

# Nitrogen use efficiency of Boro rice as affected by long term inorganic and organic fertilization

## Abstract

An experiment was carried out during January to June 2014 with Boro rice in the permanent experimental field of the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh. The objectives of the present study were to see the long term effect of manure and fertilizers on the yield and Nitrogen Use Efficiency (NUE) of BRRI dhan29 in floodplain (Subtropical) soil (Aeric Haplaquepts). The experiment was laid out in a randomized complete block design with three replications. There were ten treatment combinations viz, control, N, NP, NK, NPK, NZn, NS, NSZn, NPKSZn and NPK+FYM. The yield contributing characters and yield of BRRI dhan 29 significantly increased due to different treatments. Grain and straw yields were significantly affected by the application of nutrients in different combinations. The longest panicle length (25.3 cm), the highest 1000 grain weight (22.7 g), the highest grain yield (6.29 t ha<sup>-1</sup>), the highest nitrogen uptake in grain (70.4 kg ha<sup>-1</sup>) were found for the NPKSZn treatment. Grain yield increased by 24.8%, 85.8%, 40.7%, 68.9%, 29.2%, 33.2%, 107.1%, 28.9% and 78.9% due to N, NP, NK, NPK, NS, NSZn, NPKSZn, NZn and NPK+FYM treatments respectively and the corresponding straw yields increased by 49.6%, 51.1%, 82.0%, 95.3%, 37.8%, 34.4%, 82.7%, 41.8% and 90.2 %. The highest value of apparent nitrogen use efficiency was obtained with NPKSZn (54.06%) treatment which clearly indicated its utility for the long term fertilized soil.

**Key words:** Rice, nitrogen use efficiency, fertilization, inorganic and organic

## Introduction

Rice (*Oryza sativa* L.) is the most important food grain in the diets of billions of people of Asia, Africa and Latin America. Rice is the staple food for the people of Bangladesh and it covers some 75% of total cropped area. Bangladesh has three rice crops/seasons within a year; the Boro, the Transplant Aman (T. Aman) and the Aus, which account for approximately 52%, 40% and 8% of total annual rice production respectively (BBS, 2021). Among the three rice growing seasons, Boro cropped area of the country covers approximately 5 million hectares in 2021. About 27.87 million hectares of land are used for rice cultivation, the total annual production was 31.31 million metric tons with an average yield of 2.78 t/ha. However, the average yield of rice in Bangladesh is very much lower than that of the highest ranking country like China is 12.9 tha<sup>-1</sup> (IRRI, 2010). The reasons for this are manifold: some are varietal; some are climatic; and some are technological. Efficient fertilizer management could improve the yield and quality of rice which might contribute a lot to the economy of Bangladesh.

Fertilizer and manure application to our soils have been increased over the period and farmers are supposed to use these inputs intensively for sustained crop production. This practice of intensive fertilization and manuring undoubtedly bring some changes in the physical, chemical as well as

biological properties of soil (Karim *et al.*, 1994). Long-term application of mineral fertilizer and manure in rice based cropping system increase the organic matter and total nitrogen content in soil (Kader *et al.*, 2013). Long-term use of chemical fertilizers creates some fertility problems through soil exhaustion as well as through interaction with other elements (Rahman and Mian, 1997). Soils become compacted and turn unable to retain nutrients due to repeated and over use of chemical fertilizers (Medhi and De Datta, 1996). Continuous use of inorganic fertilizers alone to soils had a deleterious effect on soil productivity and a steadily declining trend in rice productivity is associated mainly with the loss of inherent soil fertility (Nambiar *et al.*, 1998). Combined application of organic manures and chemical fertilizers may provide higher benefit towards crop yield as compared to application of only chemical fertilizer in Bangladesh (Hasan *et al.*, 2009).

For maximizing yield of rice, nitrogenous fertilizer is very important in rice farming. It is essential for the synthesis of protein, which is the constituent of protoplasm and chloroplasts. But nitrogen use efficiency is very low and the recovery of N in wetland rice seldom exceeds 40%. Many factors determine the fertilizer use efficiency for rice crop during cultivation such as soil, cultivar, season, environment, planting time, water management, weed control, cropping pattern, source, form, rate, time of application and method of application. Nitrogen fertilization is widely adopted to enhance grain production and improve nitrogen utilization in rice all over the world. This applied fertilizer is getting lost in the environment through a number of processes including immobilization, denitrification/volatilization, leaching and fixation resulting low crop yield and reduced efficiency of applied nutrients. The volatilization loss of prilled urea (PU) is very high and farmers lose a huge amount of money for N fertilizer might be a good option to minimize the production cost as well as to increase crop yield (Khalil *et al.*, 2009). Nitrogen use efficiency (NUE) for rice crop largely ranges from 25% to 35% and seldom exceeds 50%. NUE of broadcast applied prilled urea (PU) in lowland rice field was reported to be varied between 30–45 % due to the losses from ammonia (NH<sub>3</sub>) volatilization, surface runoff, nitrification–denitrification and leaching (Sommer *et al.* 2004; Hayashi *et al.* 2008; Watanabe *et al.* 2009; Zhao *et al.* 2009; Dong *et al.* 2012). Very recently, Huda *et al.* (2016) found that NUE of Boro, Aus and Aman rice cultivated in Soil Science field laboratory of Bangladesh Agricultural University were 32, 24 and 24% respectively. Mostofa (2015) also calculated NUE in the long term field experiment of Soil Science Department, BAU in Aman season for BRRI Dhan 49 and found that NUE varied from 27.52 to 65.91%. The highest value of REN was obtained with NPKSZn (65.91 %) and the lowest value was found for NS (27.52 %). Information on the effect of long-term intensive fertilization on yield, NUE and soil properties is limited. Therefore, an experiment was undertaken to study the effect of long term fertilization on yield and nitrogen use efficiency of Boro rice (BRRI dhan 29) with assessing the Recovery Efficiency of Nitrogen (REN) of BRRI dhan 29.

