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Article

Deep placement of N fertilizers influences N use efficiency and yield of BRRI dhan29 under flooded condition

Samia Lutfa Hasan[1], Md. Rafiqul Islam[1*], Mahmud Hossain Sumon[1] and Azmul Huda[1,2]

[1]Department of Soil Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[2]Department of Soil Science, Sylhet Agricultural University, Sylhet-3100, Bangladesh

*Corresponding author: Professor Dr. Md. Rafiqul Islam, Department of Soil Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh. E-mail: rafiqss69@bau.edu.bd

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Abstract: An experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during boro season of 2014 to evaluate the effect of deep placement of nitrogen (N) fertilizers on N use efficiency and yield of BRRI dhan29 under flooded condition. The soil was silt loam in texture having pH 6.27, organic matter content 1.95%, total N 0.136%, available P 3.16 ppm, exchangeable K 0.095 me%, available S 10.5 ppm and EC 348 μS cm^{-1}. The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments and three replications. The treatments were T_1 [Control], T_2 [Prilled urea (130 kg N ha^{-1})], T_3 [USG, 130 kg N ha^{-1}], T_4 [USG, 104 kg N ha^{-1}], T_5 [USG, 78 kg N ha^{-1}], T_6 [NPK briquette, 129 kg N ha^{-1}], T_7 [NPK briquette, 102 kg N ha^{-1}] and T_8 [NPK briquette, 78 kg N ha^{-1}]. All the treatments except T_6, T_7 and T_8 received 25 kg P and 64 kg K ha^{-1} as TSP and MoP respectively. In T_6, T_7 and T_8 treatments, P and K were supplied from NPK briquettes. Prilled urea was applied in three equal splits. USG and NPK briquettes were applied at 10 DAT and were placed at 8-10 cm depth within four hills at alternate row. After deep placement of USG and NPK briquette, and each split application of PU, the water samples were collected for 5 consecutive days and analyzed for NH_4-N concentration in surface water. After application of N fertilizers, the NH_4-N in floodwater reached peak on the 2nd day in PU treated plots and then decreased rapidly over time. In the USG and NPK briquette treated plots, the NH_4-N was generated slowly but spontaneously over the entire growth period as compared to PU indicating a beneficial role of USG and NPK briquette. The highest grain yield of 7.16 t ha^{-1} was recorded for T_6 [NPK briquette, 129 kg N ha^{-1}] which was statistically similar to that of T_3 [USG, 130 kg N ha^{-1}] and T_4 [USG, 104 kg N ha^{-1}]. The highest straw yield of 8.05 t ha^{-1} was obtained for T_3 [USG, 130 kg N ha^{-1}]. The deep placement of USG and NPK briquettes enhanced the recovery of applied N and N use efficiency in comparison with the broadcast application of N fertilizers.

Keywords: deep placement; N use efficiency; yield; BRRI dhan29; flooded condition

1. Introduction

Rice (*Oryza sativa* L) is the staple food for the people of Bangladesh intrinsically associated with their culture, rites and rituals. Among the leading rice growing countries of the world, Bangladesh ranks fourth both in area and production (BRRI, 2008). Out of total rice production in this country about 43% come from Boro and the rest comes from Aman and Aus, respectively (BBS, 2011). For boosting the yield of rice, farmers are using different chemical fertilizers especially nitrogen, phosphorus and potassium. Nitrogen is the most important nutrient element for crop production. Farmers of Bangladesh use mainly urea in rice field as the most available source of nitrogen.

In rice cultivation system, generally, N fertilizer mainly urea is applied in the soil surface as conventional broadcast method. The lion part of the applied fertilizer is getting lost through a number of processes including volatilization, denitrification, run-off, leaching and fixation. So the nitrogen use efficiency especially of urea

fertilizer is very low (30-35%) in rice cultivation (IFDC, 2007). Therefore, attention must be given to minimize the production cost in a search for increasing crop yield.

