0.05	Treatment :0.40	Variety: 0.44	Interaction: NS	

Table 30. Grain yield under different soil management practices for double rice cropping for maximizing productivity of newly released BRRI rice varieties in BRRI farm, Cumilla, Boro 2022-23

Treatments	BRRI dhan89	BRRI dhan92	BRRI dhan96	Mean
STB	6.62	6.34	7.44	6.80
STB+20%N	6.70	6.01	6.85	6.52
STB+20% K	6.83	5.87	7.37	6.69
STB+CD	6.65	5.92	6.79	6.45
Mean	6.70	6.04	7.11	
CV (%)	5.3			
LSD 0.05	Treatment :NS	Variety: 0.30	Interaction: NS	

Expt. 20. GOOD AGRICULTURAL PRACTICES: TO INCREASE RICE PRODUCTIVITY

A.T.M. Sakhawat Hossain, M. Akter, F. Rahman and A. 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 and maintain soil health for sustainable rice production. To export rice and to increase farm productivity, we have to produce safe and quality rice. Good Agricultural Practice (GAP) 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. We like to include rice crop in GAP protocol for safe food production. That’s why the experiment was conducted to satisfy the following objectives.

i) To obtain quality and safe rice
ii) To sustain rice yield and maintain soil health and
iii) To minimize environmental pollution through INM practice

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 and the tested rice variety for Boro season was BRRI dhan50. The BRRI dhan50 rice variety is a good yielded, premium and aromatic rice which we can used for domestic and export purpose. The individual main-plot size was 4m×5m i.e. 20m^2. Eight different treatments of inorganic and organic combinations calculating from 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 like CD and PM were applied 5 days before transplanting of rice seedlings and incorporated the soil. All chemical 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 25 DAT and the rest one on 5 days before panicle initiation (PI) stage. Thirty five days old seedlings of BRRI dhan50 was transplanted on the 2nd week of December. Mustard oil cake was applied in two times of top dress and 1st one at early tillering and 2nd one at mid-tillering stage and incorporated the soil. Irrigation, weeding and other cultural management practices were done equally as per needed. In Boro 2022-23 we didn't apply any pesticide to rice field, actually there was no need to apply any pesticide. The other methodology were followed and documents were recorded to fulfill the GAP protocols of Bangladesh. 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 grain samples were processed properly to measure nutrient content and uptake of. 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

Growth and yield of Boro 2022-23

The growth and yield parameters of BRRI dhan50 have influenced greatly with the application of organic and inorganic fertilizers **(Table 31).** Grain yield increased significantly with application of different fertilizer combinations over control. The highest grain yield was obtained with T_5 treatment (6.51 t ha^{-1}) which was statistically significant with T_2 (6.09 t ha^{-1}), T_4 (6.07 t ha^{-1}), T_7 (5.93 t ha^{-1}), T_8 (5.75 t ha^{-1}) and T_6 (5.73 t ha^{-1}) treatments. The PM treated plots gave better yield than other organic combinations. 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 to chemical fertilizer application. The over use of chemical fertilizer (125% STB) gave worse grain yield (5.67 t ha^{-1}) than 100% STB fertilizer. Similar trend was obtained with straw yield production **(Table 31).**

Conclusion

Good Agricultural Practice (GAP) is now the time demanding option for producing healthy and safe food in Bangladesh. Organic combinations using PM and CD with 25-50% reduced doses of chemical fertilizers can gave satisfactory rice yield. It can save chemical fertilizers as well as minimize environmental pollution.

Table 31. Effect of organic and inorganic fertilizer on GAP Boro rice yield and yield contributing characters, BRRI, 2022-23

Treatment	Tiller m$^{2-1}$	Panicle m$^{2-1}$	GY (t ha^{-1})	SY (t ha^{-1})
T_1: Fertilizer control	217 c	209 b	2.73 c	2.45 c
T_2: 100% STB dose (inorganic)	403 a	317 a	6.09 ab	5.85 ab
T_3: 125% STB dose (inorganic)	422 a	327 a	5.67 b	6.20 a
T_4: 75% STB + CD @ 2 tha^{-1}	405 a	319 a	6.07 ab	5.69 ab
T_5: 75% STB + PM @ 1 tha^{-1}	398 a	307 a	6.51 a	6.22 a
T_6: 50% STB + CD @ 3 tha^{-1}	371 ab	300 a	5.73 ab	5.60 ab
T_7: 50% STB + PM @ 2 tha^{-1}	376 ab	307 a	5.93 ab	6.08 ab
T_8: CD @ 3 tha^{-1}+ Mustard oil cake @ 2 tha^{-1} (organic)	337 b	295 a	5.75 ab	5.45 b
CV (%)	4.96	4.54	4.88	4.35

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

Project 04: Problem soil management and greenhouse gas emission

Expt. 21. EFFECT OF BIOCHAR ON RICE YIELD AND SOIL HEALTH ON PROBLEM SOILS

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Introduction

A vast area (about 1 M ha) of Bangladesh is comprised of newly developed charlands (Karim et al., 2017). The soils are mostly sandy with poor water holding capacity having poor nutrient status which hinders crop production. As the agricultural land is decreasing at an alarming rate of 0.73 ha per year (Hasan et al., 2013), it has become imperative to explore the potential of these problem soils (Charlands) for crop production. Therefore, effective reclamation technologies are necessary to exploit the full potential of these soils. In that case, biochar has emerged as a promising soil remediation tool. Biochar is a carbon-rich substance, produced by thermal decomposition of organic compounds at a relatively high temperature (<700°C) under limited supply of oxygen (Lehmann et al. 2006). It contains more than 60% carbon, and is rich in various nutrients and trace elements essential for crop growth (Glaser et al. 2002; Demirbas 2004). Returning biochar to the field can quickly improve soil carbon storage, nitrogen content and soil fertility. It can also reduce the emission of greenhouse gases and improve crop yields (Lehmann et al. 2003; Steiner et al. 2007; Laird et al. 2009; Van et al. 2010a; Feng et al. 2012; Li et al. 2014). So, this investigation was undertaken to determine the effect of biochar on rice yield, nutrient use efficiency and soil health of charland soils.

Materials and Methods

The experiment was conducted at the experimental field of Bangladesh Rice Research Institute, Sirajganj in T. Aman, 2022 and Boro, 2022-23 seasons. The experiment was initiated in Boro 2019-20 and consisted of four treatments: T_1= Control, T_2= Recommended fertilizer (RF), T_3= RF + biochar @ 2 t ha^{-1} and T_4= RF + biochar @ 4 t ha^{-1}. The experiment was laid out in a RCB design with three replications. The biochar was produced from chita dhan (unfilled grain). Biochar was applied only in Boro season and incorporated with soil before 7 days of transplanting. Flat doses of NPKSZn were applied @ 100-15-40-10-4.5 kg ha^{-1} in T. Aman and 138-21-75-18-4.5 kg ha^{-1} in Boro season. Urea was applied in three 3 equal splits i.e 1/3 at basal, 1/3 active tillering stage and 1/3 at 5-7 days before PI stage. Phosphorus, K and S fertilizers were applied at final land preparation. The unit plot size was 3.6 m × 5 m in both seasons. In T. Aman season thirty days old seedlings and in Boro season thirty-five days old seedlings were transplanted. All intercultural operations were done as when required. At maturity, the crop was harvested from 5m^2 areas at the centre of each plot and 16 hills were collected for straw yield. The grain yield was recorded at 14% moisture content and straw yield as oven dry basis.

Results and Discussion

T. Aman, 2022

In T. Aman season, 30 % fertilizer was reduced from recommended dose in the biochar treated plots to observe the residual effect of biochar on rice. The residual effect of biochar, applied in the previous Boro 2021-22 season, was observed on the grain and straw yield of BRRI dhan87 over control plots **(Table 32)**. The highest grain yield was found 5.65 t ha^{-1} with T$_4$ (70% Rec. fertilizer) which was statistically similar with T$_3$ and T$_4$. The lowest grain yield was 3.68 t ha^{-1} with control plot. The highest straw yield was recorded 6.59 t ha^{-1} in T$_4$, which was statistically identical with T$_2$ and T$_3$. The lowest straw yield was 4.06 t/ha in control plot which was significantly lower than other treatments. The combination of chemical fertilizer and biochar treatments successfully induced higher yield such as grain and straw compared to control. It was indicated that reduction of 30% fertilizer from the recommended dose in the biochar treated plots produced grain yields similar to full dose of recommended fertilizer. The total nutrient uptakes of N, P and K, S by BRRI dhan87 were higher with T$_2$ (Rec. fertilizer) which was statistically similar with 4 t ha^{-1} biochar application **(Table 32).**

Table 32. Effect of biochar on the yield and total nutrient uptake of BRRI dhan87 in T Aman 2022 at BRRI farm, Sirajganj

Treatment	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**Total nutrient uptake (kg ha^{-1})**			
			N	**P**	**K**	**S**
Control	3.68 b	4.06 b	49 b	11.22 b	57.03 c	5.39 b
Rec. fertilizer	5.65 a	6.75 a	96.18 a	22.85 a	111.74 a	13.06 a
70% Rec. fertilizer + BC @ 2 t ha^{-1}	5.56 a	6.53 a	87.87 a	20.58 b	103.36 b	11.61 a
70% Rec. fertilizer + BC @ 4 t ha^{-1}	5.59 a	6.58 a	86.45 a	23.54 a	115.15 ab	12.60 a
CV (%)	5.77	12.79	13.09	5.49	6.37	11.92

Boro, 2022-23

The highest grain yield of BRRI dhan89 was found 6.77 t ha^{-1} with T$_4$ (Rec. fertilizer + BC @ 4 t ha^{1}) than the other treatments **(Table 33).** The lowest grain yield was found 2.85 t ha^{-1} with control plot. The highest straw yield was 6.64 t ha^{-1} in T$_4$. The lowest straw yield was found 2.16 t ha^{-1} in control plot.

Table 33. Effect of biochar on the yield of rice at BRRI farm, Sirajganj, Boro, 2022-23

Treatment	**Yield (t ha^{-1})**	
	Grain	**Straw**
Control	2.85 c	2.16 d
Rec. fertilizer	4.74 b	4.16 c
Rec. fertilizer + BC @ 2 t ha^{-1*}	5.32 b	5.39 b
Rec. fertilizer + BC @ 4 t ha^{-1*}	6.77 a	6.64 a
CV (%)	7.61	8.03

Conclusions

From the obtained results it can be concluded that application of biochar had positive impact on growth and yield of rice. In this study, single application of 4 t ha^{-1} biochar in Boro-Fallow-T. Aman cropping pattern performed best on rice yield.

Expt. 22. EFFECT OF WATER MANAGEMENT ON MITIGATING OF GREENHOUSE GAS EMISSION AT GAZIPUR AND KUSHTIA

Md Mozammel Haque, A. Islam and Kazunori Minamikawa

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, 2023. 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 location.

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):

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

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 GHGI= Total GWP/ Grain yield

Results and Discussion

Rice Grain yield under different water management at Gazipur and Kushtia

Yield of Boro rice varied insignificantly in different water management options at different location **(Table 34).** Statistically insignificant grain yield (ranged from 7.16 to 7.43 t ha^{-1} and 7.67 to 7.77 t ha^{-1}) were found among the treatments and location. However, the AWD treatment increased about 1-2% grain yield compared to CSW at both locations.

Methane emission and GWP during Boro season

The total CH_4 flux was not significant different because of two AWD condition at different location **(Table 34).** However, the AWD, 15 cm and AWD, 25 cm treatment reduce about 38-42% and 34-39% of total CH_4 flux than CSW at Gazipur and Kushtia. Among the irrigation system, the GWP reduce about 36-40% and 34-37% by AWD than CSW.

Table 34. Total GHG and GWP under varying irrigation management during Boro 2023

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	201	5235	0.70	7.43	205	5908	0.77	7.67
AWD,15 cm	125	3361	0.45	7.54	136	3924	0.51	7.77
AWD,25 cm	116	3159	0.44	7.16	125	3700	0.48	7.72
$LSD_{0.05}$	35	211	0.11	0.21	31	228	0.10	0.15

Conclusion

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

Expt. 23. COMPARISON OF GLOBAL WARMING POTENTIAL BETWEEN RAIN FED AND CONTINUOUS IRRIGATION IN HAOR REGION DURING T AMAN-BORO SEASON

Md Mozammel Haque, M Maniruzzaman, S Akhter and A. 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 farmer's field, Habiganj during T. Aman and Boro, 2022-23. 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, 2022 at a rate of 2-3 seedlings per hill. In Boro season, trirty five day old rice seedlings were transplanted on 7 th January, 2023 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):

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

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 GHGI= Total GWP/ Grain yield

Results and Discussion

In T. Aman season; Yield varied insignificantly in different water management options **(Table 35).** Sufficient rainfall in the whole growing season created no water stress during 2022 in T Aman season. Thus, no supplemental irrigation was applied both in continuous flooding and supplemental irrigation treatments. Statistically insignificant grain yield (ranged from 4680 to 4725 kg ha^{-1}) were found among the treatments. The GWP was significantly affected under different water management during T. Aman season **(Table 35).** 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 35).** 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 35. Total GHG and GWP under varying irrigation management during T. Aman-Boro season, 2022-23

Treatment	Season					
	T. Aman			Boro		
	GWP	GHGI	Yield	GWP	GHGI	Yield
T_1 (Rainfed)	4466	0.95	4700	5904	0.93	6350
T_2 (AWD)	5006	1.07	4680	6268	0.94	6640
T_3 (CSW)	5253	1.11	4725	7379	1.07	6900
$LSD_{0.05}$	305	0.09	230	420	0.07	380

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. 24. GLOBAL WARMING POTENTIAL AS INFLUENCED BY DIFFERENT FERTILIZER MANAGEMENT DURING T. AMAN AND BORO RICE SEASON AT KUSHTIA REGION

Md Mozammel Haque, M Maniruzzaman, S Akhter and A. Islam

Introduction

Incorporation of different organic materials and cover crop biomass into paddy soil can increase GHG such as CH_4 , N_2O emission and GWP (Haque et al., 2013, 2015a; Ibrahim et al., 2015); but they also improve crop productivity and soil net carbon budget (Haque et al., 2019a, b, 2020). Because of such anthropogenic activities, the contribution of agriculture to global GHG emission is about 10-12% (Hou et al., 2012). Many strategies have been employed to reduce CH4 emission, such as use of straw biochar (Zhang et al., 2020; Dong et al., 2013), manipulating tillage operations (Lu and Lu, 2017), selecting suitable rice cultivars (Haque et al., 2017a; Setyanto et al., 2000), fertilizer and water management (Haque et al., 2016a, b), etc. The emissions of GHG from rice-rice cropping pattern were higher than growing single rice crop in a year or rice–wheat rotation systems along with other cropping patterns (Haque et al., 2015a; Xie et al., 2017); but N_2O, CH_4 and CO_2 emission patterns, GWP and GHG intensity from rice cultivation system are not available, especially from organic amended paddy fields and different agro-ecological zone. Therefore, the objectives of this study were to find out GHG, GWP, GHG intensity and to increase rice yield by incorporating either VC or CD in comparison to other fertilizations.

Materials and Methods

Treatments, design and management

Experiment were assigned in a completely randomized block design with three replications. Unit plot size was 400 x 600 cm. Sole chemical fertilizers (SCF), farmers practice, vermicompost (VC) and cow dung (CD) as integrated plant nutrient system (IPNS) based inorganic fertilizers were tested in the experiment. T. Aman rice (wet season) was transplanted in the last week of July and harvested in the last week of November, 2022. Boro was transplanted in the 2nd week of December and harvested in the last week of May, 2023. Two to three seedlings 30-35 day-old in T. Aman season and 40-45 day-old in Boro season were transplanted at 0.2-x 0.2-m spacing. Rice were grown under irrigated conditions and after harvest, the root biomass was incorporated into rice soil. Sole chemical fertilizer used were: 138/100-10-80-5-5 kg ha^{-1} for Boro and T. Aman season as N from urea, P from triple super phosphate, K from muriate of potash, S form gypsum and Zn from zinc sulphate. Cow dong and VC were applied at two ton per hector with IPNS based inorganic fertilizations as basal dose. One third of N, total P, K, S and Zn were applied as basal fertilizers before rice transplanting. The rest of N fertilizer was applied in two equal splits at active tillering stage and one week before panicle initiation stage. BRRI dhan87 and BRRI dhan92 were used as indicator crop variety in T. Aman and Boro seasons.