### **Materials and methods**

The experiment was conducted in the permanent manurial experimental field of the Department of Soil Science at Bangladesh Agricultural University (BAU) farm, Mymensingh. Topographically the area

was slightly undulating but the experimental plot was fairly leveled. It was above normal flood level but sometimes the plot remained flooded for short time by rainwater during monsoon season. The soil of the plot was typical rice growing silt loam developed from the alluvial deposits of the river Old Brahmaputra. The soil forming processes of the field was mainly influenced by surface and ground water (AbedinMian, 1991). According to the report of the Department of Soil Survey (1967-68) the general soil type of the field was "Non-calcareous Dark Grey Floodplain Alluvium" and the soil series was sonatala silt loam. It belongs to the agro-ecological zone of "Old Brahmaputra Floodplain" i.e. AEZ 9.

**Table 1. Textural class and chemical characteristic of the permanent experimental fields**

Characteristics	Value
Particle size distribution	
%Sand (2-0.05 mm)	11.65
%Silt (0.05- 0.002 mm)	75.70
%Clay (< 0.002mm)	12.65
Textural class	Silt loam
pH	6.92
Organic matter (%)	2.82
Total Nitrogen (%)	0.12
Available Phosphorus (mg kg <sup>-1</sup> )	12.6
Exchangeable Potassium (meq 100g <sup>-1</sup> soil)	0.16
Available Ca (meq 100g <sup>-1</sup> soil)	9.43
Available Mg (meq 100g <sup>-1</sup> soil)	2.72
Available S (mg kg <sup>-1</sup> )	15.6

The experiment was laid out in randomized complete block design with three replications. Each block was subdivided into ten unit plots for placement of ten treatments of the experiment. The size of the unit plot was 11.5 m x 6.5 m (74.75 m<sup>2</sup>). The long term field experiment was established since 1978 comprised of ten different treatment combinations of manure and fertilizers namely i. Control, ii. N (120 kg), iii. NP (120 kg- N + 14 kg- P), iv. NK (120 kg-N + 58 kg- K), v. NPK (120 kg- N +14 kg-P + 5 kg-K), vi. NS (120 kg-N + 8 kg- S), vii. NSZn (120 kg- N + 8 kg- S + 1 kg Zn), viii. NPKSZn (120 kg-N+14 kg-P+58 kg-K+8 kg-S+1 kg Zn), ix. NZn (120 kg-N+1 kg Zn) and x. NPK + FYM (120 kg-N +14 kg- P +58 kg- K + 5 ton FYM). The major change was the update of fertilizer recommendation as per FRG 2012 and inclusion of full doses (100%) of N, P and K fertilizers for N (50%) + FYM treatment.

**Table 2. Old treatments for the permanent experiment**

Nutrient Element	Dose (kg ha <sup>-1</sup> )	Source (Fertilizers)
------------------	-----------------------------	----------------------

	Boro rice	Aman rice	
N	120	60	Urea
P	14	4	TSP
K	58	29	MP
S	8	6	Gypsum
Zn	1	-	Zinc Oxide
FYM	5000	-	Decomposed Cowdung

**Table 3. The doses and sources of different nutrients and FYM used for Boro rice**

The doses and sources of different nutrients and FYM used for Boro rice were as follows:

Nutrient Element	Dose (kg ha <sup>-1</sup> )		Source (Fertilizers)
	Boro rice	Aman rice	
N	90	80	Urea
P	20	20	TSP
K	19	19	MP
S	30	30	Gypsum
Zn	5	5	Zinc Oxide
FYM	5000	-	Decomposed Cowdung

BRRI dhan 29, a high yielding variety of rice developed by Bangladesh Rice Research Institute, Joydebpur, Gazipur in 1992. It is a transplant boro rice cultivar and matures after 110 days of transplanting with average yield 5.0- 7.5 t/ha. The plant height is 90-95 cm and the cultivar is of non-lodging type. It is somewhat resistant to pests and especially resistant to blast diseases. The seedlings of Boro rice (BRRI dhan 29) were transplanted on 20 January, 2014. The spacing maintained was 20 cm between row and 15 cm between hills. Three seedlings were transplanted per hill. Recommended production packages were followed for normal growth and development. The full dose of FYM was applied only in Boro season at the time of final land preparation. The entire quantity of P, K, S and Zn and one third dose of urea were applied at the time of final land preparation one day prior to transplantation. The rest of the urea was applied in three equal splits after 30, 60, 90 days of transplantation. The experimental plots were infested with some weeds which were controlled by uprooting and removing them from the field two times at both the season. Irrigation water was applied in season to the experimental plots before transplanting for the preparation of land. Optimum water was remained in the field during rest of experimental period. From each plot, the area of 4 square meter was harvested and the crop was bundled separately. The harvested crop was threshed plot wise. Grain and straw yields were recorded and moisture percentage was calculated after sun drying. Plant height, effective tillers hill<sup>-1</sup>, filled grains panicle<sup>-1</sup>, unfilled grain panicle<sup>-1</sup>, panicle length, 1000 grain weight, grain and straw yield were recorded