Urea deep placement (UDP) is a proven technology that reduces N losses by up to 50% when compared with the conventional broadcast application of urea (IFDC, 2007; Huda *et al*., 2016). Again, the deep placement of USG and NPK briquette minimizes the concentration of NH_4-N in floodwater compared to broadcast application of PU. Kapoor *et al.* (2008) reported that broadcast application of N as urea resulted on an average 10 times higher amounts of ammonium N in flood water compared to deep placement of urea briquette and NPK briquette. Bhuiyan *et al.* (1998) reported that deep point placement of USG produced significantly higher grain yield of rice than split application of PU. Further, increases in grain yield, better N use efficiency (kg grain per kg N) and higher apparent N recovery occurred when the hole was closed after USG application. Based on the reduced level of applied N required with UDP, it is apparent that there will also be a reduction in N losses to the atmosphere. Shah *et al.* (2013) reported that deep placement of NPK briquette increased rice yield by 10 percent compared to BRRI fertilizer recommended rate in Boro season. Farmers in Vietnam and Cambodia obtained 25% higher yields with deep placement of NPK briquettes over the broadcasting of fertilizers (IFDC, 2007). In this study, the effect of deep placement of N fertilizer on nitrogen use efficiency and yield of boro rice were examined. The specific objective of the present study was to evaluate the effect of deep placement of N fertilizers on the N use efficiency and yield of BRRI dhan29.

2. Materials and Methods

2.1. Experimental site and Soil

The experiment was carried out at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during boro season of 2014. The soil of the experimental site belongs to Sonatala series under the AEZ-9 (Old Brahmaputra Floodplain). The soil had silt loam texture, pH 6.27, organic matter content 1.95%, total N 0.136%, available P 3.16 mg kg^{-1}, exchangeable K 0.095 cmol kg^{-1}, available S 10.5 mg kg^{-1} and EC 348 µS cm^{-1}.

2.2. Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments and three replications. The treatments were T_1 (Control), T_2 (130 kg N as PU), T_3 (130 kg N as USG), T_4 (104 kg N as USG), T_5 (78 kg N as USG), T_6 (129 kg N as NPK briquette), T_7 (102 kg N as NPK briquette) and T_8 (78 kg N as NPK briquette).

2.3. Seedling transplanting

BRRI dhan29, a high yielding variety of rice was used as a test crop. Forty four day- old seedlings were carefully uprooted from a seedling nursery bed and transplanted in the plots maintaining a spacing of 20 cm x 20 cm. Three seedlings were transplanted in each hill.

2.4. Application of fertilizers

The fertilizers were applied as per treatment. All the treatments except T_6, T_7 and T_8 received 25 kg P, 64 kg K and 20 kg S/ha as TSP, MoP and Gypsum respectively. In T_6, T_7 and T_8 treatments, P and K were supplied from NPK briquettes. Prilled urea was applied in three splits. The first dose of PU was applied at 10 days after transplanting (DAT), the second dose was added as top dressing at 35 DAT (active tillering stage) and the third dose was top-dressed at 55 DAT (panicle initiation stage). USG and NPK briquettes were applied on 10 DAT and the briquettes were placed at 8-10 cm depth within four hills at alternate rows. Before application of N fertilizers, the water in the rice plots was drained out.

2.5. Intercultural operations

Irrigation was provided to the plots from deep tube well to maintain continuous flooding condition during the growing period of the crop. There was an infestation of Rice Hispa in the crop which was controlled by the application of Diazinon 60 EC. Weeds were controlled by uprooting and removing as many as three times from the field.

2.6. Harvesting

The crop was harvested at maturity. The grain yield was obtained on 14% moisture basis while the straw yield was recorded on sun dry basis. Five hills were selected randomly from each plot and data on yield components

including plant height, effective tillers per hill, panicle length, grains panicle^{-1} and 1000-grain weight were recorded.

2.7. Determination of N in plant samples

The N content in rice grain and straw was determined by Semi-micro Kjeldahl method. Nitrogen uptake was the calculated from N content and yield data.

2.8. Apparent recovery of applied N (ANR)

The apparent N recovery was calculated by the following formula.

ANR (kg ha^{-1}) = (UN_{+N} - UN_{0N})/FN

Where, UN_{+N} is total N uptake (kg ha^{-1}) with grain and straw; UN_{0N} is the N uptake (kg ha^{-1}) in control; FN is amount of fertilizer N applied (kg ha^{-1})

2.9. Nitrogen use efficiency

The use efficiency N was calculated by the following formula.

NUE = ($Gy_{+N} - Gy_{0N}$) / FN

Where, Gy_{+N} = grain yield in treatment with N application; Gy_{0N} = grain yield in treatment without N application; FN = amount of fertilizer N applied (kg ha^{-1})

2.10. Statistical analysis

The collected data were analyzed statistically by F-test to examine the treatment effects and the mean differences were examined by Duncan's New Multiple Range Test (DMRT).