Gas sampling and analysis

Carbon dioxide, methane, and nitrous oxide emissions were measure by using static chamber methods during T. Aman and 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):

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

where, U_i is the rate of CO_2, CH_4 and N_2O flux in g m^{-2} d^{-1} during ith sampling interval, V_i is the number of days in the fth 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 GHGI= Total GWP/ Grain yield

Results and Discussion

Grain yield

Vermicompost with IPNS fertilizer application plot showed significantly higher grain yield than CD plot during T. Aman and Boro rice cultivation. Organic fertilization plot increased about 18-25% and 11-15% grain yield than that of farmers' fertilizer management during T. Aman and Boro season. Among the treatment, farmers management showed lowest grain yield than other fertilization **(Table 36 and 37).**

Greenhouse gas emission

The lowest total CH_4, N_2O, EF, GWP and GHG intensity were found under VC treated plot than CD. About 18% reduce of GWP, 17% of EF and 22% of GHG intensity compare to CD during T. Aman season **(Table 36).** During Boro rice cultivation about 14% reduce of GWP, 15% of EF and 17% of GHG intensity **(Table 37).** Chemical fertilizer treated plot showed lower GHG intensity, GWP and EF during T. Aman and Boro rice season than farmers and organic management.

Table 36. Grain yield, emission factor, global warming potential and GHG intensity as influence by organic and inorganic fertilizer application during T. Aman rice cultivation at Kushtia region in Bangladesh, 2022

Treatments	Grain yield (t ha^{-1})	EF of CH_4 (g ha^{-1})	CH_4 (kg ha^{-1})	N_2O (kg ha^{-1})	GHG intensity (kg ha^{-1})
Farmers practice	4.95d	1.95	185c	0.47c	1.07
NPKSZn	5.30c	1.71	163d	0.39d	0.88
Cowdung with IPNS	5.85b	3.23	310a	0.68a	1.51
VC with IPNS	6.20a	2.69	256b	0.52b	1.18

Table 37. Grain yield, emission factor, global warming potential and GHG intensity as influence by organic and inorganic fertilizer application during Boro rice cultivation at Kushtia region in Bangladesh, 2022-23.

Treatments	Grain yield (t ha^{-1})	EF of CH_4 (g ha^{-1})	CH_4 (kg ha^{-1})	N_2O (kg ha^{-1})	GHG intensity (kg ha^{-1})
Farmers practice	6.85	2.14	235	0.90	099
NPKSZn	7.10	1.95	215	0.85	0.88
Cowdung with IPNS	7.60	3.41	375	1.00	1.42
VC with IPNS	7.88	2.91	320	0.98	1.17

Conclusion

Vermicompost organic amendment is important fertilizer for reducing GWP, emission factor of CH_4, GHG intensity as well as increased grain yield. Further evaluation is needed for find out the actual mitigation values and net carbon emission and absorption.

Expt. 25. GREENHOUSE GAS EMISSION AND ABSORPTION UNDER DIFFERENT FERTILIZER MANAGEMENT WITH WHEAT-RICE CROPPING PATTERN IN KUSHTIA REGION

Md Mozammel Haque, M Maniruzzaman, S Akhter and A. Islam

Introduction

Wheat is one of the important cereal crops in Asia and provides about 30% of calories to more than 4.5 billion people (Shiferaw et al. 2011). In Bangladesh, wheat is the second most important cereal after rice and covering 0.33 million ha and producing 1.02 million tonnes of grain (BBS, 2019). Different approaches can be adopted to improve crop yields like developing high yielding varieties and their cultivation by the growers, fertilizer-water-pest management, etc. Out of many avenues of crop yield improvements, fertilizer and water management play an essential role. Adoption of higher fertilizer rates in a balanced way can improve crop yields and maintain soil health (Haque et al. 2019a, b, Sihi et al. 2017), but such practice is also responsible for augmented emissions of N_2O, CH_4 and CO_2 (Hoben et al. 2011; Zhang et al. 2014; Haque et al. 2020a, b, 2021b).

Greenhouse gases are produced in variable amounts under aerobic and anaerobic conditions from agriculture fields, of which CH_4 is one of the major ones having 28 times higher GWP than CO_2 (IPCC 2014). On the other hand, one third of N_2O emission occurs from agricultural practices and human interventions (Zaehle et al. 2011) are also important gas having 265 times higher GWP than CO_2 (IPCC 2014). Methane is emitted from anaerobic environments, but its oxidation occurs in aerobic conditions. Wheat is generally cultivated with residual soil moisture or with a few irrigations in Bangladesh; no measured data on CH_4, CO_2 and N_2O emissions are available considering net GWP, net carbon emission and GHG intensity. Wheat is one of the most important cereals globally and is grown under variable environments along with varying levels of fertilizer and water management. Besides, soil organic matter contents, soil pH, and winter temperature greatly influence GHG emissions and heavy dressings of N fertilizers (Leppelt et al. 2014). Therefore, the objectives of the present investigation were to identify GHG emission patterns, net GWP, net carbon emission and GHG intensity during wheat-rice cropping pattern with different fertilizer applications.

Materials and Methods

Experimental design and set-up

The experiment was conducted at farmers' field in Kushtia. The treatments were: (i) recommendation chemical fertilizer (RCF), (ii) farmers practice chemical fertilizer (FP), (iii) cowdung (CD) and (iv) vermicompost (VC). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The recommended dose of commercial fertilizers for wheat cultivation was $N_{150}P_{40}K_{120}S_{20}Zn_{1.5}$ B_1 kg ha^{-1} and were supplied from Urea, TSP, MoP, gypsum, zinc sulphate (hepta) and boric acid, respectively. Farmers' chemical fertilizer doses was $N_{170}P_{30}K_{100}S_{20}Zn_1B_1$ kg ha^{-1}. The unit plot size was 6m x 5m. Wheat seeds were sown in line continuously from November 2021 with row to row spacing of 20 cm. After that, the first flooded irrigation was applied at 25-27 days after sowing seeds, and the second irrigation was applied at 38-40 DAS. T. Aman rice (wet season) was transplanted in the last week of July and harvested in the last week of November, 2022. Sole chemical fertilizer used were: 100-10-80-5-5 kg ha^{-1} for T. Aman season as N from urea, P from triple super phosphate, K from muriate of potash, S form gypsum and Zn from zinc sulphate. Cow dong and VC were applied at two ton per hector with IPNS based inorganic fertilizations as basal dose. One third of N, total P, K, S and Zn were applied as basal fertilizers before rice transplanting. The rest of N fertilizer was applied in two equal splits at active tillering stage and one week before panicle initiation stage. BRRI dhan87 was used as indicator crop variety in T. Aman seasons.

Gas sampling and analyses

The static closed-chamber method (Haque et al. 2013, 2020a, 2021a, b, 2022) was used to estimate CO_2, N_2O and CH_4 emission rates during wheat and rice cultivation. In acrylic column chambers which had 20 cm diameter and 20 cm height were placed in between two rows for evaluating heterotrophic respiration rates (CO_2 emission), N_2O and CH_4 emissions rates during wheat cultivation (Lou et al. 2004; Xiao et al. 2005; Iqbal et al. 2008; Haque et al. 2015, 2022) in 2018-2021. The bottom 20 cm of each chamber was interred into the soil surface for preventing plant root intrusion and the growth of weeds. Weeds within the chamber were removed continually to minimize plant CO_2 uptake loss during investigation. 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. All chambers were kept open throughout the investigation period except during the gas sampling in the experimental fields. The chamber was equipped with a circulating fan for gas mixing and a thermometer inside to monitor the temperature during the sampling time. Air-gas samples were collected using 50 ml gas-tight syringes at 0 and 30 min after chamber closing. Gas samplings were carried out at three times (8 AM -12 AM -16 PM) in a day to get the average GHGs emission rates. Collected gas samples were immediately transferred into 20 ml air-evacuated glass vials sealed with a butyl rubber septum for gas analysis. Two GHGs concentrations in the collected air samples were measured by Gas Chromatography (Shimadzu, GC-2014, Japan) with a Porapak NQ column (Q 80-100 mesh). A thermal conductivity detector (TCD), ^{63}Ni electron capture detector (ECD) and flame ionization detector (FID) were used for quantifying CO_2, N_2O and CH_4 concentration, respectively.

Greenhouse gas emission rates were calculated following by Haque et al. (2021a)

$$M = N \text{ x } (C/B) \text{ x } (\Delta d/\Delta t) \text{ x } (273/T)$$

where, M is the CO_2 (mg m^{-2} hr^{-1}), CH_4 (mg m^{-2} hr^{-1}) and N_2O flux (μg N_2O m^{-2} hr^{-1}), N is the gas density of CO_2, CH_4 and N_2O under a standardized state (mg cm^{-3}), C is the volume of chamber (m^3), B is the surface area of chamber (m^2), $\Delta d/\Delta t$ is the rate of increase of CO_2, N_2O and CH_4 gas concentrations in the chamber (mg m^{-3} hr^{-1}) and T (absolute temperature) is 273 + mean temperature (°C) of the chamber.

The seasonal total GHG fluxes were computed according to Singh et al. (1999):

Total GHG flux = $\sum_f^e (O_i \times P_i)$

where, O_i is the rate of CO_2, N_2O and CH_4 flux in g m^{-2} d^{-1} during i^{th} sampling interval, P_i is the number of days in the f^{th} sampling interval, and e the number of sampling. The relative ability of different gases was expressed in terms of CO_2 equivalent (Robertson et al. 2000), and net GWP was calculated considering 28 for CH_4 and 265 for N_2O (IPCC 2014). GWP (kg CO_2 eq. ha^{-1}) = $N_2O \times 265 + CH_4 \times 28$. The following equation are used for calculation of net carbon balance= NPP+fertilizer-CH_4-C- respiration carbon- biomass carbon.

Statistical analysis

Analyses of variances were conducted by using SAS software (SAS Institute, 1995). Fishers protected least significant difference (LSD) was calculated at the 0.05 probability level for making treatment mean comparisons.

Results and Discussion

Yield; In wheat- rice cropping pattern, about 3% higher yields were obtained because of VC application than CD uses. The FP showed a lower yield 2980 kg ha^{-1} than other treatment. In T Aman season, VC application showed significantly higher grain yield than that of only chemical fertilizer **(Table 38).** On the other hand, wheat cultivation showed significantly higher CO_2 absorption than rice cultivation. The CO_2 absorption rats was about 1121-4057 kg ha^{-1} under wheat-rice cropping system during the study period based on fertilizer management **(Fig. 20).**

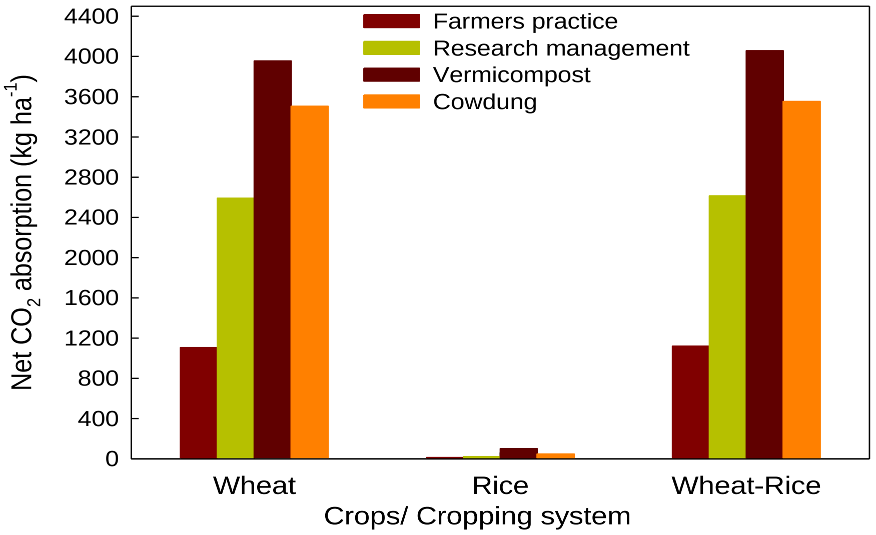

Fig. 20. Net CO_2 absorption as influenced by organic and inorganic fertilizer management under wheat-rice cropping pattern, at Kushtia region, 2022-2023

Table 38. Grain yield as influenced by organic and inorganic fertilizer management under wheat-rice cropping pattern, at Kushtia region, 2022-2023

Treatment	Grain Yield (kg ha^{-1})	
	Wheat	Rice
Farmers practice	2980c	4730c
Research practice	3360b	4980b
Vermicompost with IPNS	3880a	5590a
Cowdung with IPNS	3770a	5450a

Conclusion

The VC with IPNS treatment significantly decreased seasonal CH_4 flux by 23%, N_2O flux by 9% and CO_2 flux by 11% and increased yield and CO_2 absorption compared to CD with IPNS treatments. We suggested that a suitable combination of organic and inorganic fertilization is essential for soil health improvement, carbon sequestration, and crop yield improvement under changing climate in future.

Expt. 26. GLOBAL WARMING POTENTIAL ON JUTE- RICE CROPPING SYSTEM IN BANGLADESH

Md Mozammel Haque, M Maniruzzaman, S Akhter and A. Islam

Introduction

Jute is the cheapest natural fiber and is considered the golden fiber due to its color and cash value. Jute fiber is mainly composed of cellulose, lignin, and pectin. China, India, Bangladesh, Uzbekistan, and Nepal are the main producers of jute in the world. Among these countries, the topmost jute producers are India and Bangladesh, but management practices are important to enhance crop productivity as well as produce greenhouse gas emission. Rice fields are also main sources of GHG production. Incorporation of different organic materials into paddy soil can increase GHG such as CH_4 , N_2O emission and GWP (Haque et al., 2013, 2015a; Ibrahim et al., 2015); but they also improve crop productivity and soil net carbon budget (Haque et al., 2019a, b, 2020). Management strategies have been employed to reduce CH_4 emission, such as biochar, water management, tillage system (Haque et la., 2022; Zhang et al., 2020; Dong et al., 2013), selecting suitable rice cultivars (Haque et al., 2017; Setyanto et al., 2000), fertilizer and water management (Haque et al., 2016a, b), etc. The emissions of GHG from rice-rice cropping pattern were higher than growing single rice crop in a year or rice–wheat rotation systems along with other cropping patterns (Haque et al., 2015a; Xie et al., 2017); but N_2O, CH_4 and CO_2 emission patterns, GWP and GHG intensity from jute-rice cultivation system are not available, especially from organic amended paddy fields and different agro-ecological zone. Therefore, the objectives was to identify of greenhouse gas emission and GWP during jute-rice cropping system in Bangladesh.