#### ***Chemical analysis of plant sample***

The representative grain and straw samples were dried in an oven at 65<sup>o</sup> for about 24 hours before they

were ground by a grinding machine. The prepared samples were then stored in paper bags and finally they were kept into desiccators until analysis was done.

For the determination of nitrogen, 0.1g of oven dried ground plant sample (both grain and straw separately) was taken in a micro-kjeldahl flask. 1.1 g catalyst mixture ( $K_2SO_4:CuSO_4.5H_2O:Se = 100:10:1$ ), 2 ml 30%  $H_2O_2$  and 3 ml  $H_2SO_4$  were added into the flask. The flask was swirled and allowed to stand for about 30 minutes. Then heating ( $380^{\circ}C$ ) was continued until the digest was clear and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. The digest was used for nitrogen determination.

After completion of digestion, 40% NaOH was added with the digest for distillation. The evolved ammonia was trapped into 4%  $H_3BO_3$  solution and 5 drops of mixed indicator of bromocresol green ( $C_{21}H_{14}O_5Br_4S$ ) and methyl red solution. Finally, the distillate was titrated with standard 0.01 N  $H_2SO_4$  until the color changed from green to pink (Bremner and Mulvaney, 1982). The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100 \div S$$

Where,

T= Sample titration value (ml) of standard  $H_2SO_4$

B= Blank titration value (ml) of standard  $H_2SO_4$

N = Strength of  $H_2SO_4$

S= Weight of soil sample in gram

### ***Nitrogen uptake***

After chemical analysis of grain and straw samples, the nutrient content was calculated and from the value of nutrient concentration. Nutrient uptakes were also calculated by the following formula of Jackson (1967).

$$\text{Nitrogen uptake (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen content (\%)} \times \text{Yield kg/ha}}{100}$$

### ***Recovery Efficiency of Nitrogen***

Nitrogen use efficiency is defined as kg grain yield increase  $kg^{-1}$  N applied. As N Fertilizers were applied in different plots at different doses, the use of N efficiency was calculated by the following formula.

$$REN (\%) = (NU_{NA} - NU_{0N}) / N_{RN} \times 100$$

Where,  $NU_{NA}$  = N uptake by grain and straw in treatment due to N addition (kg/ha)

$NU_{0N}$  = N uptake by grain and straw in treatment due to N omission (kg/ha)

$N_{RN}$  = Rate of N addition ( $kg ha^{-1}$ )

### ***Statistical analysis***

The analysis of variances for different yield contributing characteristics, yield and nutrient uptake were done following the ANOVA technique and the mean results in case of significant F-value were adjudged by the Duncan's Multiple Range Test (DMRT).

## Results

### **Effect of long-term mineral fertilization and manuring on yield and yield contributing characters of boro rice**

#### ***Plant height (cm)***

The plant height of Boro rice (BRRI dhan 29) in the experimental plot was significantly influenced by different treatments (Table 4). The highest plant height (87.3 cm) was recorded for NPK +FYM treatment. Results revealed that plant height obtained for NP, NPK, NPKSZn and NPK+FYM were statistically similar. Again Plant heights for N, NP, NK, NZn and NPK as well as N, NK, NS and NZn were also statistically similar. Statistical similarity was also found between the Control, NS and NSZn. The lowest plant height (72.1 cm) was recorded for NSZn treatment.

#### ***Effective tillers hill<sup>-1</sup>***

It is evident from Table 4 that tillering was significantly affected by various treatment combinations. The highest number of effective tillers per hill (12.9) was found for the treatment NPK and the lowest (7.2) was recorded for control. The number of tillers hill<sup>-1</sup> for the treatments NP, NPK, NPKSZn and NPK+FYM remained statistically similar. Again the tillers hill<sup>-1</sup> remained statistically similar for the NP, NK, NS, NZn and as well as N, NS, NK, NSZn and NZn treatments.

#### ***Non-effective tillers hill<sup>-1</sup>***

There was also some effect of treatments on the production of non-effective tillers. Non-effective tillers ranged between 1.07 for NPK+FYM treatment and 1.8 for Control treatment. The numbers of non-effective tillers for the treatments N, NP, NK, NPK, NS, NSZn, NPKSZn, NZn and Control were statistically same.

#### ***Panicle length (cm)***

The panicle length was significantly increased due to different treatments. The highest panicle length (25.3 cm) was recorded for NPKSZn treatment and the lowest (21.9cm) for Control. Results revealed that panicle length recorded NP, NK, NPK, NPKSZn, NPK+FYM and as well as N, NP, NK, NPK, NZn were statistically similar. Statistical similarity was also found between the Control, N, NP, NK, NS, NSZn and NZn treatment.

