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Forms and Placement of Nitrogen Fertilizers Influence Nitrogen Use Efficiency and Yield of BRRI Dhan49 under Continuous Flooded Condition

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Abstract

An experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during Aman season of 2016 to evaluate the effects of deep placement of N fertilizers in the form of USG and NPK briquettes in comparison with PU on nitrogen use efficiency and yield of BRRI dhan49. The soil was silt loam in texture having pH 6.27, organic matter content 1.95% and total N 0.136%. The experiment was laid out in a RCBD with eight treatments and three replications. The PU was applied in three equal splits. The USG and NPK briquettes were deep placed at 10 DAT and the briquettes were placed at 8-10 cm depth between four hills at alternate rows. The maximum grain yield of 5981 kg ha^{-1} was recorded in T_3 which was statistically similar with T_2 and T_6. The highest straw yield of 6381 kg ha^{-1} was observed in T_3. The lowest grain yield (3265 kg ha^{-1}) and straw yield (4280 kg ha^{-1}) was recorded in T_3. The deep placement of USG and NPK briquettes enhanced both the recovery of applied N and N use efficiency in comparison with broadcast application of prilled urea.

Key words: BRRI dhan49, Nitrogen fertilizer, T aman rice

Introduction

Rice (*Oryza sativa* L) dominates Bangladesh agriculture sector covering 80% of the total cropped area of the country (AIS, 2008). Rice is grown in Bangladesh in three seasons namely aus, aman and boro. Among them aman rice covers the largest area of 9.82 million hectares with a production of 12.84 million tons (AIS, 2008). Present yield level of rice is not enough to meet the future demands due to low fertility level of soil. So, the researchers have to develop high yielding varieties and find out suitable management practices, especially, fertilizer management for the modern varieties. 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. Annual requirement of urea of the country is about 28 lakh ton of which 50% is met by the domestic production. The rest amount of urea needs to be imported by spending a large amount of foreign currency (BBS, 2008). The nitrogen use efficiency especially of urea fertilizer is very low (30-35%) in rice cultivation (IFDC, 2007). Khalil *et al.* (2009) reported that the volatilization loss of prilled urea (PU) is very high and farmers lose a huge amount of money for N fertilizer and proposed that to control this loss, deep placement of fertilizer might be a good option to minimize the production cost as well as to increase crop yield. Bhuiyan *et al.* (1988) reported that deep point placement of USG produced significantly higher grain yield of rice than split application of PU. Excessive N fertilization is one of the major concerns in sustainable agriculture for its decreased N-utilization efficiency by crops and increased N release to the environment, resulting atmosphere and water systems pollution (Zhu *et al.* 1997). This applied fertilizer is getting lost to the environment through a number of processes including immobilization, denitrification, volatilization, leaching and fixation resulting low crop yield and reduced efficiency of applied nutrients. Therefore, attention must be given to minimize the production cost in a search for increasing crop yield. A technology called fertilizer deep placement (FDP) is followed in Bangladesh, which ensures 40% more efficiency of urea utilization. Urea deep placement is a simple but a very effective technology which involves the placement of 1-3 grams of urea super granules or briquettes at a 7-10 centimeters (cm) soil depth shortly after the paddy is transplanted. The UDP increases nitrogen use efficiency because most of the urea nitrogen stays in the soil, close to the plant roots where it is absorbed more effectively.

Deep placement of Urea Super Granule (USG) and NPK briquette increases N fertilizer use efficiency in wetland rice. The placement of USG at 8-10 cm depth of soil can save 30% nitrogen than prilled urea, increases nutrient absorption, improves soil health ultimately increases the

crop yields (Savant *et al.* 1983). This not only improves fertilizer N use efficiency in flooded rice but also minimizes N loss resulting from ammonia volatilization and denitrification (Savantan *et al.* 1998; Mohanty, 1999). The USG dissolves slowly in the soil providing a steady supply of available N throughout the growing period of the crop. 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 as compared to deep placement of urea and NPK briquette. Islam *et al.* (2017) demonstrated higher grain yield and N use efficiency of rice with the deep placement of N fertilizers. A good number of research works were conducted on N management and N use efficiency in rice but still there is a gap in data on deep placement of N fertilizers for maximizing rice yield and N use efficiency. The specific objectives of the present study were to evaluate the effect of deep placement of N fertilizers on the yield components, yield, N recovery and N use efficiency of BRRI dhan49.