Materials and Methods

Experimental site and design

An experiment was conducted to estimate the emission of GHG at different growth stages of jute and rice cultivation during 2022. The experiment were conducted at farmers' field in Kushtia regions. The experiment was laid out in a randomized complete block design (RCBD) with four treatments with three replication. The treatments were: farmers does chemical fertilizer practice (FP), recommended chemical fertilizer practice (RP), vermicompost (VC), cowdung (CD) with integrated plant nutrient system (IPNS). The recommended dose of chemical fertilizer for Jute was N_{60}, $P_{30,}$ K_{30} kg ha^{-1} and N_{100}-P_{10}-K_{80}-S_5-Zn_5 kg ha^{-1} for T. Aman rice. The recommended fertilizer doses were used to supply N, P and K from Urea, TSP and MoP respectively. The unit plot size was 4m x 5m. The jute seeds were sown in line continuously in last week of March, and harvest last week of July, 2022. T. Aman rice (wet season) was transplanted in the first week of August and harvested in the last week of November, 2022. Different intercultural operations such as irrigation, weeding, pest control, etc. were done as and when required**.**

Gas sampling and analysis

Static closed-chamber method (Haque et al., 2015, 2021) was used to estimate GHG emission rates during Jute-rice cropping system. In acrylic column chambers which have diameter 20 cm and height 20 cm were placed inner plant excluded soil surface between jute plants for evaluating GHG emission during jute season (Lou et al., 2004; Xiao et al., 2005; Iqbal et al., 2008; Haque et al., 2015).). 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. All chambers were kept open throughout the investigation period except during the gas sampling in the experimental fields. The chamber was equipped with a circulating fan for gas mixing and a thermometer inside to monitor the temperature during the sampling time. Air gas samples were collected using 50 ml gas-tight syringes at 0 and 30 min after chamber placement. Gas samplings were carried out at three times (8:00–12:00–16:00) in a day to get the average GHGs emission rates. Three gas samples in each replicate of each treatment were then drawn off from the chamber headspace equipped with 3-way stop cock. Collected gas samples were immediately transferred into 20-ml air-evacuated glass vials sealed with a butyl rubber septum for gas analysis.

Three GHGs concentrations in the collected air samples were measured by Gas Chromatography (Shimadzu, GC-2014, Japan) with Porapak NQ column (Q 80–100 mesh). A thermal conductivity detector (TCD), ^{63}Ni electron capture detector (ECD) and flame ionization detector (FID) were used for quantifying CO_2, N_2O and CH_4 concentration, respectively.

Greenhouse gas emission rates were calculated following by Haque et al., 2021a

$$M = N \times (C/B) \times (\Delta d/\Delta t) \times (273/T)$$

where, M is the CO_2 (mg m^{-2} hr^{-1}), CH_4 (mg m^{-2} hr^{-1}) and N_2O flux (μg N_2O m^{-2} hr^{-1}), N is the gas density of CO_2, CH_4 and N_2O under a standardized state (mg cm^{-3}), C is the volume of chamber (m^3), B is the surface area of chamber (m^2), $\Delta d/\Delta t$ is the rate of increase of CO_2, N_2O and CH_4 gas concentrations in the chamber (mg m^{-3} hr^{-1}) and T (absolute temperature) is 273 + mean temperature in (°C) of the chamber.

The relative ability of different gases were expressed in terms of CO_2 equivalent (Robertson et al. 2000), and net GWP was calculated considering 28 for CH_4, and 265 for N_2O (IPCC 2014).

$$\text{The net GWP (kg } CO_2 \text{ eq. ha}^{-1}) = N_2O\times265 + CH_4\times28 + CO_2\times1$$

The following equation are used for calculation of net carbon balance/absorption= NPP+fertilizer-CH_4-C- respiration carbon- biomass carbon.

Results and Discussion

Greenhouse gas emission from jute-rice cropping system

GHG emissions

Cowdung fertilizer management showed higher total CH_4, N_2O and CO_2 fluxes than other fertilizer management **(Table 39).** Research management reduce about 12% of CH_4, and 15% of N_2O in jute and 14% of CH_4 and 17% of N_2O in rice season than farmers practice.

Table 39. Total GHG and GWP under jute cultivation during 2022

Treatments	Cropping pattern			
	Jute		Rice	
	Greenhouse gas emission (kg ha^{-1})		Greenhouse gas emission (kg ha^{-1})	
	CH_4	N_2O	CH_4	N_2O
FP	1.08	0.26	169	0.81
RP	0.95	0.22	145	0.67
VC	1.13	0.24	221	0.91
CD	1.29	0.29	270	1.01

Global warming potential and yield: Among the treatment, the GWP was significantly different during jute and rice cultivation. Research management reduce about 13%of GWP than farmers' management during T. Aman season. About 44-1380 kg CO_2 ha^{-1} are absorbed under Jute-T. Aman cropping system with different fertilizer management. Rice and jute yield also were significantly different with different fertilizer management. The lowest yield were found under the farmers practice fertilizer management under both crop cultivation **(Table 40).** In jute cultivation, root, leaf, stick and fiber biomass yield were significantly different among the treatment **(Fig. 21).**

Conclusion

In Jute-Rice cropping system, RP fertilizer management significantly increased of CO_2 absorption than other fertilizer management. Therefore, we conclude recommended chemical fertilizer is important for increasing CO_2 absorption without sacrificing yield under jute-rice cropping system. Further evaluation is needed for find out the actual mitigation values and net carbon emission and absorption at different location.

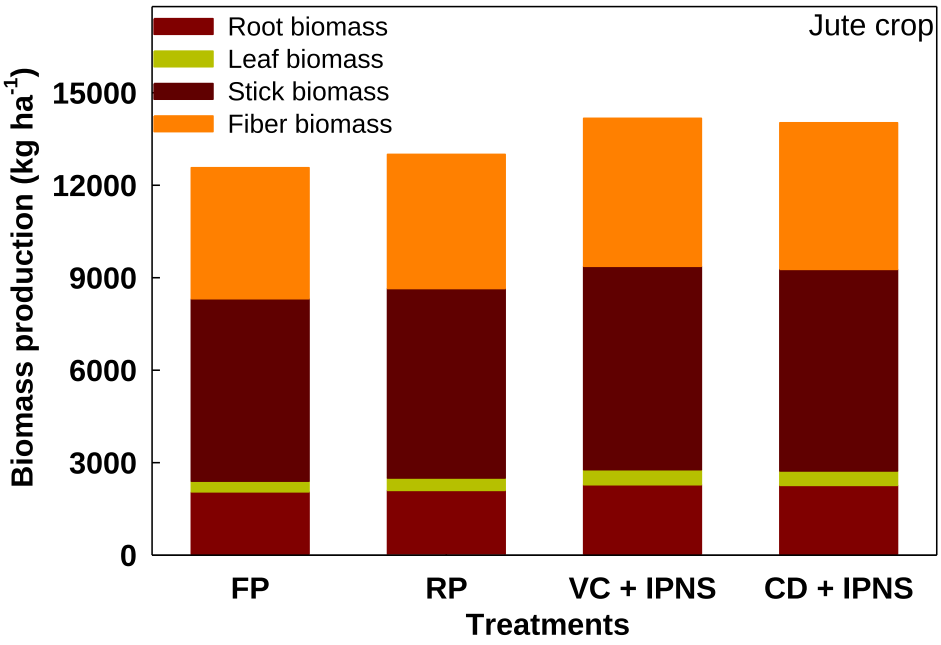

Fig. 21. Different parts of jute biomass production under different fertilizer management

Table 40. Total GHG and GWP under jute cultivation during 2022

Treatment	GWP (kg CO_2 eq. ha^{-1})			Yield (kg ha^{-1})	
	Crops		Cropping pattern	Crops	
	Jute	Rice	Jute-T. Aman	Jute (fibre)	Rice (grain)
Farmers practice	-4310b	3644b	-665b	4200c	4830c
Research practice	-4567a	3187c	-1380a	4350b	5090b
VC with IPNS	-4618a	4449a	-169c	4800a	5990a
CD with IPNS	-4575a	4531a	-44d	4810a	5850a

Note: VC= Vermicompost, CD=Cowdung

Expt. 27. TILLAGE SYSTEM MINIMIZING GLOBAL WARMING POTENTIAL UNDER RICE-MUSTARD-RICE CROPPING SYSTEM

Md Mozammel Haque, S. Akhter, M Maniruzaman and A. Islam

Introduction

The emissions of GHG from agricultural fields, especially from continuously flooded paddy fields are one of the vital sources of CH_4 emission that contribute greatly for increased GHG emission (Hwang et al., 2017, Haque et al., 2021a). Rice plants mediate CH_4 emission by about 10% (Haque e al. 2018), its emission also takes place from other marshy lands and thus contributes to GWP along with other gases like N_2O and CO_2. Since the GWP of CO_2, CH_4 and N_2O are 1, 28 and 265 times than CO_2 in a time horizon of 100 years, respectively (IPCC, 2014), it is necessary to minimize GHG emissions from rice fields. There are available agricultural management techniques for the reduction of GHG emissions from single or double major cropping systems (Jat et al., 2019; Haque et al., 2021a). However, farmers are growing three or even four crops yearly in Bangladesh and some other Asian countries that warrant special efforts for the reduction of GHG emissions. Three crops based cropping systems, having at least one or two rice crops, are found in about two million ha in Bangladesh (Nasim et al., 2017) in which rice-mustard-rice systems occupy around 15% areas. As cultural management is one of the important strategies for improved crop production, it should also address other challenges confronting intensified cropping systems, like resource conservation and minimization of GHG emission for cleaner crop production under changing climate (Yadav et al., 2018).

Among different available technologies, water management, organic amendment and reduced tillage can influence GHG emissions favorably (Nishimura et al., 2004; Haque et al., 2020a, b). Conventional tillage (CT) and no-tillage can also significantly influence GHG emission depending on production environments (Kong et al., 2009; Mangalassery et al., 2014). Conservation agriculture, such as strip and zero tillage along with use of mulch (Gupta et al., 2016; Yadav et al., 2018), cover crop or residue (Haque et al., 2020b) and diverse crop rotations, is the best way of maintaining nature sustainably (Kassam et al., 2009). Generally, strip or zero tillage aims to conserve, improve and make efficient use of natural wealth through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhance and to sustain agricultural production and to minimize soil carbon loss (Lal et al., 2003). The CT practice is dominant in Bangladesh, although some changes are taking place gradually because of mechanization and enhanced knowledge of the farmers. Such practice negatively influences soil properties and its productivity, damages macro-aggregates and increases soil erosion (Borie et al., 2006; Palm et al., 2014). Therefore, now a day, strip or zero tillage practice is being adopting all over the world because it can also save time and energy, improve soil organic C (SOC), improve soil structure (Abdalla et al., 2013), control soil erosion effectively and minimize labor costs, but no data are available on GHG emission, GHG intensity, GWP, and soil C stock as affected by tillage operations under rice-mustard-rice system. Therefore, the aim of this research was to determine above mentioned parameters and to identify the influencing factors of controlling GHG emission and GHG intensity under CT and ST with similar fertilization under rice-mustard-rice cropping system.

Materials and Methods

The experiment was initiated at farmers field Kushtia during 2021-2023. The treatments were conventional tillage (CT) and strip tillage (ST) under recommended of NPKSZn fertilization for rice and NPKSZnB for mustard crop cultivation. The unit experimental plot area was 7.0 m × 5.0 m. The design of the experiment was RCBD with three replications. Rice seedlings were transplanted in the first week of August and harvested in second week of November for T Aman season (Monsoon season). Boro season irrigated rice was transplanted in the second week of February and harvested in the fourth week of May. Two to three seedlings (25-35 day-old in wet season, and 35-40 day-old in dry season) were transplanted at 0.2 m x 0.2 m spacing. Rice crops were grown under fully anaerobic conditions but mustard in aerobic environment. After the harvests of crops, root biomass was incorporated into field soil. Synthetic fertilizers (NPKSZn) used were: 100-10-80-5-5 kg ha^{-1} for wet season and 138-10-80-5-5 kg ha^{-1} for dry season rice as N from urea, P from triple super phosphate, K from muriate of potash, S form gypsum and Zn from zinc sulphate. One third of N, total P, K, S and Zn were applied as basal fertilizers before rice transplanting. The rest of N fertilizer was applied in two equal splits at active tillering stage and one week before panicle initiation stage. BRRI dhan75 and BRRI dhan58 were used as indicator crop variety in wet and dry seasons, respectively. Mustard seeds were sown on 16th November 2021 and 15th November 2022 at 30 cm row spacing in a continuous line. The rates of synthetic fertilizers (NPKSZNB) used were 102-22-54-10-1-0.5 kg ha^{-1} for mustard. Half dose of N and whole amounts of other the fertilizers were applied as basal dose and the remaining half of N as urea was applied at 25 days after sowing (DAS). Weeds were cleaned by hand at 24th DAS only. No soil pulverization occurred in ST practice during weeding. Strip tillage was done by power tiller operated seeder (PTOS) with one pass, whereas conventional tillage was accomplished by power tiller with two-three passes followed by two laddering.

Greenhouse gas sampling during mustard crop

Nitrous oxide, CO_2 and CH_4 emissions were measured by using static chamber methods during mustard cultivation (Haque et al., 2013, 2020a). Smaller close chambers (20 cm x 50 cm) were placed in between rows of mustard plants for measuring CH_4, CO_2 and N_2O emission rates (Lou et al., 2004; Xiao et al., 2005; Iqbal et al., 2008; Haque et al., 2015). All chambers were inserted into soil up to 20 cm, removed weeds regularly. Gas chambers kept open always except during sampling time. Each chamber was operational with a circulating fans and a thermometer inside.

GHG sampling during rice cultivation

Methane, N_2O and CO_2 emissions were measured by using static chamber methods (Haque et al., 2013, 2020). Transparent glass chambers (0.62 m x 0.62 m and height 1.12 m) were placed permanently in the plots after rice transplanting. 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. 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., 2015). All chambers were inserted into soil up to 20 cm, removed weeds regularly and maintained water depth at 5-7 cm. Gas chambers were kept open always except during sampling. Each chamber was operational with one circulating fans and one thermometer inside.

Gas samples were collected in 50 ml air-tight syringes at 0 and 30 min after closing the chambers. Gas samples 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, CO_2 and CH_4 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 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 in µg 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 is the number of sampling.

Net ecosystem C balance

Net C balance was calculated according to Ma et al. (2010); Zhang et al. (2017); Haque et al. (2020a, b, 2021a)

$$NECB = NPP - R_h - \text{Harvest} - CH_4 + \text{Fertilizer}$$

The relative ability of measured gases were expressed in terms of CO_2 equivalent according to Robertson et al. 2000, and GWP was calculated considering 28 for CH_4, and 265 for N_2O (IPCC, 2014): The net GWP was estimated according to Ma et al. 2013 and Haque et al. 2015.

Net GWP (kg CO_2 eq. ha^{-1}) = $CH_4 \times 28 + N_2O \times 265$ - NECB×44/12×1

Statistical analysis

SAS package (version 9.1) was used for statistical analyses (SAS Institute, 2003). Tukey's test was used for treatment comparison and differences were considered significant at $p \leq 0.05$ level.

Results and Discussion

Grain and straw/stover yields

Different tillage practices showed variations in grain and straw/stover yields under rice-mustard-rice cropping system in both the years. In ST, grain yields increased yield by 2-8% and RYT by 10-11% than CT **(Table 41).** The ST also gave higher straw/stover yields than CT. Among two types of crops tested, mustard crop gave significantly higher grain and stover yields with ST than CT.

Table 41. Effects of tillage practices on yield productivity of rice-mustard-rice cropping system, 2021-2023

Tillage practices	Yield (t ha^{-1})						
	T Aman		Mustard		Boro		REY
	Grain	Straw	Grain	Stover	Grain	Straw	
Conventional tillage	4.20	4.90	0.77b	0.97b	5.39	6.10	11.36b
Strip tillage	4.32	4.95	0.83a	1.03a	5.49	6.35	12.44a
Conventional tillage	4.47	5.12	0.77b	0.96b	5.15	5.88	11.25b
Strip tillage	4.56	5.16	0.83a	1.01a	5.32	6.15	12.45a

Small letters in a column compare means at 5% level of probability by LSD

REY = Rice equivalent yield.