#### ***Number of filled grains panicle<sup>-1</sup>***

The highest number of filled grains (147.9) was found for NPK+FYM treatment, whereas the lowest number (106.2) was recorded for NS treatment. Filled grains panicle<sup>-1</sup> for the treatments NP, NPK, NPKSZn and NPK+FYM were statistically similar. (Table 4). Statistical similarity was also found between the N, NP, NK, NPK, NZn treatments. Again Control, N, NK, NS, NSZn and NZn treatments were statistically similar also.

#### ***Number of unfilled grains panicle<sup>-1</sup>***

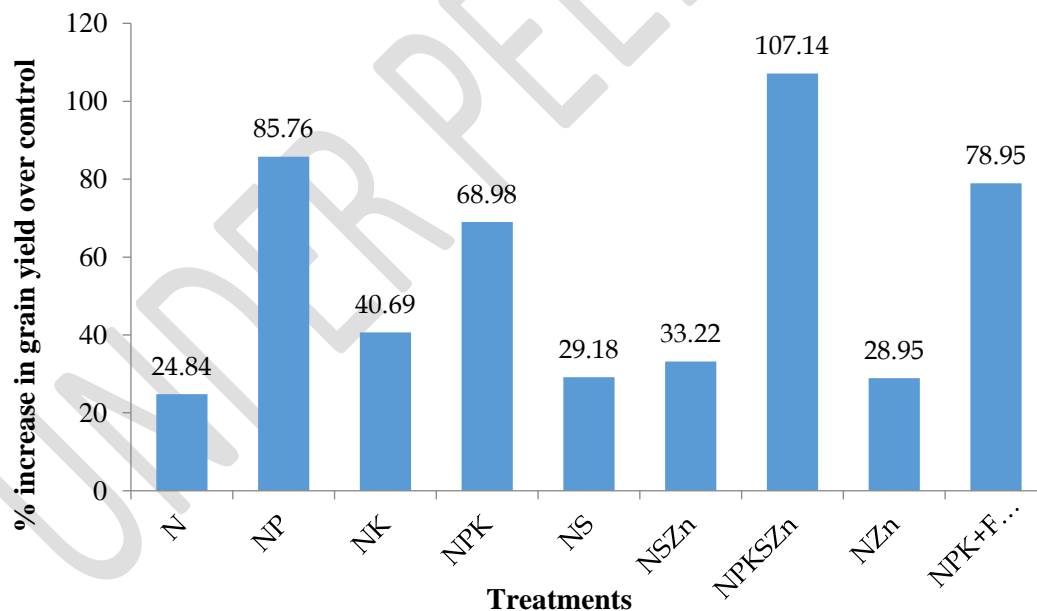
The highest number of unfilled grains (15.9) was recorded for NK treatment, and the lowest number (13.03) was in NPK+FYM. Unfilled grain panicle<sup>-1</sup> was found statistically similar for the treatments Control, N, NP, NK, NPK, NS, NSZn and NPKSZn as well as for NPK+ FYM, NZn, NPKSZn, NSZn, NPK, N, Control and NP. (Table 4)

**1000-grain weight (g)**

The 1000-grain weight ranged from 21.3 to 22.7g. Statistically similarity was found between the N, NP, NK, NPK, NPKSZn, NPK+FYM. Again Control, N, NP, NK, NZn and NPK+FYM as well as Control, N, NS, NSZn and NZn were also statistically similar.