3. Results and Discussion

3.1. Growth and yield contributing characters

The yield components (plant height, effective tillers hill^{-1}, panicle length and filled grains panicle^{-1}) except 1000-grain weight of BRRI dhan29 responded significantly to application of PU, USG and NPK briquettes (Table 1). The tallest plant of 93.5 cm was found in T_6 [NPK briquette, 129 kg N ha^{-1}] which was identical to T_3 [USG, 130 kg N ha^{-1}], T_4 [USG, 104 kg N ha^{-1}], T_5 [USG, 78 kg N ha^{-1}], T_7 [NPK briquette, 102 kg N ha^{-1}] and T_8 [NPK briquette, 78 kg N ha^{-1}] and the shortest plant of 78.6 cm was found in control. The maximum number of effective tillers hill^{-1} (14.5) was found in T_4 [USG, 104 kg N ha^{-1}] which was identical with all other treatments except T_1. The largest panicle (24.8 cm) was found in T_2 [PU, 130 kg N ha^{-1}] and the smallest panicle (21.4 cm) was observed in T_1 (control). The number of filled grains panicle^{-1} varied from 109 to 142.9. The highest value (142.9) was found in T_3 [USG, 130 kg N ha^{-1}] and the lowest value (109) was found in T_1. The 1000-grain weight of BRRI dhan29 varied insignificantly due to application of nitrogen as PU, USG and NPK briquettes. These results are in agreement with the findings of Islam *et al.* (2014) and Jahan *et al.* (2014) who reported that yield attributes of rice were influenced by the application of urea briquette as compared to PU.

3.2. Grain yield

Application of PU, USG and NPK briquettes showed a positive effect on grain yield of BRRI dhan29 (Table 2). The highest grain yield of 7.16 t ha^{-1} was recorded in T_6 [NPK briquette, 129 kg N ha^{-1}] and the lowest value of 3.5 t ha^{-1} was recorded in T_1 (control). The grain yield produced by the treatment T_6 [NPK briquette, 129 kg N ha^{-1}] was statistically similar with T_3 [USG, 130 kg N ha^{-1}] and T_4 [USG, 104 kg N ha^{-1}] although there were numerical variations in grain yield among the treatments. The highest increase over control was obtained due to T_6 and the lowest one was obtained with T_2 [PU, 130 kg N ha^{-1}] as shown in Table 2. The grain yields obtained from different treatments may be ranked in the order of T_6> T_3> T_4> T_7> T_5> T_8> T_2>T_1. Urea super granule followed by NPK briquettes performed better in increasing grain yield of rice as compared to PU. These results indicate positive effects of deep placement of N fertilizers on rice yield. The increase in rice yield as observed in the present study is due to the spontaneous supply of nitrogen from USG throughout the growing period of rice and due to minimum loss of nitrogen as because of deep placement. These findings are well corroborated with Kapoor *et al.* (2008), Islam *et al.* (2011), and Afroz *et al.* (2014) and Huda *et al*. (2016) who observed increased rice yield due to application of USG and NPK briquettes. Islam et al. (2014) also reported that grain yield of BRRI dhan28 increased by 97.03% over control with the application of USG and 87.58% with NPK briquette whereas 66.24% grain yield increase was obtained with PU application.

Table 1. Effect of nitrogen supplied from PU, USG, and NPK briquettes on the growth and yield components of BRRI dhan29.

Treatments	Plant height (cm)	Tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	1000-grain weight (g)
T_1 (control)	78.6c	9.45b	21.4b	109.0d	20.34
T_2 [PU, 130 kg N ha-^{1})]	84.7b	12.3a	24.8a	134.7ab	20.53
T_3 [USG, 130 kg N ha^{-1}]	91.2a	13.2a	24.3a	142.9a	20.65
T_4 [USG, 104 kg N ha^{-1}]	91.0a	14.5a	23.4ab	132.6abc	20.55
T_5 [USG, 78 kg N ha^{-1}]	90.3a	12.2a	23.0ab	122.1c	20.53
T_6 [NPK briquette, 129 kg N ha^{-1}]	93.5a	12.8a	23.7a	140.3a	20.51
T_7 [NPK briquette, 102 kg N ha^{-1}]	93.0a	12.9a	23.1ab	127.6bc	20.48
T_8 [NPK briquette, 78 kg N ha^{-1}]	89.8a	12.6a	22.7ab	125.0bc	20.50
CV (%)	2.40	10.72a	4.73	4.88	0.68
Significance level	***	*	*	***	NS
SE (±)	1.233	0.771	0.636	3.641	0.081

Figures in a column having common letters do not differ significantly at 5% level of significance.
CV (%) = Coefficient of variation; SE (±) = Standard error of means; * = P<0.05; *** = P<0.001

Table 2. Effect of nitrogen supplied from PU, USG and NPK briquettes on the grain and straw yields of BRRI dhan29.