Greenhouse gas emission

CH_4 emission

In Boro season irrigated rice, the ST significantly reduced CH_4 emission rate compared to CT **(Table 42).** The CH_4 emission rates were 383-390 mg m^{-2} day^{-1} with CT, whereas it was 307-317 mg m^{-2} day^{-1} with ST indicating that ST reduced about 20% CH_4 emission compared to CT with irrigated rice culture. In wet season, CH_4 emission rates were 243-258 mg m^{-2} day^{-1} with ST, but it was 363-375 mg m^{-2} day^{-1} with CT indicating that ST reduced CH_4 emission by 29-35%. In mustard crop, CH_4 emission rates varied from -0.61 to -0.73 mg m^{-2} day^{-1} with CT and the values with ST were -1.57 to -1.92 mg m^{-2} day^{-1} **(Table 42).**

Carbon dioxide emission

In both rice seasons, CT emitted the lowest respiratory CO_2 compared to ST in both the tested years **(Table 42).** In Boro season, the CO_2 rates were 685-705 mg m^{-2} day^{-1} and 918-932 mg m^{-2} day^{-1} with CT and ST system, respectively. Similarly in T Aman season, CT and ST produced 1110-1160 mg m^{-2} day^{-1} and 1220-1260 mg m^{-2} day^{-1}, respectively. Mustard crop, CO_2 emission rates were 780-820 mg m^{-2} day^{-1} and 930-960 mg m^{-2} day^{-1} under CT and ST. In general, there was about 10-37% higher CO_2 emissions in ST compared to CT depending on year and growing seasons.

Table 42. Greenhouse gas emissions as influence by tillage system under rice-mustard-rice cropping system.

Cropping season	Parameters	2021-22		2022-23		Statistical Analysis		
		CT	ST	CT	ST	Treatment (A)	Year (B)	A×B
Boro	Mean emission rate (mg m^{-2} day^{-1})							
	CH_4	383	307	390	317	***	ns	ns
	CO_2	705	918	685	932	***	ns	ns
	N_2O	0.72	0.88	0.83	0.98	***	*	***
Mustard	Mean emission rate (mg m^{-2} day^{-1})							
	CH_4	-0.73	-1.57	-0.61	-1.92	***	ns	ns
	CO_2	820	930	780	960	***	ns	ns
	N_2O	1.30	1.66	1.23	1.78	***	ns	ns
T Aman	Mean emission rate (mg m^{-2} day^{-1})							
	CH_4	375	243	363	258	***	ns	ns
	CO_2	1160	1260	1110	1220	***	ns	ns
	N_2O	1.49	2.09	1.44	2.04	***	ns	ns

CT = Conventional tillage, ST = Strip tillage

Nitrous oxide emission

Nitrous oxide emissions varied greatly depending on crop growing seasons over the years **(Table 42).** In general, the highest N_2O emissions (1.44-2.09 mg m^{-2} day^{-1}) were observed with T Aman season rice followed by mustard crop (1.23-1.78 mg m^{-2} day^{-1}) and the least (0.72-0.98 mg m^{-2} day^{-1}) with Boro season irrigated rice irrespective of tillage systems. The ST was responsible for 22-44% increase in N_2O emissions compared to CT.

Global warming potential

In dry season irrigated rice, the GWP were 5305-5791 and 3404-3969 kg CO_2 eq. ha^{-1} with CT and ST, respectively **(Fig. 22).** While on the other hand, the GWP varied from 6374-6808 and 3602-3814 kg CO_2 eq. ha^{-1}, respectively with CT and ST in wet season. In contrast, the GWP values were 172-177 and 75-83 kg CO_2 eq. ha^{-1}, respectively for CT and ST system during mustard crop cultivation. These results indicate that GWP was reduced with ST than CT system during tested crop cultivations. Considering the rice-mustard-rice system as a whole, the GWP can be reduced by about 43-45% if ST system is followed than CT.

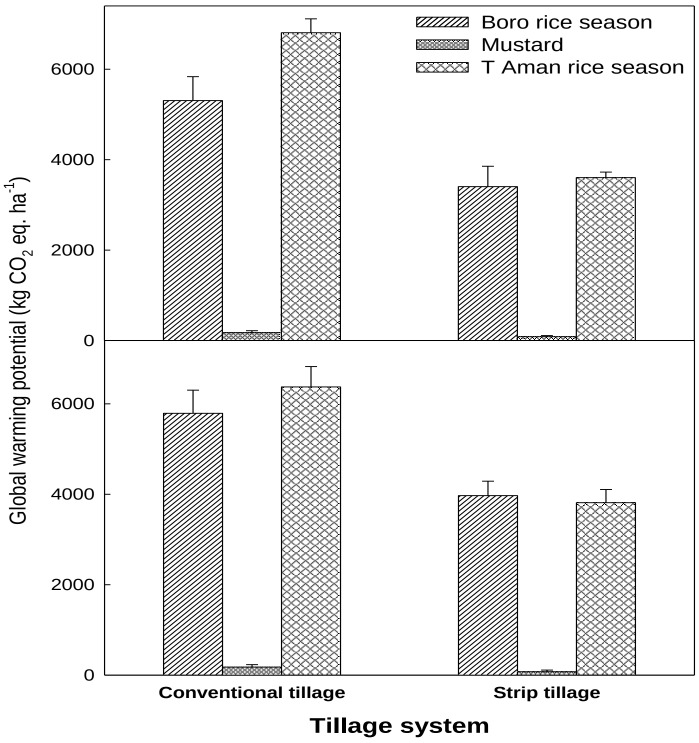

Fig. 22. Global warming potential under different tillage system with rice-mustard-rice cropping system.

Conclusions

As a whole, we have seen that strip tillage can reduce 20-32% CH_4 emission, 31-55% GWP and 32-58% GHG intensity than conventional tillage depending on growing seasons. Therefore, it is concluded that ST could be one of the important techniques for reducing greenhouse gas emission, GWP, GHG intensity and also to increase crop yields under rice-mustard-rice cropping system.

Expt. 28. INFLUENCE OF GREENHOUSE GAS EMISSION DURING WHEAT AND MAIZE CULTIVATION WITH RESEARCHER AND FARMERS MANAGEMENT

Md Mozammel Haque, M Maniruzzaman, S Akhter and A. Islam

Introduction

Wheat and maize is the second/third cereal crop in Asia and provides about 30% of food calories to more than 4.5 billion people (Shiferaw et al., 2011). However, population is increasing and will continue to increase from 7.2 to 8.1 billion by 2025 and 10.9 billion by 2100 in the developing countries (Gerland et al., 2014). Cereal crop production is needed for meet up the increasing population. But balance fertilizer and other management practices are important to enhance crop productivity. After application of chemical fertilization to increased crop productivity but also produce greenhouse gas emission. Therefore, the objectives was to identify of greenhouse gas emission and GWP during wheat and maize cultivation under different fertilizer application in Bangladesh.

Materials and Methods

Experimental plot installation, fertilization and design

An experiment was conducted to estimate the emission of CH_4, CO_2 and N_2O at different growth stages of wheat and maize as influenced by chemical fertilizer application and to find out the suitable management for minimizing greenhouse gas emission for wheat (variety-BARI Gom 30) and Maize cultivation during the rabi season of 2022-2023. The experiment were conducted at the Meherpur district. The experiment was laid out in a randomized complete block design (RCBD) with four treatments replicated three times. The treatments were: T_1= farmers' chemical fertilizer management, T_2 = researcher chemical fertilizer application for Meherpur. The recommended dose of chemical fertilizer (RDCF) for wheat was $N_{150}P_{40}K_{120}S_{20}Zn_{1.5}$ B_1 kg ha^{-1}. The farmers practice fertilizer dose was $N_{160}P_{50}K_{110}S_{20}Zn_{1.0}$ B_1 kg ha^{-1}. The recommended fertilizer doses were used to supply N, P, K, S, Zn and B from Urea, TSP, MoP, gypsum, zinc sulphate (hepta) and boric acid, respectively.The unit plot size was 4m x 2.5m. The wheat and maize seeds were sown in line continuously in November, 2021 with row to row spacing 20 cm. All PKSZnB and 2/3rd N was applied at the time of final land preparation. Different intercultural operations such as irrigation, weeding, pest control, etc.were done as and when required.

Gas sampling and analysis

Static closed-chamber method (Ali et al., 2009; Haque et al., 2013, 2015b, 2015c) was used to estimate CH_4, CO_2, and N_2O emission rates during wheat and maize season. In acrylic column chambers which have diameter 20 cm and height 20 cm were placed inner plant excluded soil surface between wheat and maize plants for evaluating heterotrophic respiration rates (CO_2 emission), CH_4 and N_2O emission during wheat and maize season (Lou et al., 2004; Xiao et al., 2005; Iqbal et al., 2008; Haque etal., 2015b). The bottom 20 cm of chamber was interred inner soil to prevent plant root intrusion, and weeds inner the chamber were continually removed to minimize plant CO_2 uptake loss during the investigation. All chambers were kept open throughout the investigation period except during the gas sampling in the experimental fields. The chamber was equipped with a circulating fan for gas mixing and a thermometer inside to monitor the temperature during the sampling time. Air gas samples were collected using 50 mL gas-tight syringes at 0 and 30 min after chamber placement. Gas samplings were carried out at three times (8:00–12:00–16:00) in a day to get the average GHGs emission rates. Three gas samples in each replicate of each treatment were then drawn off from the chamber headspace equipped with 3-way stop cock. Collected gas samples were immediately transferred into 20-ml air-evacuated glass vials sealed with a butyl rubber septum for gas analysis.

Two GHGs concentrations in the collected air samples were measured by Gas Chromatography (Shimadzu, GC-2014, Japan) with Porapak NQ column (Q 80–100 mesh). A thermal conductivity detector (TCD) and ^{63}Ni electron capture detector (ECD) were used for quantifying CO_2 and N_2O concentration, respectively. The temperatures of the column, injector and detector were adjusted at 45, 75, and 270^{o}Cfor CO_2, and 70, 80, and 320^{o}Cfor N_2O, respectively. Argon, Helium and H_2 gases were used as the carrier and burning gases, respectively.

Carbon dioxide and N_2O emission rates were calculated from the increase in CO_2 and N_2O concentrations per unit surface area of the chamber for a specific time interval. A closed-chamber equation (Lou et al., 2004) was used to estimate seasonal fluxes from each treatment.

$$F = \rho \times (V/A) \times (\Delta c/\Delta t) \times (273/T)$$

where, F is the CO_2 (mg m^{-2} hr^{-1}), and N_2O flux (μg N_2O m^{-2} hr^{-1}), ρ is the gas density of CO_2, and N_2O under a standardized state (mg cm^{-3}), V is the volume of chamber (m^{3}), A is the surface area of chamber (m^{2}), Δc/Δt is the rate of increase of CO_2, and N_2O gas concentrations in the chamber (mg m^{-3} hr^{-1}) and T (absolute temperature) is 273 + mean temperature in (°C) of the chamber.

The seasonal CO_2, and N_2O flux for the entire crop period was computed as reported by Singh et al. (1999): Seasonal CO_2 and N_2O flux = $\sum_i^n (R_i \text{ x } D_i)$

Where R_i is the rate of CO_2 and N_2O flux (g m^{-2} d^{-1}) in the *i*th sampling interval, D_i is the number of days in the *i* th sampling interval, and *n* the number of sampling. The relative ability of measured gases were expressed in terms of CO_2 equivalent according to Robertson et al. 2000, and GWP was calculated considering 28 for CH_4, and 265 for N_2O (IPCC, 2014): GWP (kg CO_2 eq. ha^{-1}) = $CH_4 \times 28 + N_2O \times 265 + CO_2 \times 1$

Greenhouse gas emission intensity (GHGI)

The GHGI is the level of GHG emissions per unit of economic activity such as crop culture, generation of electricity, etc. It is a ratio comparing GHG emissions of an activity (eg rice, mustard, etc. production) to economic output (eg grain yield). We have calculated GHGI according to following formula: GHGI= Net GWP/Grain yield.

Results and Discussion

Greenhouse gas emission at Meherpur during wheat and maize cultivation

During the study period, farmers practice showed higher total GHG flux, GWP than researcher fertilization plot during wheat and maize cultivations **(Table 43).** Researcher fertilizer management reduce about 12% and 11% of GWP than farmers practice fertilization under wheat and maize cultivation. In contrast, wheat and maize yield also increase about 2-6% than that of farmers practice during crops cultivation.

Table 43. GHG emission and GWP at Kushtia region in Wheat and Maize crops

Parameter	**Wheat crop**		**Maize crop**	
	Farmer practice fertilizer application	Researcher fertilizer application	Farmer practice fertilizer application	Researcher fertilizer application
CH_4 (kg ha^{-1})	13.5	11.2	22.8	20.5
N_2O (kg ha^{-1})	0.46	0.38	0.96	0.70
CO_2 (kg ha^{-1})	827	690	1090	975
GWP (kg ha^{-1})	1327	1104	1983	1735
GHG intensity (g ha^{-1})	0.41	0.32	0.23	0.19
Yield (kg ha^{-1})	3.20	3.40	8.80	9.02

Conclusion

Farmers practice increased the greenhouse gas emissions than research fertilizer management. Therefore, it could be concluded that researcher fertilizer imposed is good management option for reducing of GHG and increased crop productivity.

Expt. 29. MANAGEMENT INTERVENTIONS TO IMPROVE N USE EFFICIENCY WITH THE LEAST ENVIRONMENTAL POLLUTION IN DOUBLE RICE CROPPING OF BANGLADESH

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Introduction

Global warming due to climate change, greenhouse gas emission and food security are the vital global issues, as such important issues in South Asia including Bangladesh. Agriculture sector is considered as one of the important sources of anthropogenic greenhouse gases emission especially methane (CH_4) and nitrous oxide (N_2O). Worldwide rice cultivation held liability for up to 12% of CH_4 flux (IPCC, 2007) and 13-24% of N_2O emission amongst agricultural soils (Hossen et al., 2015). Although irrigated rice paddies are thought to be potential source of CH_4 emission, it is influenced by several interrelated factors like soil, rice cultivars and growth stages, water management, organic manure and fertilizer application, climatic factors and so on. Water management and improve organic manure and fertilizer management are the two important approaches to mitigate CH_4 and N_2O emission from paddy fields. Bangladesh is the third largest rice producing countries in the world and rice is grown in 80% of its cultivable land with double rice cropping occupying the largest share. On the other hand, nitrogen (N) fertilizer use in Bangladesh has remarkably increased over the past 38 years, and widely applied by the rice farmers to maximize yield but often at lower or over rates. This either limits crop growth by N deficiency or losses of N to adjacent water bodies and atmosphere, hence lowers farm profitability. Half of the Bangladeshi government's fertilizer subsidies are also dedicated to urea, and so efficient use of fertilizer-N is crucial to save national investments (Miah et al., 2016). Synchrony between N supply and crop N demand without excess or deficiency is also the key to optimize rice yield, ensure food security, improve farm profitability and reduce environmental harm. Despite driving productivity, poor N fertilizer use efficiency (30-50%) is characteristic of irrigated rice systems (Cassman et al., 1998; Miah et al., 2016), indicating huge N loss mostly through NH_3 volatilization, denitrification, leaching and surface runoff. To maintain soil fertility and organic C level in the long run it is indispensable to use balance fertilizer nutrients (N, P, K), better to follow IPNS (Integrated plant nutrient system) based nutrients management, even though organic manure application may upsurge methane emission. Despite all these facts, reliable data on the fates of applied N and GHGs emission with N applied either at optimum or over/under rates from inorganic sources, and organic plus inorganic sources, are still lacking for the typical (double) rice cropping in Bangladesh. Therefore, a field experiment was conducted during T. Aman (2022) and Boro (2023) seasons, at the field of BRRI Soil Science Division to evaluate the fates of N fertilizer (crop, soil and losses), N use efficiency (NUE) and N_2O and CH_4 emission under various N fertilizer managements.

Materials and Methods

The field experiment was conducted from during T. Aman (Aug-Nov, 2022) and Boro (Jan-May, 2023) rice seasons at the field of BRRI Soil Science Division (23°59'27" N; E: 90°24'14"E). The main physical and chemical properties of the initial soil in surface (0-15 cm) and subsoil (16-30 cm) layers are given in **Table 44**. The surface soil texture was silt loam with near neutral pH(H_2O). Soil bulk density was lower but soil organic C and N contents were greater in surface than that in subsoil. The selected rice cultivars were BRRI dhan87 for T.