**Grain yield (t ha<sup>-1</sup>)**

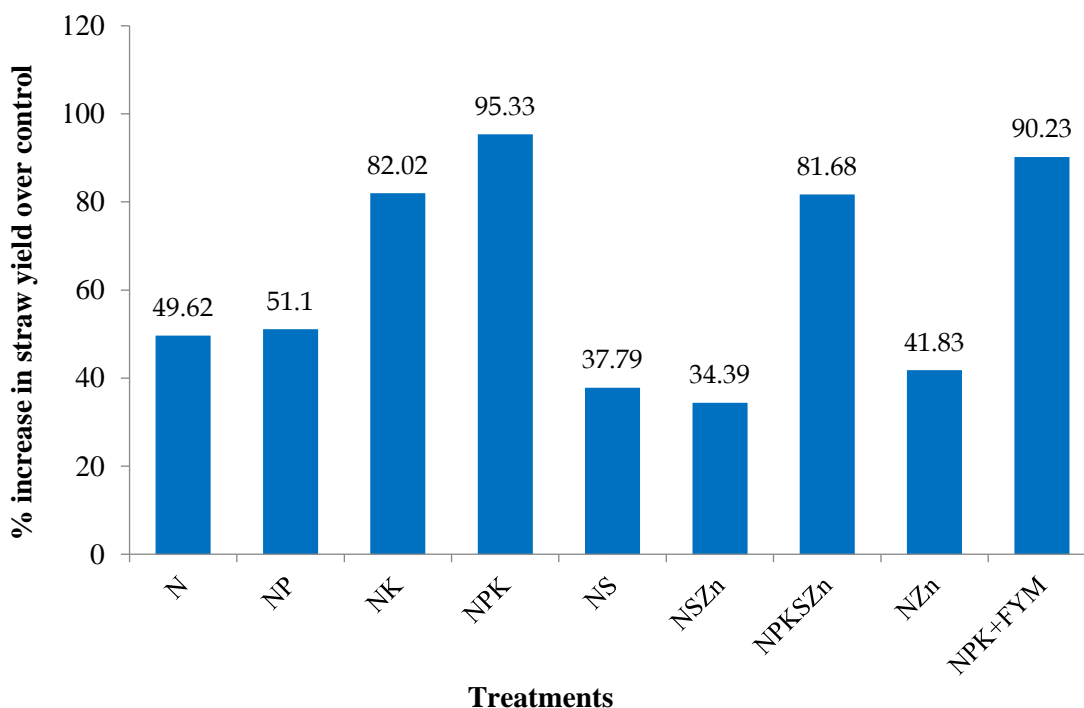
Grain yield of rice is the ultimate product of yield components which was found to be significantly influenced by different treatments (Table 4). The highest grain yield (6.29 t ha<sup>-1</sup>) was recorded for the treatment NPKSZn where the lowest (3.04 t ha<sup>-1</sup>) was observed for the control. Grain yield due to different treatment ranked in the order of NPKSZn>NP>NPK+FYM>NPK>NK>NSZn>NS=NZn>N>Control. Result revealed that the grain yield for NP, NPKSZn and NPK+FYM as well as NP, NPK, NPK+FYM again NK, NPK and NSZn were statistically similar. Statistical similarity also found between N, NK, NS, NSZn and NZn as well as Control, N, NS, NSZn and NZn. Grain yields were increased by 24.8%, 85.8%, 40.7%, 68.9%, 29.2%, 33.2%, 107.1%, 28.9% and 78.9% for the treatments of N, NP, NK, NPK, NS, NSZn, NPKSZn, NZn and NPK+FYM, respectively (Figure 1)



**Figure 1. Effects of different fertilizers and manures on % increase of grain yield over the control**

**Straw yield (t ha<sup>-1</sup>)**

Like the grain yields, the straw yields of Boro rice also varied remarkably due to different treatment combinations (Table 4). The yields varied from 4.7 t ha<sup>-1</sup> for the control to 9.2 t ha<sup>-1</sup> for the treatment NPK. Results showed that straw yields against NK, NPK, NPKSZn and NPK+FYM as well as N, NP, NK and NPKSZn remained statistically similar. Again N, NP, NS, NSZn and NZn as well as Control, NSZn also were statistically similar. Straw yields were increased by 49.6%, 51.1%, 82.0%, 95.3%, 37.8%, 34.4%, 82.7%, 41.8% and 90.2 % for the treatments of N, NP, NK, NPK, NS, NSZn, NPKSZn, NZn and NPK+FYM respectively (Figure 2).



**Figure 2. Effects of different fertilizers and manures on % increase of straw yield over the control**

**Table 4. Yield and yield contributing characters of Boro rice (BRRI dhan 29)**

Treatment	Plant height (cm)	Effective tiller hill <sup>-1</sup>	Non-effective tiller hill <sup>-1</sup>	Panicle length (cm)	Filled grain panicle <sup>-1</sup>	Unfilled grain panicle <sup>-1</sup>	1000 grain weight (g)	Grain yield (t ha <sup>-1</sup> )	Straw yield (t ha <sup>-1</sup> )
Control	73.3d	7.2d	1.8a	21.9c	109.8d	14.6ab	21.8bc	3.04e	4.7d
N	78.7bc	9.3c	1.2a	22.7bc	117.1cd	15.1ab	22.0abc	3.8de	7.05bc
NP	83.3ab	11.3ab	1.5a	23.7abc	134.1abc	14.6ab	22.5ab	5.7ab	7.1bc
NK	79.6bc	9.9bc	1.5a	23.5abc	121.5cd	15.9a	22.5ab	4.3cd	8.6ab
NPK	83.5ab	12.9a	1.2a	24.2ab	133.7abc	14.6ab	22.7a	5.1bc	9.2a
NS	75.2cd	9.8bc	1.3a	22.1c	106.1d	15.8a	21.5c	3.9de	6.5c
NSZn	72.1d	9.0c	1.7a	21.9c	111.9d	14.5ab	21.3c	4.05cde	6.3cd
NPKSZn	86.3a	12.2a	1.3a	25.3a	143.9ab	14.1ab	22.7a	6.29a	8.6ab
NZn	78.7bc	10.3bc	1.4a	22.4bc	124.7bcd	13.4b	21.8bc	3.9de	6.7c
NPK+FYM	87.3a	12.5a	1.07b	25.2a	147.9a	13.03b	22.5ab	5.4ab	8.9a
SE±	2.17	0.73	0.29	0.83	8.21	0.95	0.28	0.46	0.46
CV (%)	7.47	19.29	34.18	7.36	14.61	11.20	2.84	26.01	23.09