Treatments	Grain yield (t ha^{-1})	Increase over control (%)	Straw yield (t ha^{-1})	Increase over control (%)
T_1 (control)	3.5e		4.00d	
T_2 [PU, 130 kg N ha-^{1})]	5.20d	48.57	5.90c	47.5
T_3 [USG, 130 kg N ha^{-1}]	7.03a	100.85	8.05a	101.25
T_4 [USG, 104 kg N ha^{-1}]	6.61ab	88.85	7.02abc	75.5
T_5 [USG, 78 kg N ha^{-1}]	6.00c	71.42	6.23bc	55.75
T_6 [NPK briquette, 129 kg N ha^{-1}]	7.16a	104.57	7.69ab	92.25
T_7 [NPK briquette, 102 kg N ha^{-1}]	6.40bc	82.85	6.61abc	65.25
T_8 [NPK briquette, 78 kg N ha^{-1}]	5.42d	54.85	5.71c	42.75
CV (%)	5.27		14.9	
Sig. level	***		***	
SE (±)	0.176		0.538	

Figures in a column having common letters do not differ significantly at 5% level of significance.
CV (%) = Coefficient of variation; SE (±) = Standard error of mean; *** =P<0.001

Table 3. Effect of nitrogen supplied from PU, USG and NPK briquettes on nitrogen content and uptake by grain and straw of BRRI dhan29.

Treatments	N content (%)		N uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1 (control)	0.797d	0.585cd	27.89d	23.4d	51.29d
T_2 [PU, 130 kg N/ha)]	1.003c	0.640bc	52.23c	38.14c	90.38c
T_3 [USG, 130 kg N ha^{-1}]	1.207a	0.744a	84.87a	59.82a	144.69a
T_4 [USG, 104 kg N ha^{-1}]	1.087b	0.610c	71.74b	42.76bc	114.49b
T_5 [USG, 78 kg N ha^{-1}]	0.947c	0.550d	56.73c	34.21c	90.94c
T_6 [NPK briquette, 129 kg N ha^{-1}]	1.160a	0.690ab	82.95a	53.08ab	136.04a
T_7 [NPK briquette, 102 kg N ha^{-1}]	1.100b	0.620c	70.37b	40.97c	111.34b
T_8 [NPK briquette, 78 kg N ha^{-1}]	0.990c	0.550d	53.75c	31.39c	85.14c
CV (%)	3.11	4.67	6.67	15.2	7.27
Sig. level	***	***	***	***	***
SE (±)	0.0186	0.0168	2.369	2.593	4.23

Figures in a column having common letters do not differ significantly at 5% level of significance.
CV (%) = Coefficient of variation; SE (±) = Standard error of mean; *** =P<0.001

Table 4. Effect of nitrogen supplied from PU, USG, and NPK briquettes on apparent N recovery (%) and nitrogen use efficiency (NUE) of BRRI dhan29.

Treatments	Apparent N recovery (%)	N use efficiency
T_1 (Control)	-	-
T_2 (PU, 130 kg N ha^{-1})	30.07	13.07
T_3 (USG, 130 kg N ha^{-1})	71.85	27.15
T_4 (USG, 104 kg N ha^{-1})	60.77	29.90
T_5 (USG, 78 kg N ha^{-1})	50.83	32.05
T_6 (NPK briquette, 129 kg N ha^{-1})	65.69	28.37
T_7 (NPK briquette, 102 kg N ha^{-1})	58.87	28.43
T_8 (NPK briquette, 78 kg N ha^{-1})	43.39	24.61

3.3. Straw yield

The straw yield of BRRI dhan29 was also influenced significantly due to the application of PU, USG and NPK briquettes as shown in Table 2. The highest straw yield of 8.05 t ha^{-1} was obtained in T_3 [USG, 130 kg N ha^{-1}] and the lowest value of 4.00 t ha^{-1} was noted in T_1 (Control). The treatments may be ranked in the order of T_3> T_6 > T_4> T_7>T_5> T_2 >T_8> T_1 in terms of straw yield. Regarding the percent increase of straw yield, maximum straw yield increase (101.25%) was noted in T_3 and the minimum increase (42.75%) was found in T_8 as demonstrated in Table 2. The findings of the present study are well corroborated with Islam *et al*., (2014) and Das *et al*. (2015) who demonstrated that straw yield of boro rice was increased due to application of USG and NPK briquette.