Aman and BRRI dhan89 for Boro season. In both seasons, overall 28 (7 Treatments × 4 Replication), 20m^2 plots were established. The experiment was laid out in a RCB design. The blocks were separated from each other by 1 m irrigation channel and each plot is separated from each other by 40 cm earth bund to prevent exchange of water and fertilizer across the plots. In T. Aman season, the tested seven treatments were: T_1: no N fertilizer (N0), T_2: 110 kg N ha^{-1} from prilled urea (N110PU), T_3: T_2+25% N (N138PU), T_4: T_2-25% N (N83PU), T_5: Cow dung (CD) (2 t ha^{-1}) + IPNS with T_2 (N110 PU+CD), T_6: BRRI Organic Fertilizer (BOF) (2 t ha^{-1}) + IPNS with T_4 (N83 PU+ BOF) and T_7: Deep Placed Urea (UDP) alike T_4 (N83 UDP). During Boro season, these treatments were: T_1: no N fertilizer (N0), T_2: 140 kg N ha^{-1} from PU (N140PU), T_3: T_2+25% N (N175PU), T_4: T_2-25% N (N105PU), T_5: CD (2 t ha^{-1}) + IPNS with T_2 (N140 PU+CD), T_6: BOF (2 t ha^{-1}) + IPNS with T_4 (N105 PU+ BOF) and T_7: UDP alike T_4 (N105 UDP). The blanket rates of P-K-S-Zn were 20-60-10-1 kg ha^{-1}, resp. in T. Aman and 25-80-10-1 kg ha^{-1}, resp. in Boro season. The whole amount of P, K, S and Zn fertilizers were broad-casted and mixed with soil on the day of transplanting in all treatments with a subtracted amount of P and K from CD and BOF in T_5 and T_6, respectively. The sources of P, K, S and Zn were triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate monohydrate, respectively. Partially decomposed CD in T_5 and BOF in T_6 at the rate of 4 kg plot^{-1} (oven dry basis) (both equals the dose of 2 t ha^{-1}) were applied on 3 (in T. Aman) and 7 (in Boro) days before final land preparation and transplanting. In T_2, T_3, T_4, T_5 and T_6, N fertilizer was applied as urea into three equal splits on 12, 27 and 39DAT (days after transplanting) in T. Aman, and on 17, 38 and 52 DAT in Boro season, respectively. In case of T_7, the full amount of UDP was applied at once into 7 to 10 cm on 12 DAT in T. Aman and on 17 DAT in Boro season. Air samples were collected covering a total of 27 (T. Aman) and 28 (Boro) sampling events to analyze CH_4 and N_2O emission. Locally fabricated lysimeter was installed to analyze NH_4^+-N and NO_3^--N in the collected leachates from 21 plots (7 Treat. × 3 rep.) for several sampling events throughout the cropping seasons. Measurement of NH_3 emission (volatilization) was performed by using closed chamber technique and Boric Acid Trap method. The soil (0-15 and 16-30 cm depths) and plant samples were collected at 3 to 4 sampling events (active tillering, maximum tillering, flowering and at harvest) to determine soil available N (NH_4^+-N and NO_3^--N) and plant N uptake. In Boro 2023, aerial vehicle (DRONE) was used to take digital image, and SPAD readings and N concentrations in flag leaves were recorded on 32, 41, 60 and 81 DAT to observe the relationships between measured and predicted (by aerial vehicle based image analysis) leaf N status. At maturity, grain, straw and root yields were recorded, and N concentrations of all these samples were analyzed to assess N use efficiencies.

Table 44. Relevant physio-chemical properties (mean ± SE) of the initial soil

Soil properties	Surface layer (0-15 cm)	Subsoil (16-30 cm)
Texture	Clay Loam	-
Sand (%)	23	-
Silt (%)	46	-
Clay (%)	31	-
Bulk density (g cm^{-3}±SE)	1.18 ±0.04	1.43±0.06
pH_2O (1:2.5±SE)	6.82±0.02	6.66±0.00
Organic C (%±SE)	1.45±0.00	1.24±0.00
Total N (%±SE)	0.13±0.00	0.12±0.00

Results and Discussion

T. Aman 2022

Grain yield and N use efficiencies

The grain yield was significantly ($p<0.01$) greater in all N fertilizer applied treatments than no N applied treatment (N0) (**Fig. 23**). The grain yield was again statistically identical between the N fertilizer applied treatments. In T. Aman, the agronomic (AE_N) and physiological (PE_N) N use efficiencies were ranged from 5-11 kg grain kg^{-1} N applied and 9-27 kg grain kg^{-1} N in plant, respectively (**Fig. 24**). The $\mathrm{AE_N}$ was greater in N83PU (11), N83UDP (10) and N83 (PU+BOF) (9) treatments. Likewise, the $\mathrm{PE_N}$ was greater in N83PU (27) followed by N83 (PU+BOF) (19) and N83UDP (13) treatments. A desirable range of the recovery ($\mathrm{RE_N}$) N use efficiency (34 to 69%) was achieved in this season with its greater values attained from the N83UDP (69%), N110PU (49%) and N83 (PU+BOF) (42%) treatments **(Fig. 24**).

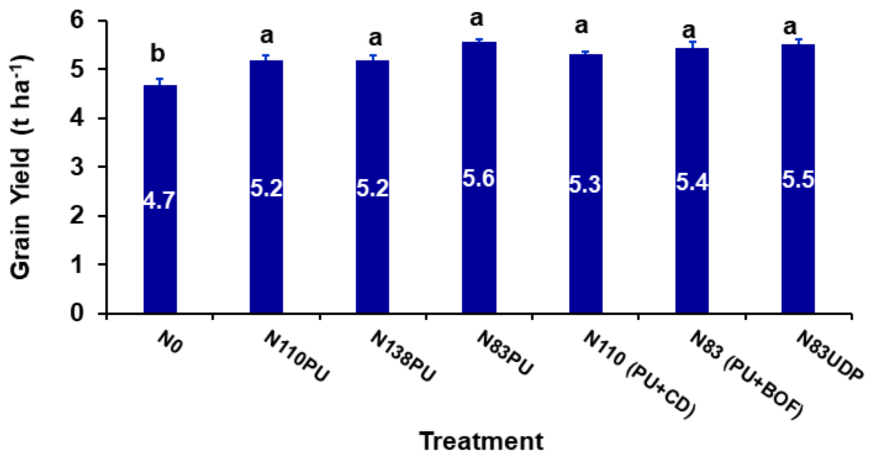


Fig.23. Grain yield (mean ± SE, n=4) influenced by different N management options in T. Aman season rice, 2022. Different lower case letters after group mean of grain yield indicates the significant (p<0.01) differences according to Duncan's Multiple Range Post Hoc Test.

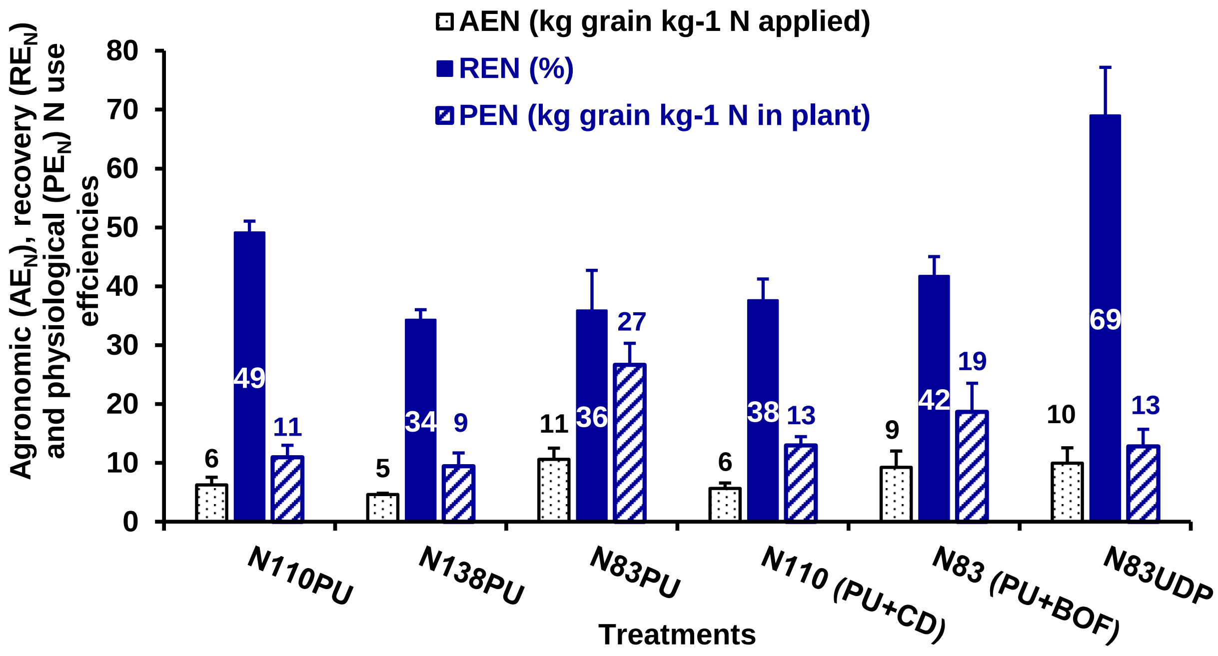


Fig.24. Agronomic ($\mathrm{AE_N}$), recovery ($\mathrm{RE_N}$) and physiological ($\mathrm{PE_N}$) N use efficiencies (mean ± SE, n=4) influenced by different N management options in T. Aman season rice, 2022.

Boro 2023

Grain yield

The grain yield was significantly (p<0.01) greater in all N fertilizer applied treatments than no N applied treatment (N0) (**Fig. 25**). Among N fertilizer applied treatments, the higher grain yield was attained in N applied at 140 kg N ha^{-1} from PU plus CD (N140 PU+CD), which was statistically identical with that in N140PU, N175PU, N105(PU+BOF) and N105UDP but significantly (p<0.01) greater than that in N105PU.

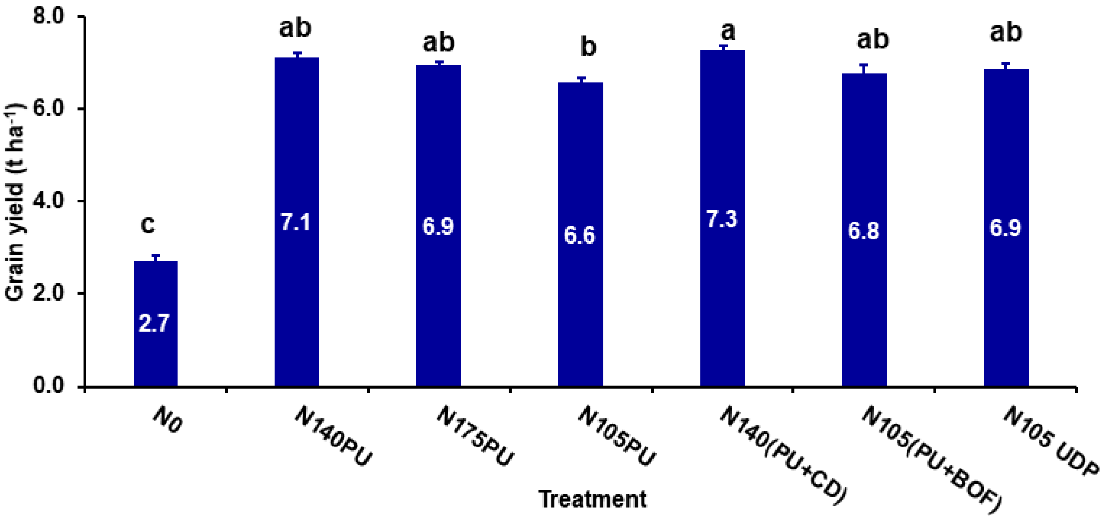


Fig. 25. Grain yield (mean ± SE, n=4) influenced by different N management options in Boro season rice, 2023. Different lower case letters after group mean of grain yield indicates the significant ($p<0.01$) differences according to Duncan's Multiple Range Post Hoc Test.

N use efficiencies

The greater AE$_N$ (kg grain kg^{-1} N applied) was obtained from N applied at 105 kg N ha^{-1} from UDP (N105UDP), PU (N105PU) and PU+BOF (N105 PU+BOF) (39, 38 and 37, respectively) (**Fig. 26**). Alike previous Boro (dry) seasons out comes, the greater RE$_N$ was attained from the N applied at 105 kg N ha^{-1} from deep placed urea (N105UDP) (58%).

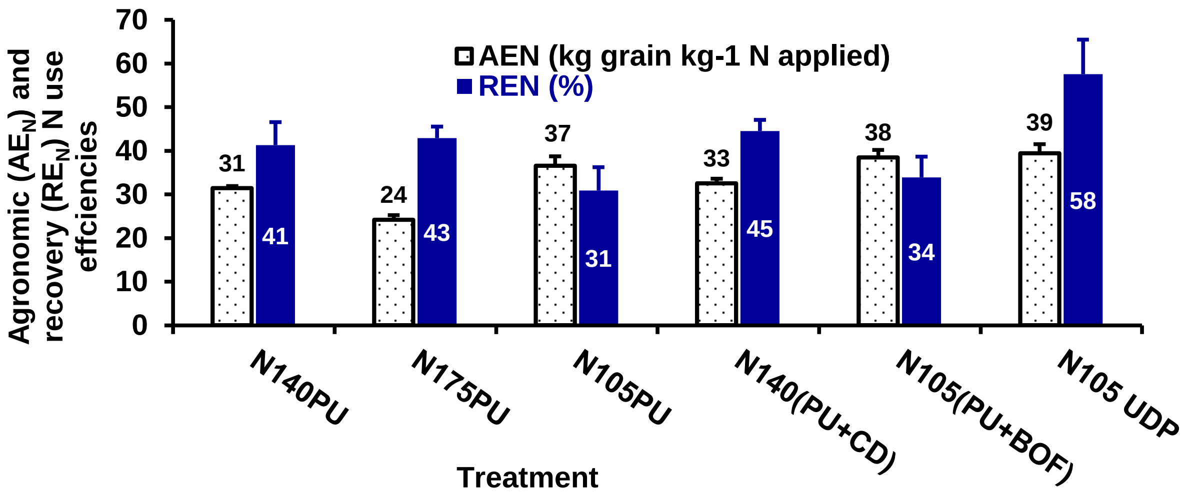


Fig. 26. Agronomic (AE$_N$) and recovery (RE$_N$) N use efficiencies (mean ± SE, n=4) influenced by different N management options in Boro season rice, 2023.

Relationship between leaf SPAD readings and measured N concentrations

Among only PU treatments, the overall SPAD readings were greater in higher rates of PU applied treatments (N175PU, N140PU) than that in lower N rate (N105PU) and no N applied (N0) treatments, particularly during first three sampling events. In N105UDP, the SPAD readings were consistently greater in all four sampling events (**Fig. 27a**). Except 4th sampling event in N0, the overall 1st leaves N concentrations were gradually decreased towards the growing season and considerably greater in all N fertilizer applied treatments than N0 treatment (**Fig. 27b**). In 1st sampling event (on 32DAT), SPAD readings and measured N concentrations in 1st leaves revealed moderate positive correlation ($R^2=0.64$) irrespective of fertilizer treatments (**Fig. 28a**). However, their overall relationships (**Fig. 28c)** and the relationships between SPAD readings and measured N concentrations in 1st leaves during other three sampling events (**Fig. 28a and 28b**) were very weak or almost absent.