### *Nitrogen uptake*

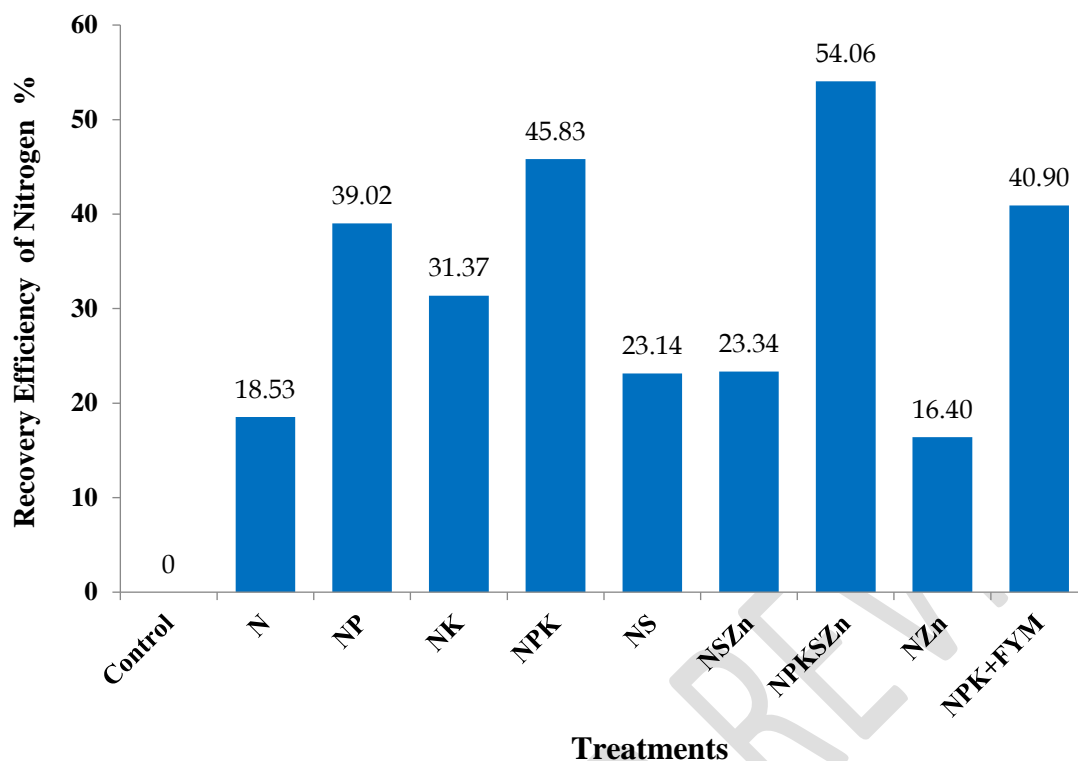
The different treatments significantly influenced total N uptake by both grain and straw of Boro (BRRI dhan29) rice (Table 4). The total N uptake in grains varied from 28.3 to 70.4 kg ha<sup>-1</sup>. The highest N uptake (70.4 kg ha<sup>-1</sup>) in grains was recorded in the treatment NPKSZn which differed significantly from all other treatments. The lowest N uptake (28.3 kg ha<sup>-1</sup>) was obtained for the control treatment. In Straw, the N uptake ranged from 23.6 to 52.4 kg ha<sup>-1</sup>. The highest N uptake (52.4 kg ha<sup>-1</sup>) in straw was recorded in the treatment NPK. The lowest N uptake (23.6 kg ha<sup>-1</sup>) was observed for the control treatment. It was noted that N uptake in the grain was higher than that of straw in all the treatments except that of NK.

**Table 5. Effect of long term fertilization on nitrogen uptake by grain and straw of BRRI dhan 29**

Treatment	N uptake (kg ha <sup>-1</sup> )		
	Grain	Straw	Total
Control	28.3e	23.6d	51.9e
N	37.5de	36.7bc	74.2de
NP	57.9ab	40.8bc	98.8abc
NK	41.4cd	48.2ab	89.6bcd
NPK	54.6b	52.4a	106.9ab
NS	40.8de	38.9bc	79.7cd
NSZn	40.5de	39.5bc	79.9cd
NPKSZn	70.4a	46.5ab	116.8a
NZn	36.7de	34.9cd	71.6de
NPK+FYM	54.01bc	46.9ab	101.01abc
SE±	5.34	4.79	9.31
CV (%)	31.10	25.75	26.36
LSD at 5%	12.84	11.51	22.36

### **Recovery Efficiency of Nitrogen (REN)**

Recovery Efficiency of Nitrogen (REN) is a term used to indicate the relative balance between the amount of fertilizer N taken up and used by the crop versus the amount of fertilizer N lost compared to the control treatment. The range of REN varied from 16.4 to 54.06 % (Figure 3). The highest value of REN was obtained with NPKSZn (54.06 %) and lowest value was found for NZn (16.4 %). Such results indicate that application of NPKSZn fertilizers may lead to efficient uptake and utilization for applied N. The REN values in this study appeared little higher compared to the national REN values for rice field (around 30%). This might be due to the fact that no other fertilizers were applied in the control treatment.