3.4. Nitrogen uptake by BRRI dhan29

The N uptake both in grain and straw of BRRI dhan29 increased significantly due to application of PU, USG and NPK briquettes. The highest N uptake by grain (84.87 kg ha^{-1}) was obtained in T_3 [USG, 130 kg N ha^{-1}] and the lowest N uptake by grain (27.89 kg ha^{-1}) was found in T_1 (control) as shown in Table 3. The highest grain N uptake by T_3 was statistically similar with T_6 [NPK briquette, 129 kg N ha^{-1}]. Application of deep placement of USG increased the N uptake in rice grain. The highest N uptake by straw (59.82 kg ha^{-1}) was obtained in T_3 [USG, 130 kg N ha^{-1}] and the lowest straw uptake (23.4 kg ha^{-1}) was found in T_1 (Control). The highest straw N uptake by T_3 was statistically similar with T_6 [NPK briquette, 129 kg N ha^{-1}]. The treatments may be ranked in the order of T_3> T_6> T_4> T_7> T_5> T_2>T_8> T_1 in terms of total N uptake. The N uptake and recovery of applied N by rice were increased when nitrogen was deep placed in the form of USG and NPK briquette. However, the broadcast application of N in the form of PU demonstrated lower uptake of N and recovery of added N by rice. Islam *et al*. (2014), Jahan *et al*. (2014) and Afroz *et al* (2014) also observed that N uptake by rice was influenced significantly due to application of urea briquette.

3.5. Apparent N recovery (ANR)

The maximum value of apparent N recovery was obtained with the application of USG in T_3 (USG, 130 kg N ha^{-1}) followed by T_6 (NPK briquette, 129 kg N ha^{-1}), T_4 (USG, 104 kg N ha^{-1}), T_7 (NPK briquette, 102 kg N ha^{-1}) , T_5 (USG, 78 kg N ha^{-1}) and T_8 (NPK briquette, 78 kg N ha^{-1}) and the minimum value was found in T_2 (PU,130 kg N ha^{-1}) (Table 4). The data clearly indicate that the deep placement of USG and NPK briquettes enhanced the recovery of applied N compared to broadcast application of NPK fertilizers. Similar results were also obtained by Jahan *et al.* (2014), Afroz *et al*. (2014) and Das *et al*. (2015).

3.6. Nitrogen use efficiency (NUE)

The highest value of NUE (32.05 kg grain increase per kg N applied) was obtained in T_5 (USG, 78 kg N ha^{-1}) followed by T_4 (29.90 kg grain increase per kg N applied), T_7(28.43 kg grain increase per kg N applied), T_6 (28.37 kg grain increase per kg N applied), T_3 (27.15 kg grain increase per kg N applied) and T_8 (24.61 kg grain increase per kg N applied) and the lowest value was found in T_2 (130 kg N ha^{-1} from PU) (Table 4). The nitrogen use efficiency by rice was almost double in USG and NPK briquette treated plots than PU treated ones. These results clearly indicate that the deep placement of N in the form of USG and NPK briquette minimizes the loss of N that results in higher N use efficiency and increased grain yield of rice as compared to broadcast application of N in the form of PU. Islam et al. (2014) obtained 25.11% and 28% N use efficiency with the application of USG and NPK briquette whereas the value stood for only 13.84 with the application of PU. Afroz

et al. (2014), Das *et al.* (2015) and Huda *et al.* (2016) also reported higher efficiency of applied N due to application of USG and NPK briquette as compared to PU.

4. Conclusions

The deep placement of N fertilizers has numerous benefits over broadcast application of PU. From the results of the present study it is observed that the application of N supplied from deep placement of USG and NPK briquettes had better performances on NH_4-N availability in rice field water, grain and straw yields, nitrogen recovery and nitrogen use efficiency as compared to the broadcast application of PU. Based on grain yield, and N use efficiency it can be concluded that application of N @ 104 kg ha^{-1} (80% of recommended N) as USG can be used for successful cultivation of BRRI dhan29.

Conflict of interest

None to declare.

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