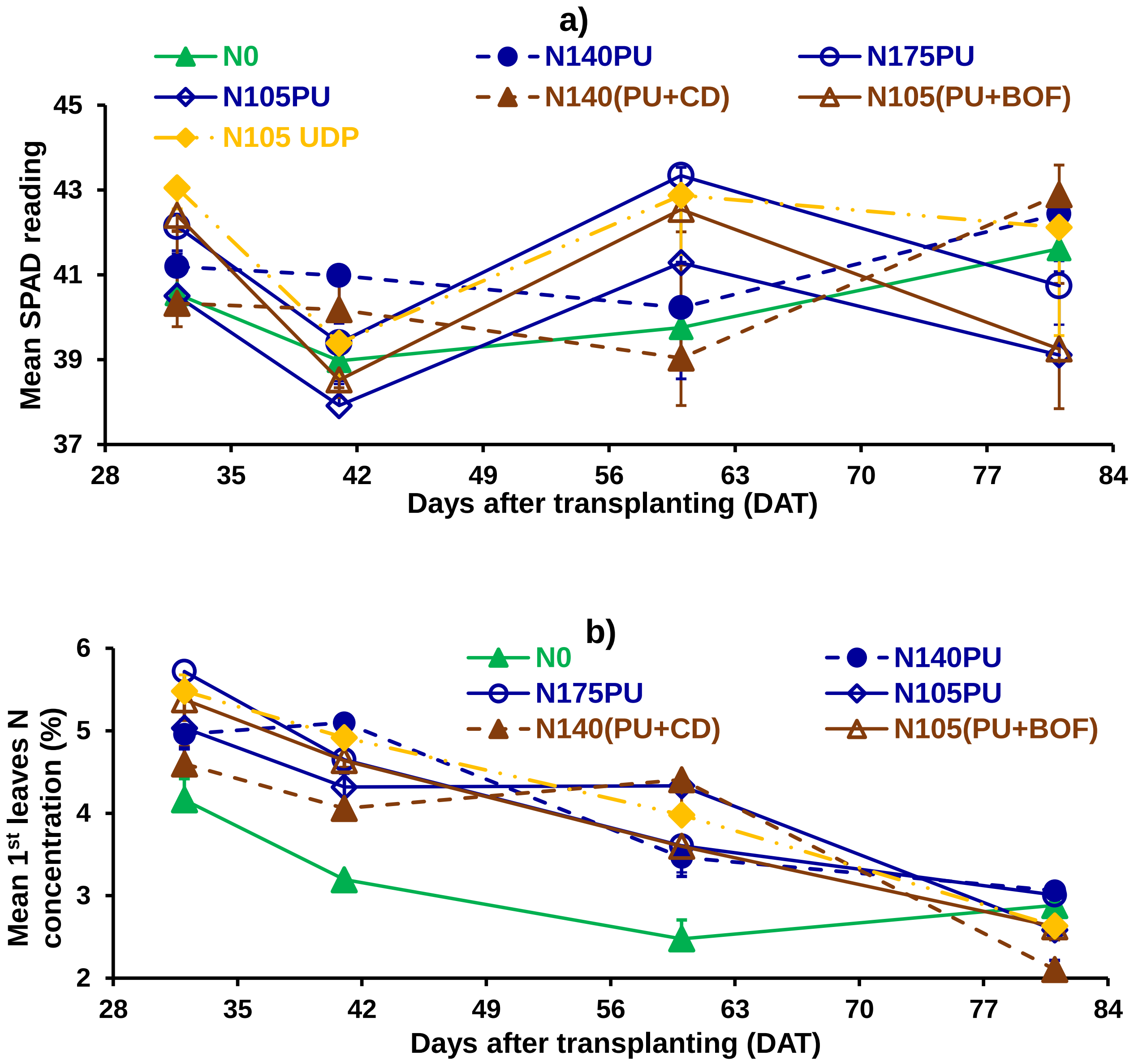
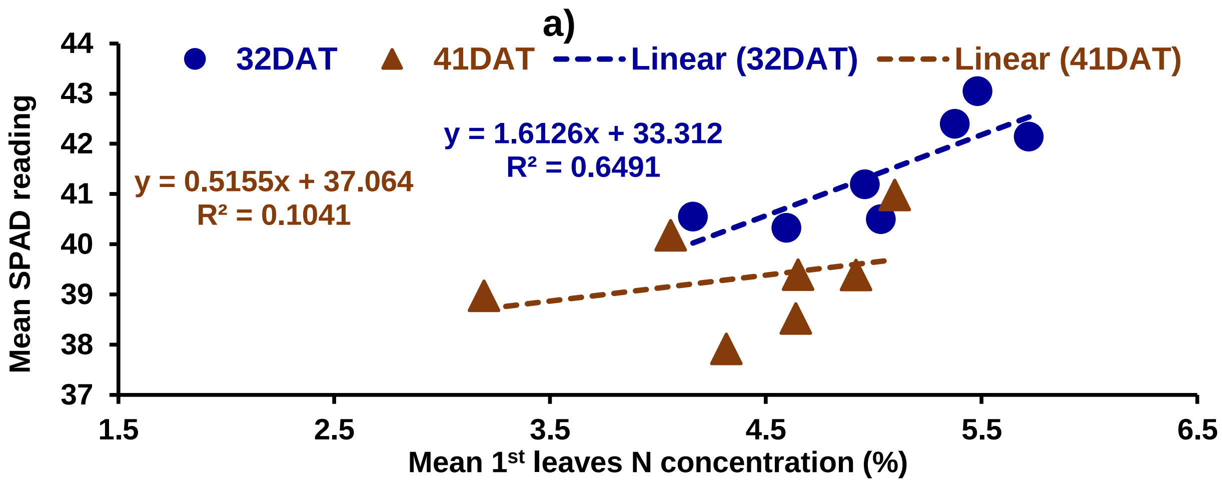
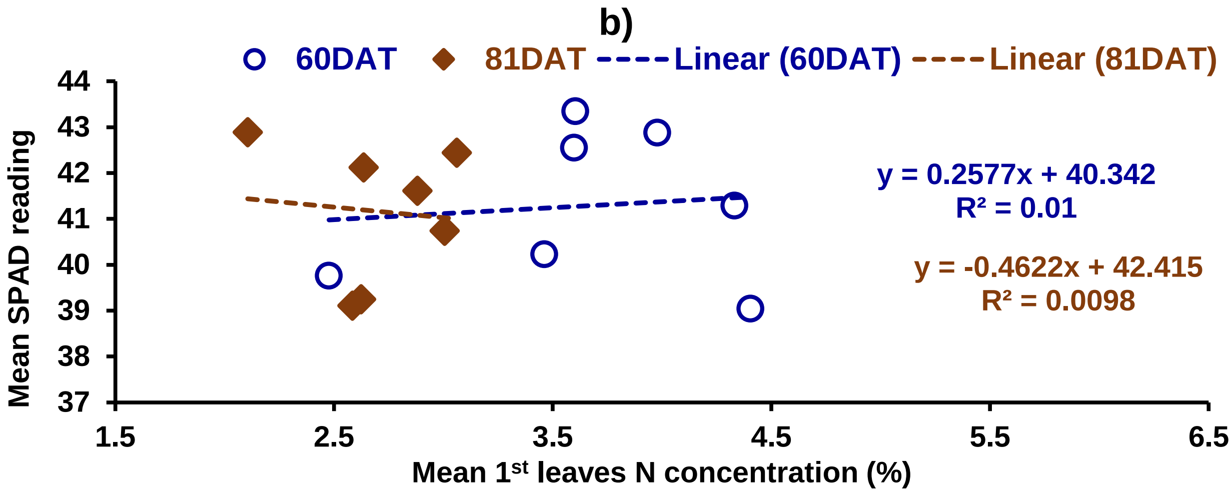


Fig. 27. SPAD readings (a) and N concentrations (b) in 1st leaves (mean ± SE; n = 4) during Boro (dry) rice season, 2023.





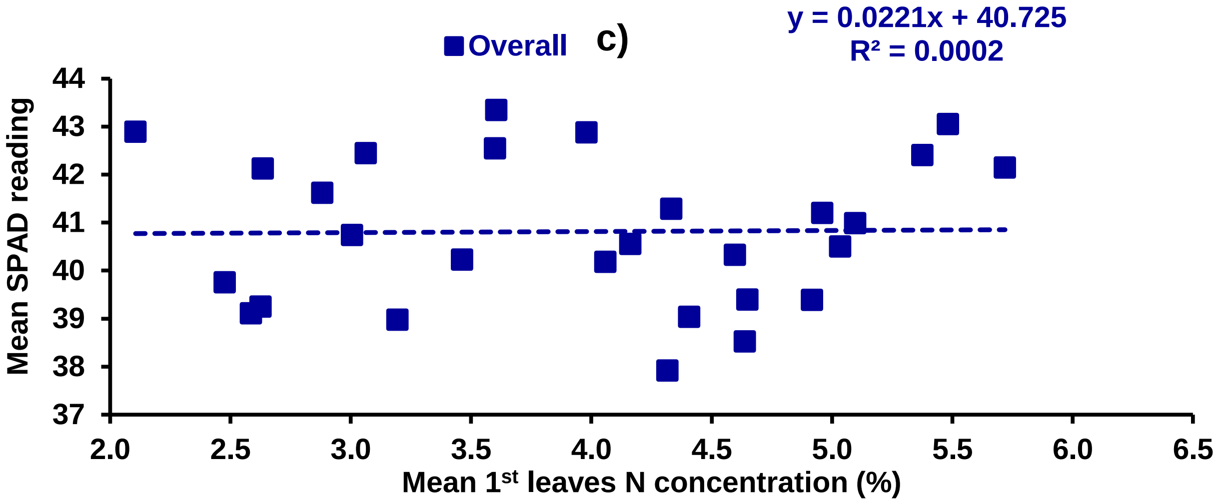


Fig. 28. Stage wise (a, b) and overall (c) relationships between mean (n = 4) SPAD readings and measured N concentrations in 1st leaves during Boro season rice, 2023.

Time course of NH_3 emission fluxes after urea application

The NH_3 emission peaks were usually observed on day 4-7, day 4-5, and day 2-3, after the 1st, 2nd and 3rd split application of urea, respectively **(Fig. 29a and 29b)**. In case of all three splits, the peak NH_3 emissions were greater in the treatment with higher rate of N application i.e. in the N175PU (T_3) resulting 64, 116 and 52 mg NH_3-N m^{-2} d^{-1} after 1st, 2nd and 3rd splits of urea application, respectively **(Fig. 29a)**. The lowering of NH_3-N emission peaks was found with reducing rates of N fertilizer application ensuing 23, 60 and 35 mg NH_3-N m^{-2} d^{-1} in N140PU and 20, 52 and 31 in N105 PU, after 1st, 2nd and 3rd splits of urea application, respectively **(Fig. 29a)**. The overall peak NH_3 emissions were comparable between N105PU+BOF (19, 57 and 41 mg NH_3-N m^{-2} d^{-1}) and N140 PU+CD (18, 54 and 35 mg NH_3-N m^{-2} d^{-1}) treatments **(Fig. 29b)**. In N105UDP, the NH_3-N emission was lower than other five N fertilizer applied treatments and only detected during its full application coincided with 1st topdressing (2-21 mg NH_3-N m^{-2} d^{-1}). In N0 treatment, some NH_3-N emission was recorded initially which possibly ensued from native soil organic matter mineralization with lesser plant N uptake after two weeks of crop establishment, later on the emission was below the detection. Across the N fertilizer application treatments, the NH_3-N emission was declined to below detection limit on day 14 after 1st split, day 10 after 2nd split and day 9 after 3rd split.

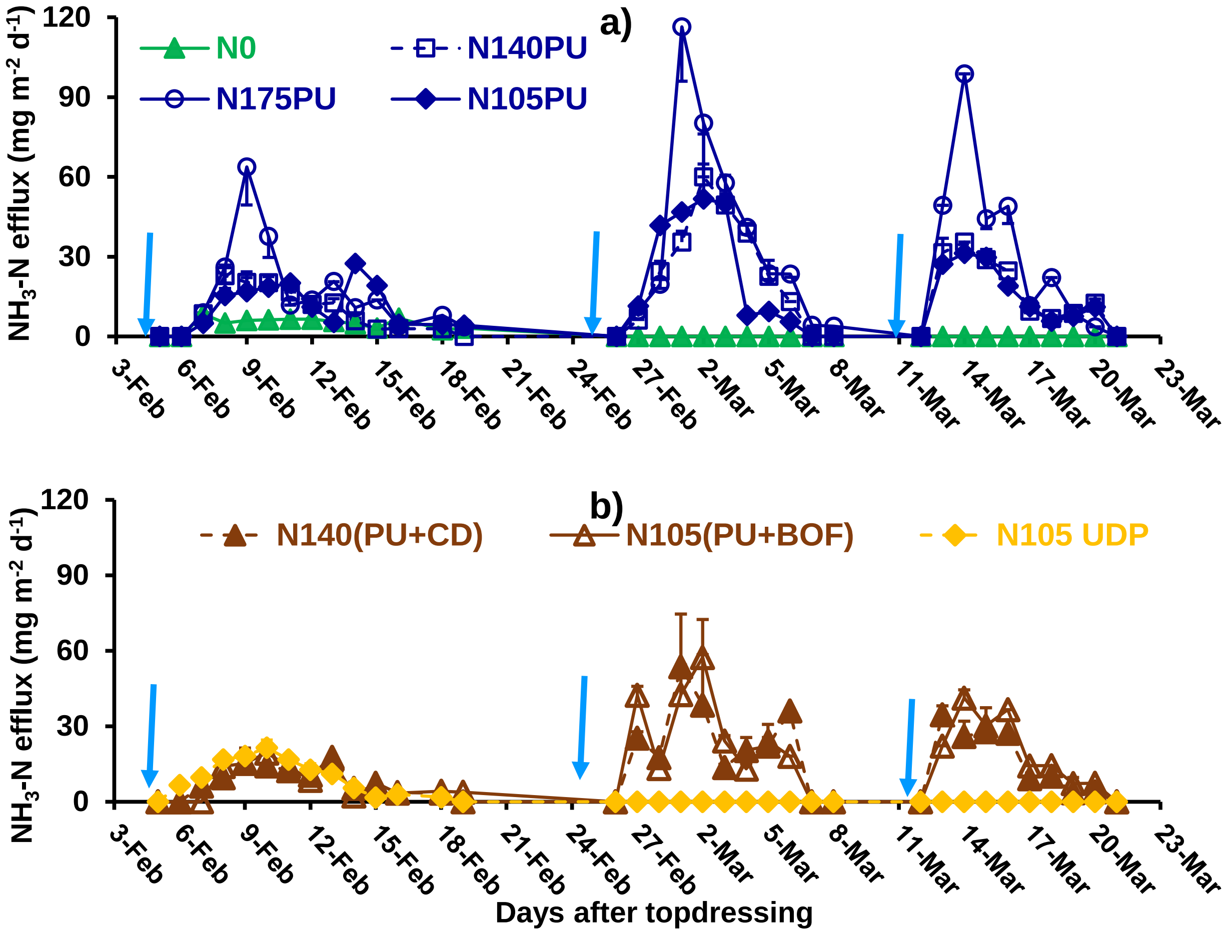


Fig. 29. Daily NH$_3$ emission fluxes (mean ± SE; n = 3) (a, b) at different N managements in dry season rice, 2023; arrow shows the day of split application of urea or UDP.

Conclusion

Results on yield, AE$_N$, RE$_N$ and NH$_3$ emission indicate that 105 (Boro) or 83 (T. Aman) kg N ha^{-1} from UDP could be the most suitable N management intervention with second alternative of N105/83(PU+BOF) to sustain rice production with least environmental harm for Nr in terrace paddy field of Gazipur, Bangladesh. However, further verification with ^{15}N tracing will provide detail insights.

Expt. 30. EFFECTS OF RICE CULTIVARS AND FERTILIZER MANAGEMENT ON RICE YIELD AND GREENHOUSE GAS EMISSIONS

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Introduction

Rice is the staple food crop in Bangladesh and cultivated in is 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).