**Figure 3. Effect of long term fertilization on Recovery Efficiency of Nitrogen by grain and straw of BRR1 dhan29**

#### Discussion

The longest panicle length (25.3 cm), the highest grain yield (6.29 t ha<sup>-1</sup>), the highest nitrogen uptake (70.4 kg ha<sup>-1</sup>) by the grain and the highest value of recovery efficiency of nitrogen (54.06 %) were recorded for the NPKSZn treatment. This might be due to the fact that the treatment NPKSZn provided almost all the essential plant nutrients required for rice plants. Therefore, a balanced dose of fertilizers covering most of these nutrients resulted in highest grain yield from the test variety. Haque and Sattar (1974) observed a maximum plant height, effective tiller and grain yield (4.0 t ha<sup>-1</sup>) under N, P and K fertilizer application with a local variety of rice namely Hashikalmi in the non-calcareous dark grey floodplain soil of BAU farm. Kulkarni et al. (1978) also reported that the grain yield of Joya variety of rice increased with increasing N, P, K and ZnSO<sub>4</sub> application. BRR1 (1992) also observed the highest number of panicles per meter square (178) and grain yield (3.48 t ha<sup>-1</sup>) with BR11 rice in the complete fertilized plot where N, P, K, S and Zn were applied.

Grain yields in treatments N (3.8 t/ha), NS (3.9 t/ha) and NZn (3.9 t/ha) were found statistically similar with control (3.04 t/ha) treatment. However, treatment covering at least two major nutrients from NPK viz. NP (5.7 t/ha) and NK (4.3 t/ha) resulted in much better grain yield as compared to N, NS, NZn and NSZn. These findings indicated the essentiality of applying balanced doses of fertilizers covering all the major nutrients particularly nitrogen, phosphorus and potassium for rice cultivation in most of the soil conditions.

The treatment NPKSZn was found best considering all the parameters which were followed by the treatment NPK+FYM and in most of the cases they both were found statistically identical. The highest plants height (87.3 cm) was recorded for the NPK+FYM among the treatments. Interestingly, plants height and grain yields were increased 3.8 cm and 0.3 t/ha, respectively in NPK+FYM treatment as compared to NPK. These results revealed the benefits of applying FYM. Perhaps, these increased plant height and grain yield resulted from the improved soil conditions and enhanced microbial activity caused by the application of FYM with NPK.

These results are similar to Wang *et al.* (2004) and Chalk *et al.* (2003) who found that in most long-term experiments, a combination of mineral fertilizers and farmyard manures had generally given the best crop yield and soil quality. The results are also in agreement with results obtained by Rasool *et al.* (2007) who concluded that application of manure and an inorganic fertilizer in rice-wheat cropping system increased the paddy yield because manure application improves soil health and provides plant nutrients.

The recovery efficiency of nitrogen (REN) recorded in this experiment varied from 16.4 to 54.06 %. The highest value of REN was obtained with NPKSZn (54.06 %) and lowest value was found for NZn (16.4 %). Such results indicate that application of NPKSZn fertilizers may lead to efficient uptake and utilization for applied N. The REN values in this study appeared little higher compared to earlier reported REN in rice fields. For an example, REN of broadcast applied prilled urea (PU) in lowland rice field was reported to be varied between 30–45 % due to the losses from ammonia (NH<sub>3</sub>) volatilization, surface runoff, nitrification–denitrification and leaching (Sommer *et al.* 2004; Hayashi *et al.* 2008; Watanabe *et al.* 2009; Zhao *et al.* 2009; Dong *et al.* 2012). Very recently, Huda *et al.* (2016) found that REN of Boro, Aus and Aman rice cultivated in Soil Science field laboratory of Bangladesh Agricultural University were 32, 24 and 24% respectively.

Higher REN in our experiment compared to the earlier reported might be due to the fact that no other fertilizers were applied in the control treatment. The control treatment was not N control rather it was an absolute control. Marzia (2015) also calculated NUE in the same field experiment with similar treatments but in Aman season (BRRI Dhan 49) and found that REN varied from 27.52 to 65.91 %. The highest value of REN was similarly obtained with NPKSZn (65.91 %) and the lowest value was found for NS (27.52 %).

Therefore, it is clear that complete fertilization consisting N, P, K, S and Zn increased the vegetative growth of the rice plants and thereby increased the yield, N uptake as well as nitrogen use efficiency of rice.

### **Conclusion**

The highest grain yield of BRRI dhan 29 and nitrogen use efficiency were found for the treatment NPKSZn compared to other treatments. It indicates, the necessity of using complete and balanced fertilization i.e. application of N, P, K, S, Zn fertilizer combined to increase yield and Nitrogen use efficiency of rice. It also indicates that our soil is deficient in N, P, K, S and Zn. Therefore, the treatment NPKSZn may be recommended for Boro rice (BRRI dhan 29) cultivation in the areas with soils, climate and management similar to this study site. However, these results were from the experiment conducted in one location, more studies across different soils, climate and management

practices are needed to understand the site and season specific response of long term fertilization and their possible interaction effects on yields, NUE and soil fertility.