The coastal region covers almost 29,000 km^2 or about 20% of the country. About 53% of the coastal areas are affected by different levels of salinity. It was evidently due to salinity causing unfavorable ecosystem and hydrological situations that limit the normal crop production throughout the year. The factors which contribute significantly to the development of saline soil are tidal flooding during the wet season (June-October), direct inundation by saline water, and upward or lateral movement of saline groundwater during the dry season (November-May). Therefore, land use efficiency in these areas is very poor, which is much lower than the country’s average cropping intensity.

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.

However, emissions could be affected by different rice cultivars. Previous studies have shown considerable differences in emissions among the rice cultivars. The differences in emission rates are associated with the amounts of root exudates, decaying of root tissue and leaf litter, accumulation of photosynthate in grain and straw, and crop growth duration (Malayan et al., 2016). There is a potential option to reduce CH4 emissions through rice breeding i.e., developing new varieties with a high-yielding capacity (Chen et al., 2019, 2021). However, emissions could be affected by different rice cultivars. Previous studies have shown considerable differences in emissions among the rice cultivars. The differences in emission rates are associated with the amounts of root exudates, decaying of root tissue and leaf litter, accumulation of photosynthate in grain and straw, and crop growth duration (Malayan et al., 2016). There is a potential option to reduce CH_4 emissions through rice breeding i.e., developing new varieties with a high-yielding capacity (Chen et al., 2019, 2021). Most previous studies have been conducted to quantify the effects of fertilizer and water regimes on GHG emissions from rice fields (Islam et al., 2020, 2022). However, the impacts of different rice cultivars with fertilizer management on CH_4 emissions and rice yields are not well documented. Therefore, the present investigation was conducted to determine the effects of the rice cultivars and fertilizer management on rice yield and CH_4 emissions during the Boro (dry) season.

Materials and Methods

The field experiments were conducted in Bangladesh Rice Research Institute (BRRI) farm, Satkhira and Gazipur. Four rice varieties were used including BRRI dhan50, BRRI dhan67, BRRI dhan92, and BRRI hybrid dhan3 in both locations. Two fertilizer treatments were tested: (i) recommended N rate @ 150 kg/ha and (ii) (PU) at 128 kg N ha^{-1}. The experiment was laid out in factorial RCB with three replications. Nutrients viz. P, K, S & Zn were used as basal at the recommended rate to all plots and the rates were 15 kg P/ha, 70 kg K/ha, 15 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 weight of grain was recorded for every plot and the weight in g $plot^{-1}$ was adjusted at 14% moisture and finally expressed in t ha^{-1}. The sundry weight of straw was also recorded plot-wise and expressed as t ha^{-1}.

Estimation of CH_4 and N_2O emissions

Emission rates were determined from the slope of the linear regression curves of CH_4 and N_2O concentration against chamber closer time using the following equation (Islam et al., 2020).

$$CH_4 \text{ and } N_2O \text{ emissions rate (mg m}^{-2}\text{ d}^{-1}) = \frac{\text{Slope (ppm min}^{-1}) \times Vc \times MW \times 60 \times 24}{22.4 \times \{(273 + T)/273\} \times Ac \times 1000}$$

Where Vc is the volume of the gas chamber in liters (L), MW is the molecular weight of the respective gas, 60 is min h^{-1}, 24 is h d^{-1}, 22.4 is the volume of 1 mol of gas in L at standard temperature and pressure, 273 is the standard temperature in °K, T is the temperature inside the chamber in °C, Ac is the area of the chamber in m^2, and 1000 is µg mg^{-1}.

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.

Results and Discussion

Rice yield

Rice cultivars and locations had a significant interaction with grain yield and total nitrogen uptake (TNU) in the Boro seasons **(Table 45).** BRRI hybrid dhan3 significantly increased grain yield compared to other cultivars in both locations. At BRRI farm, Satkhira, BRRI dhan67 showed a similar grain yield with BRRI hybrid dhan3 and BRRI dhan92, while at BRRI farm Gazipur, BRRI dhan67 gave a lower yield relative to BRRI hybrid dhan3 and BRRI dhan92 **(Table 45).** The lower rice yield under BRRI dhan92 and BRRI dhan50 at Satkhira might be correlated to soil salinity. Similarly, higher rice yield under BRRI dhan92 and BRRI hybrid dhan3 at Gazipur are probably associated with yield potentiality and genetic makeup of these cultivars. Higher TNU was found in BRRI dhan92 and BRRI hybrid dhan3 in both locations. BRRI dhan67 significantly reduced TNU compared to BRRI dhan92 and BRRI hybrid dhan3 at Gazipur, while BRRI dhan67 showed similar TNU with BRRI dhan92 and BRRI hybrid dhan3 at Satkhira. However, no significant variation was observed in rice yield and TNU between the two N rates **(Table 45).** Across the rice cultivars and N rates, higher rice yield and TNU was observed in BRRI farm, Gazipur compared to BRRI farm, Satkhira.

Table 45. Effects of rice cultivars and N rates on rice yield and total nitrogen uptake during Boro season at BRRI farm Gazipur and Satkhira

Rice cultivars	N rates	Grain yield (t/ha)		Straw yield (t/ha)		TNU (kg/ha)	
		Gazipur	Satkhira	Mean of 2 locations		Gazipur	Satkhira
Effects of rice cultivars (means across N rates and locations)							
BRRI dhan50	Mean	5.6c	4.6c	5.2c		66.2c	60.9b
BRRI dhan67		6.1b	6.3ab	6.0b		75.0b	83.8a
BRRI dhan92		7.3a	6.0b	6.6a		86.2a	79.6a
BRRI hybrid dhan3		7.4a	6.6a	6.8a		93.9a	80.2a
Effects of N rates (means across cultivars and locations)							
Mean	PU-N128	6.1a		6.0a		76.3a	
	PU-N150	6.3a		6.2a		80.2a	
Effects of locations (means across cultivars and N rates)							
		Gazipur	Satkhira	Gazipur	Satkhira	Gazipur	Satkhira
Mean	Mean	6.6A	5.8B	6.3A	5.9B	80.3A	76.1B
ANOVA (p values)							
Cultivars (C)		*		*		*	
Locations (L)		*		*		*	
N rates (N)		ns		ns		ns	
C × L		*		ns		*	
C × N		ns		ns		ns	
L × N		ns		ns		ns	
C × L × N		ns		ns		ns	

TNU indicates total nitrogen uptake. * and ns correspond to significant and non-significant at 0.05 level of probability.

Greenhouse gas emissions

Across the N rates, BRRI dhan67 and BRRI hybrid dhan3 significantly ($p<0.05$) reduced cumulative CH_4 emissions compared to BRRI dhan50 and BRRI dhan92 in both locations of BRRI farm Satkhira and Gazipur **(Fig. 30).** The higher CH_4 emissions under BRRI dhan50 and BRRI dhan92 are probably linked to the longer growth duration of rice varieties. However, the higher N rates (N150) significantly ($p<0.05$) increased cumulative CH_4 emissions compared to lower N rates (N128). The presence of high NH_4^+ concentration from urea hydrolysis can inhibit CH_4 oxidation and enhance CH_4 emissions (Singh et al., 1999). Lower CH_4 emissions were observed in BRRI farm Satkhira compared to BRRI farm, Gazipur due to soil salinity. High salt concentrations in soil adversely affect microbial activities leading to inhibition of methanogenesis (Fagodiya et al., 2022).

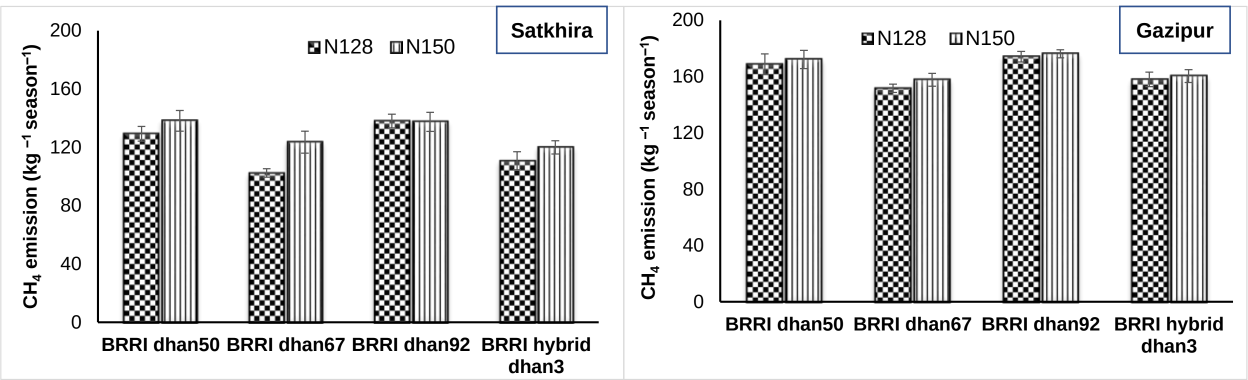

Fig. 30. Effects of rice cultivars and N rates on CH_4 emissions during Boro 2022-23 at BRRI farm, Satkhira and Gazipur.

Conclusion

The CH_4 emissions data presented in this report are preliminary. Since the findings are a one-year experiment it could be continued for another few years across the different ecosystems of Bangladesh for getting consistent results and a complete picture of GHG emissions.

SUB-SUB PROGRAM V: SOIL MICROBIOLOGICAL STUDIES

Project 05: Soil microbiology and bio-fertilizer

Expt. 31. EVALUATION OF BRRI-ORGANIC FERTILIZER IN SOIL-PLANT SYSTEM

U. A. Naher, A. A. Rim and A. 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 substitute 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 2022 and Boro 2022-23 at BRRI farm Gazipur. Soil properties were described in **Table 46.** The treatment combinations were T_1= NPKS (100%), T_2= BoF + 70% (N) +100% (KS), T_3 = BoF @ 2 t ha^{-1} + NKS (100%), T_4= Control. Recommended rates of chemical fertilizers for T. Aman and Boro were N-P-K-S @ 67-10-41-10 kg ha^{-1} and N-P-K-S @ 140-20-80-10 kg ha^{-1}respectively. BRRI dhan87 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. Crop was harvested at maturity and grain yield was adjusted at 14% moisture.

Table 46. Bio-chemical properties of initial soil of the experiment site

pH	OM (%)	Total N (%)	K ($mgkg^{-1}$)	P ($mgkg^{-1}$)	S ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)	Free-living N_2 fixing bacteria (Cfu/g soil)	Phosphate solubilizing bacteria (Cfu/g soil)
6.9	1.5	0.11	42	22	21	2	2.4×10^4	6.2×10^4
Nutral	Low	Low	Medium	Medium	Medium	Medium	Low	Low

Results and Discussion

Effect of BRRI-organic fertilizer on grain and straw yield

Study result proved bio-organic fertilizer (BoF@ 2t ha^{-1}) has potential to supplement 30% N and 100% P requirement for HYV rice without sacrificing yield. In the T. Aman, statistically similar grain yield was obtained in 100% NPKS (5.61 t ha^{-1}), BoF + N (70%)+K (100%) and BoF +100% NKS (5.68) treatment. However, in the Boro season, the highest grain yield was recorded (7.0 t ha^{-1}) in the BoF with 100% NKS treatment followed by (6.5 t ha^{-1}) with BoF with 70% (N) +100% (KS) treatment. BoF with 100% NPKS application produced 6.0 t ha^{-1} grain yield. The significantly lowest grain yield was found at the control treatment (2.6 t ha^{-1}). Application of BRRI-organic fertilizer @2 t ha^{-1} (dry weight basis) along with 30% reduced urea and 100% removal of TSP fertilizer gave 8.5 % yield improvement in Boro season over chemical fertilizer application **(Table 47).**

Table 47. **Effect of BRRI-organic fertilizer on grain and straw yield (t ha^{-1}) of BRRI dhan87, and BRRI dhan89 in T. Aman and Boro seasons, 2022-2023, BRRI, Gazipur**

Treatment	**T. Aman (2022)**		**Boro (2022-2023)**	
	Grain	**Straw**	**Grain**	**Straw**
T_1 = NPKS (100%)	5.61	5.39	6c	6.7
T_2 = BoF + 70% (N) +100% (KS)	5.35	6.07	6.5b	7.2
T_3 = BoF @ 2 t ha^{-1} + NKS (100%)	5.68	6.16	7a	7.5
T_4 = Control	3.56	3.15	2.6d	4
CV (%)	**13**	**-**	**15**	**-**

BoF: BRRI organic fertilizer. Different letters used within the column denote significant differences ($p<0.05$) between the treatments according to ANOVA and LSD Test.

Conclusion

Application of BRRI-organic fertilizer 2 t ha^{-1} (dry weight basis) along with 30% reduced urea and 100% removal of TSP fertilizer gave 8.5 % yield improvement in Boro season over chemical fertilizer application.

Expt. 32. BIO-COATED UREA: A NEW APPROACH TO IMPROVE N FERTILIZER USE EFFICIENCY AND RICE YIELD

U. A. Naher, Mosud Iqbal, Tamal Patro Shuvo and A. 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 FUE 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 and unfavorable soil plant system.

Methodology

A number of 13 plant growth promoting bacteria were added with wheat-flour, zeolite, gypsum and formed Bio-coated urea granule. Bio-chemical properties of the bacteria were described in **Table 48.** 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 7.12 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 49).** Treatment combinations were as; $T_{1\ =\ (\text{Control})}$, $T_{2\ =}$ ($N_{100\%\ \text{PU}}$ + PKS), $T_{3\ =}$ ($N_{100\%\ \text{BCU}}$ + PKS), $T_{4\ =}$ ($N_{75\%\ \text{PU}}$ + PKS), $T_{5\ =}$ ($N_{75\%\ \text{BCU}}$ + PKS), $T_{6\ =}$ ($N_{50\%\ \text{PU}}$ + PKS), $T_{7\ =}$ ($N_{50\%\ \text{BCU}}$ + PKS). Experiment was designed in RCB with 3 replications. Standard fertilizer doses for NPKS (kg ha^{-1}) was @ 140-20-50-10. Forty-five days old rice plant (BRRI dhan89) was transplanted as test crop. Another study was conducted BRRI R/S Satkhira in AEZ13 (Saline soil) where EC was 12-14ds/m during crop growth stage. Five treatments as T_1 = Control, T_2= $N_{(\text{PU})}$PKSZn (kg ha^{-1})@ 120-20-50-20-1, T_3= $N_{(\text{PU})}$PKSZn (kg ha^{-1})@ 120-20-120-20-1, T_4= $N_{(\text{BCU})}$PKSZn (kg ha^{-1})@ 120-20-50-20-1, T_5=$N_{(\text{BCU})}$PKSZn (kg ha^{-1})@ 120-20-120-20-1 were assigned randomly in randomized complete block design with three replications. About 45 days old BRRI dhan67 seedling was transplanted. 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 1/3$^{\text{rd}}$ 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 48. Bio-chemical properties of the plant growth promoting bacteria used in the bio-coated urea formulation

Scientific Name	N (mg kg^{-1})	Avail. P (mg kg^{-1})	*IAA (mg kg^{-1})	Exopolysaccharide production
Bacillus cereus (B2)	14	2166	7.48	+
Bacillus cereus (B5)	14	1885	6.7	+
Bacillus tropicus (B14)	21	1792	2.3	+
Bacillus pumilis (B20)	14	1947	4.3	+
Stenotrophomonas sp. (B31)	14	2616	7	+
Bacillus thuringiensis (B49)	28	1763	5	-
Bacillus cereus (B51)	14	1475	20	+
Stenotrophomonas sp. (B59)	14	2961	145	+
*Stenotrophomonas maltophilia (*B61)	28	1403	12	+
Bacillus cereus (B70)	21	1448	11	+
Bacillus sp. (B75)	14	2409	7.6	-
Not identified (B77)	14	2394	68.63	+
Bacillus amyloliquefaciens (B81)	14	2353	14	+

*IAA, indole acetic acid

Table 49. Chemical properties of initial soil of the experiment site at BRRI farm Gazipur

pH	OM (%)	Total N (%)	K (meq/100 g soil)	P (mg kg^{-1})	S (mg kg^{-1})	Zn (mg kg^{-1})
7.12	1.73	0.18	0.17	29	20	3.2
Nutral	Low	Low	Medium	Medium	Medium	Medium

Results and Discussion

Plant growth and yield in BRRI farm Gazipur. There were significant variation ($p<0.5$) found for tiller no/plant, panicle/plant, grain and straw yield due to applied treatments. Study result showed that application of Bio-coated urea enhanced plant growth, yield and saved 25 to 50% PU in rice cultivation **(Table 50).** The highest tiller/plant (14) and panicle (13) per plant obtained in both T_2 ($N_{100\%\ PU}$ + PKS) and T_5 ($N_{75\%\ BCU}$ + PKS) treatments. The highest grain yield 7.3 t ha^{-1} recorded in the T_5 treatment where 25% reduced N was applied as BCU and it was statistically similar with recommended (100%) N from BCU (T_3), 50% reduced N from BCU (T_7) and recommended (100%) N from PU (T_2) applied treatment. The lowest grain yield was obtained in the control plot (T_1). The highest straw yield was recorded in the T_2 treatment where N (100%) applied as PU and it was statistically similar with T_3 ($N_{100\%\ BCU}$ + PKS) and T_5 ($N_{75\%\ BCU}$ + PKS) treatments. The lowest tiller/plant, panicle/ plant and straw yield also recorded in the control treatment (T_1).

Table 50. Effect of bio-coated urea (BCU) and prilled urea (PU) fertilizer on growth of BRRI dhan89 in Boro 2022-2023 at BRRI farm Gazipur.

Treatments	Tiller /hill	Panicle /hill	Straw yield (t ha^{-1})	Grain Yield (t ha^{-1})	Total N uptake (kg ha^{-1})
T_{1}= (Control)	7d	6c	4.51d	3.6 c	48.08
T_2 = ($N_{100\%\ PU}$ + PKS)	14a	13a	8.43a	6.4 ab	87.88
T_3 = ($N_{100\%\ BCU}$ + PKS)	12ab	12a	8.04ab	6.7 ab	99.21
T_4 = ($N_{75\%\ PU}$ + PKS)	11bc	10b	7.34 c	6.3b	80.91
T_5 = ($N_{75\%\ BCU}$ + PKS)	14a	13a	8.12ab	7.3a	95.41
T_6 = ($N_{50\%\ PU}$ + PKS)	9cd	9b	7.71bc	6.0 b	80.07
T_7 = ($N_{50\%\ BCU}$ + PKS)	10bc	10b	7.39c	6.8ab	88.45
CV (%)	13.38	8.77	14	9	

In the column, means followed by the letter were significant at 5% level of significance. Treatment means were separated using LSD values.

Nitrogen use efficiencies (NUE)

There were significant variation found for grain and straw nutrient uptake **(Table 50)** and N use efficiencies within assigned treatments **(Fig. 31).** The highest plant N uptake (99.21 kg ha^{-1}) was found in the Bio-coated urea treatments, where N was applied @ 140 kg N/ha followed by N @105 kg N/ha ($N_{75\%\ BCU}$ + PKS) treatment. The highest agronomic N use efficiency (AE_N) 45 kg kg^{-1}, recovery efficiency (RE_N) 58.7 kg kg^{-1} and partial factor productivity (PFP_N) of applied N fertilizer was found in the $N_{75\%\ BCU}$ + PKS treatment. The lowest AE_N (20 kg kg^{-1}), RE_N (29 kg kg^{-1}) and PFP_N (25 kg kg^{-1}) was recorded in the 100% prilled urea applied treatment.

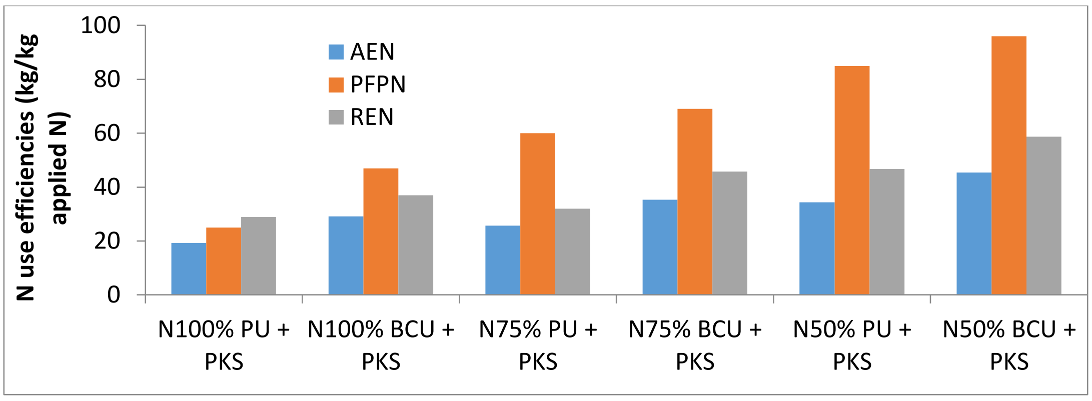

Fig. 31. Effect of Bio-coated urea (BCU) and prilled urea (PU) fertilizer on N use efficiencies (AE_N, RE_N) and partial factor productivity (PFP_N) in BRRI dhan89 at Boro 2022-2023.

Grain yield at BRRI farm Satkhira (unfavorable ecosystem)

There were significant differences found for plant growth parameters, grain and straw yield among the treatments. Compared to control higher number of tillers, panicle/hill, panicle length, grain and straw weight obtained due to application of treatments. The highest grain yield (7.0 t ha^{-1}) obtained in the T_5, followed by T_4 (6.6 t ha^{-1}) treatment, where N was applied as Bio-coated urea instead of prilled urea **(Fig. 32)**. Among the Prilled urea applied treatments, T_2 produced 5.2 t ha^{-1} grain yield and it was statistically similar with T_3 treatment (5.0 t ha^{-1}). The insignificant effect of extra K application was recorded among the treatments. Application of Bio-coated urea (BCU) improved grain yield 27-39% in saline soil (12-14 ds/m) compared to prilled urea (PU). Significantly highest grain yield obtained in the BCU applied treatments (T_4 and T_5) compared to PU application (T_2 and T_3) **(Fig. 30).** From the study report we may have hypothesized that bio-coated zeolite based urea granule may reduce reactive N loss, improve N fertilizer use efficiency along with crop productivity for sustainable rice production in saline soil.

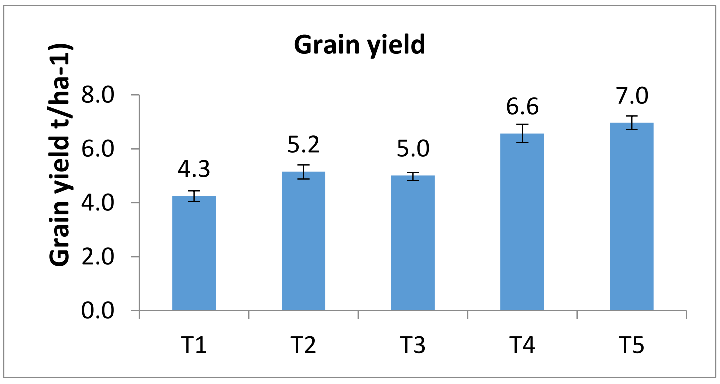

Fig.32. Effect of Bio-coated urea and Prilled urea on rice grain yield in saline soil at BRRI R/S Satkhira in Boro 22-23. Here; T_1 = Control, T_2= $N_{(PU)}$PKSZn (kg ha^{-1}) @ 120-20-50-20-1, T_3= $N_{(PU)}$PKSZn (kg ha^{-1})@ 120-20-120-20-1, T_4= $N_{(BCU)}$PKSZn (kg ha^{-1})@ 120-20-50-20-1, T_5=$N_{(BCU)}$PKSZn (kg ha^{-1})@ 120-20-120-20-1.

Conclusion

At BRRI Gazipur (favorable ecosystem), application of Bio-coated urea (BCU) improved rice yield and saved 25 to 50% N. Simultaneously, in the unfavorable ecosystem BCU can be an option to mitigate saline stress and application of BCU increased 27-39% grain yield in 12-14 ds/m in BRRI farm Satkhira.

Expt. 33. MICROBIAL CHARACTERIZATION OF DIFFERENT AEZS SOIL

U. A. Naher, A. A. Rim and A. Islam

Introduction

Long-term use of chemical fertilizer impairs soil biology and causes environment pollution. It is reported that total bacteria, urease and phosphatase activities, population of ammonia-oxidizing bacteria (Ali *et al*., 2013), methanotrophs (Dai *et al*., 2013) and denitrifiers (Tang *et al*., 2010) were shifted due to long-term chemical fertilizer applications. Damage of soil health is directly related to crop production. Loses of biodiversity is related to deterioration of soil health as nutrient cycling is the direct contribution of microbial activity. Soil health reflects the status of soil physical, chemical and biological attributes and processes. The interaction between plants, soil and microorganisms is considered to be the major driver of ecosystem functions. Improved understanding of the soil microbiome will help identify management practices to optimize soil functions e.g. nutrient availability, optimize fertilizer practices and reduce environmental impacts of farming. Physico-chemical properties of soils of Bangladesh have been documented, but very little or no information is available on microbial community structure and dynamics, and their interactions with soils and plants. However, correction of only nutrients deficiency in all kind of soil is the short- term management of nutrient degraded soil, but if we consider soil health, breaking yield sealing and sustainable crop production for the future, we need to correlate the soil biology and soil physics with soil chemistry. Understanding the microbial community and composition following long-term fertilization may have significant implications for the development of better fertilizer regime in any agro-ecosystems which is the primary requirement of national food security. In this context, a study was conducted to enumerate soil microbial status of different AEZ's and this information will be the first time documentation of soil microbial status in agricultural soils of Bangladesh. Elucidation of rice soil biology and replenish soil with beneficial microbes using rice based biofertilizer is important to maintain long-term soil fertility, soil health and improve crop productivity. Objectives of the study were to identify and determine biochemical properties of isolated potential plant growth promoting bacteria (PGPB)

Materials and Methods

The study was initiated in the year of 2019 with the objective to determine the microbial properties of different AEZ soils of Bangladesh. Soil sample collection was started after harvest of Boro 2019 to 2020 and Boro 2020 to 2021. A total 250 soil samples (composite of 2500 samples) were collected (0-15 cm) from nine AEZ's using GPS recording from AEZ8 (Kishoreganj), AEZ10 (Faridpur), AEZ11 (Jashore- Rajshahi), AEZ13 (Satkhira), AEZ15 (Munshiganj), AEZ16 (Brahmanbaria- Munshiganj), AEZ19 (Cumilla- Kishoreganj), AEZ22 (Moulavibazar- Habiganj) and AEZ27 (Rangpur- Bogura) and tested for microbial properties. Plant growth promoting bacteria (PGPB), such as free living N_2 fixing bacteria, phosphate solubilizing and rhizobium were isolated in the N-free media and Pikovasakaya respectively. Potential bacteria were identified using molecular techniques (16S rRNA gene amplification and sequencing using appropriate primers). Finally, the purified product was sent to "Macrogen" Korea for the identification of strain (s). For the determination of potential bacteria from respective AEZ's, N_2 fixation was determined according to Kjeldhal method, P solubilization by Molybdenum blue method following Murphy and Riley, 1962, and indoleacetic acid content was determined using, colorimetric technique according to Gordon, and Weber, 1951. Soil Biomass carbon was determined by chloroform fumigation-extraction method. Soil pH, organic carbon determined following standard protocol.

Results and Discussion

Soil biomass carbon (C) and soil organic matter of different AEZ's. The results showed that the average highest biomass C was recorded in the AEZ21 (307 mg/kg soil) from Hobiganj and Moulovibazar soil, and also from AEZ8 (287.82 mg/kg soil) of Kishoreganj (Karimganj and Bazitpur) soil **(Fig. 33a).** Among the tested soil the lowest biomass C was found in the charland of AEZ10 of Faridpur. Among the tested nine AEZ's, the highest organic matter (3.90%) and total N (0.21%) was recorded in the Chadnighat union of Moulovibazar Sadar upazila in AEZ22 followed by AEZ8 soil. There is a relationship (r^2=0.74) found for soil organic matter and soil biomass C of the tested AEZs soil **(Fig.33b**) which proved organic matter enhance microbial growth.

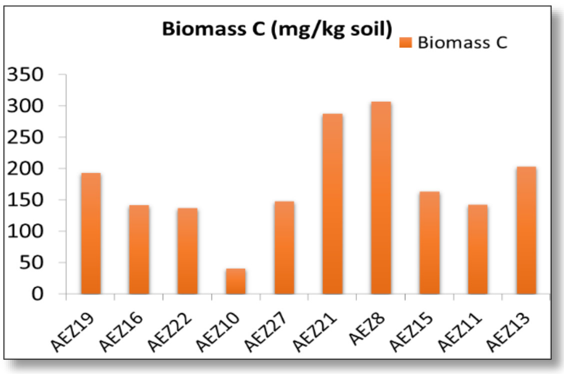

Fig.33a. Soil Biomass C of different AEZs soil.

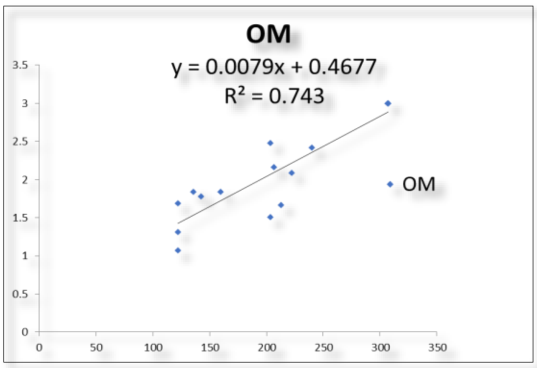

Fig. 33b. Relationship between soil biomass C and soil organic matter

Biomolecular characteristics of the isolated strains. The dominant potential bacteria from each AEZ's were identified and tested for biomolecular characteristics. Bacillus is the dominant species in the agricultural soils of the tested AEZ's. The identified bacteria were *Bacillus cereus, Bacillus albus, Bacillus subtilis, Bacillus mycoides, Bacillus thuringiensis, Bacillus paramycoides, Stenotrophomonas sp., Pseudomonas putida, Priestia megaterium, Gamma proteobacterium, Pseudomonas songnenensis, Stenotrophomonas maltophilia, Brevundimonas faecalis, Rossellomorea aquimaris, Sphingobacterium athyrii, Paenibacillus azoreducens, Achromobacter sp., Bacillus paramycoides, Rhizobiaceae bacterium, Sporosarcina pasteurii, Bacillus tropicus, Stenotrophomonas pavanii, Bacillus wiedmannii, Priestia flexa* and *Bacillus pumilus.* Among the strains, the highest N_2 fixation (28 ppm) NH_4) was recorded by *Bacillus thuringiensis* (B49) isolated from AEZ-27 and *Pseudomonas geniculata* (B61) isolated from AEZ-15. The highest 3746 ppm P was solubilized by the *Stentrophomonas maltophilia* (B53), isolated from Shahjahnpur upazela of AEZ-27. The highest amount of indoleacetic acid (144 ppm) was produced by the *Bacillus sp*. (B59) isolated from Shyamshiddhi union of Sreenagar upazila (AEZ-15). The isolated potential PGPB can be used for biofertilizer production.

Conclusion

Bacillus spp. is the dominant species in the agricultural soils of the tested nine AEZ's. There is a relationship (r^2=0.74) found for soil organic matter and soil biomass C of the tested AEZs soil which proved soil organic matter enhanced microbial growth.