### References

- Abedin Mian MJ 1991: Air, water and nitrogen dynamics in paddy soil. Seasonal changes in electrochemical properties of soil. In: Proceedings of BAU Research Program. 255-267.
- BBS (Bangladesh Bureau of statistics) 2021: Yearbook of Agricultural Statistics, Government of Peoples Republic of Bangladesh, Dhaka. 68-69.
- BRRI (Bangladesh Rice Research Institute) 1992: Annual internal review Report. Bangladesh Rice Research Institute. Joydebpur, Gazipur. P.157.
- Bremner, J.M. and Mulvaney, C.S. (1982) Nitrogen-Total. In: Methods of soil analysis. Part 2. Chemical and microbiological properties, Page, A.L., Miller, R.H. and Keeney, D.R. Eds., American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, 595-624.
- Chalk PM, Heng LK, Moutonnet P 2003: Nitrogen fertilization and its environmental impact. In: Proceeding of 12<sup>th</sup> International World Fertilizer Congress, Beijing, China. 1-15.
- Dong NM, Brandt KK, Sorenson J, Hung NN, Hach CV, Tan PS, Dalsgaard T (2012) Effects of alternate wetting and drying versus continuous flooding on fertilizer nitrogen fate in rice fields in the Mekong Delta, Vietnam. *Soil Biol Biochem* 47:166–174.
- FRG (2012) Fertilizer recommendation guide. Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215.
- Haque, S.A. and H. A. Sattar (1974): Response of rice to N, P and K fertilizers under subtropical soil condition. *Bangladesh J. Agric. Sci.* 1(1): 10-13.
- Hasan Ahmed, MJ Abedin Mian, Mostofa Amran Hossain 2009: Effect of Long-Term Mineral Fertilization and Manuring on Soil Properties, Yield and Nutrient Uptake by T.aman Rice. *Bangladesh Research Publications Journal* 3 774-786.
- Hayashi K, Nishimura S, Yagi K (2008). Ammonia volatilization from a paddy field following applications of urea: rice plants are both an absorber and an emitter for atmospheric ammonia. *Sci Total Environ* 390:486–495.
- Huda A, Gaihre YK, Islam MR (2016) Floodwater ammonium, nitrogen use efficiency and rice yields with fertilizer deep placement and alternate wetting and drying under triple rice cropping systems. BAU, Mymensingh.
- IRRI (International Rice Research Institute) 2010: World Rice Statistics 2009-2010 International Rice Research Institute. Philippines: 318.
- Jackson ML (1967). *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi. pp. 498.
- Kader MA, Sleutel S, Begum SA, Moslehuddin AZM, De Neve S 2013: Nitrogen mineralization in sub-tropical paddy soils in relation to soil mineralogy, management, pH, carbon, nitrogen and iron contents. *European Journal of Soil Science* 64 47-57.

- Karim Z, Miali MMU, Razia S 1994: Fertilizer in the national economy and sustainable environmental development. *Asia Pacific Journal on Environment and Development* 2 48-67.
- Khalil, M. I.; Buegger, F.; Schraml, M.; Gutser, R.; Richards, K. G. and Schmidhalter, U. 2009. Gaseous Nitrogen Losses from a Cambisol Cropped to Spring Wheat with Urea Sizes and Placement Depths. In *Soil Fertility & Plant Nutrition*. Soil Sci. Soc. Am. J., 73:1335-1344.
- Kulkarni, K. R., T. G. Shivappa, M. K. Munegowda, S. Raju and T. Sadashivaiah. 1978. Response of Joya variety of paddy to N, P, K and S on farmer's field in Mysore district. *Mysore. J. Agric. Sci* 12(1) : 29-34.
- Medhi B, De Datta SK 1996: Nitrogen use efficiency and <sup>15</sup>N balance following incorporation of green manure and urea in flooded, transplanted and broadcasted rice. *Journal of Indian Society of Soil Science* 44 422-427.
- Nambiar KKM, Sehgal J, Blum WE, Gajbhiye KS 1998: Integrated use of organic manures and chemical fertilizers in red soils for sustainable agriculture. *Red and lateric soils-managing-red and lateric soils for sustainable agriculture*. 1 367-376.
- Rahman MH, Abedin Mian MJ 1997: Effect of long-term fertilization on soil fertility and rice yield. *Bangladesh Journal of Nuclear Agriculture* 13 65-70.
- Rasool R, Kakul SS, Hira GS 2007: Soil fertility and crop performance as affected by long term application of FYM and inorganic fertilizers in rice-wheat cropping system. 96 64-72.
- Sommer SG, Schjoerring JK, Denmead OT (2004) Ammonia emission from mineral fertilizers and fertilized crops. *Adv Agron* 82:557-622. doi:10.1016/S0065-2113(03)82008-4
- Wang CH 2004: Response of rice yield to deep placement of fertilizer and nitrogen top-dressing during panicle initiation stage and its diagnosis of fertilizer application. *Taiwanese Journal Agricultural Chemistry Food Science* 42 3-3.
- Wang, C.H. 2004. Response of rice yield to deep placement of fertilizer and nitrogen top-dressing during panicle initiation stage and its diagnosis of fertilizer application. *Taiwanese J. Agril. Chem. F. Sci.* 42(5): 383-395.
- Watanabe T, Son TT, Hung NN, Van Truong N, Giau TQ, Hayashi K, Ito O (2009) Measurement of ammonia volatilization from flooded paddy fields in Vietnam. *Soil Sci Plant Nutr* 55:793-799. doi:10.1111/j.1747-0765.2009.00419.x
- Zhao X, Xie YX, Xiong ZQ, Yan XY, Xing GX, Zhu ZL (2009) Nitrogen fate and environmental consequence in paddy soil under rice-wheat rotation in the Taihu lake region, China. *Plant Soil* 319:225-234. doi:10.1007/s11104-008-0865-0.