Materials and Methods

The experiment was carried out in the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during the Aman season of 2016. The study was performed to evaluate the effects of deep placement of N fertilizers in the form of urea super granule (USG) and NPK briquettes in comparison with prilled urea (PU) on nitrogen use efficiency and yield of BRRI dhan49. The soil of the experimental site belongs to the Sonatala series under the AEZ of Old Brahmaputra Floodplain. The soil was silt loam in texture having pH 6.27, organic matter content 1.95% and total N 0.136%. The treatments were T_1 (Control), T_2 (PU, 104 kg N ha^{-1}), T_3 (USG, 104 kg N ha^{-1}), T_4 (USG 78 kg N ha^{-1}), T_5 (USG, 52 kg N ha^{-1}), T_6 (NPK briquettes, 104 kg N ha^{-1}), T_7 (NPK briquettes, 78 kg N ha^{-1}) and T_8 (NPK briquettes, 52 kg N ha^{-1}). All the treatments except T_6, T_7 and T_8 received 16 kg P and 42 kg K ha^{-1} TSP and MoP, respectively. In T_6, T_7 and T_8 treatments, P and K were supplied from NPK briquettes. BRRI dhan49, a high yielding variety of rice was used as a test crop. Forty day-old seedlings were transplanted in the plots maintaining a spacing of 20 cm x 20 cm. The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments and three replications. All the fertilizers except urea i.e. TSP, MoP, gypsum and zinc sulphate were applied as basal doses in all the plots at final land preparation. Prilled urea was applied in three equal splits. The USG and NPK briquettes were deep placed at 10 DAT and the briquettes were placed at 8-10 cm depth between four hills at alternate rows. 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). Intercultural operations such as irrigation, weeding, pest control etc. were done as and when required. The crop was harvested at maturity. The grain yield was assessed with 14% moisture basis while the straw yield was recorded on sundry basis. Five hills were selected randomly from each plot and data on plant height, tillers $hill^{-1}$, panicle length, grains $panicle^{-1}$ and 1000-grain weight were recorded. The N content in rice grain and straw was determined by Semi-micro Kjeldahl method (Bremner and Mulvaney, 1982). Nitrogen uptakes, apparent nitrogen recovery and nitrogen use efficiency were calculated from N content and yield data. The collected data were analyzed statistically by F-test to examine the treatment effects and mean differences were examined by Duncanôs New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Yield components

The results revealed that the yield components (plant height, panicle length, tillers $hill^{-1}$ and grains $panicle^{-1}$) of BRRI dhan49 responded significantly to deep placement of USG and NPK briquettes as compared to PU. The tallest plant of 91.07 cm was found in T_3 (USG, 104 kg N ha^{-1}) which was identical to all other treatments except T_1 (Control) and T_2 (PU, 104 kg N ha^{-1}). The smallest plant (72.33 cm) was observed in T_1 (Control). The highest panicle length (25 cm) was found in T_3. The lowest panicle length (17.67) was observed in T_1. The number of grains $panicle^{-1}$ varied from 128.33 to 156.67 with the highest value in T_3 which was identical with T_2. The treatment T_3 (USG, 104 kg N ha^{-1}), produced the highest tillers $hill^{-1}$ (16.33). The lowest value (9.67) was obtained in T_1 (Control). The treatment T_2, T_4, T_6 and T_7 demonstrated statistically similar effective tillers $hill^{-1}$. The 1000-grain weight was not influenced significantly by the treatments. These results are in consistent with the findings of Das *et al*. (2015) and Islam *et al*. (2017) who reported that deep placement of N in the form of USG and NPK briquette enhanced the yield attributes of rice as compared to broadcast application of PU.

Table 1. Effect of deep placement of N fertilizers in the form of USG and NPK briquettes as compared to PU on the yield components of BRRI dhan49

Treatments	Plant height (cm)	Tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicles^{-1} (no.)	1000-grain weight (g)
T_1 (Control)	72.33f	9.67e	17.67f	135.00bc	35.64b
T_2 (PU, 104 kg N ha^{-1})	85.57bc	14.00b	23.00b	156.67a	37.95a
T_3 (USG, 104 kg N ha^{-1})	91.07a	16.33a	25.00a	156.67a	38.77a
T_4 (USG, 78 kg N ha^{-1})	87.00b	13.33bc	22.33b	147.67ab	36.41b
T_5 (USG, 52 kg N ha^{-1})	83.33c	12.00cd	20.33d	144.00abc	36.79b
T_6 (NPK briquette, 104 kg N ha^{-1})	84.67bc	13.67b	22.90b	145.00abc	37.91a
T_7 (NPK briquettes, 78 kg N ha^{-1})	81.00d	12.67bcd	21.33c	136.67bc	36.59b
T_8 (NPK briquettes, 52 kg N ha^{-1})	78.33e	11.33d	19.33e	128.33c	35.67b
CV%	1.57	6.14	2.36	6.18	1.69
SE(±)	0.75	0.46	0.29	5.13	0.36

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

Grain yield

Significant response of the grain yield of BRRI dhan49 was found due to the deep placement of N fertilizers (Table 2). The grain yield ranged from 3265 to 5981 kg ha^{-1}. The highest grain yield of 5981 kg ha^{-1} was recorded in T_3 (USG, 104 kg N ha^{-1}) which was statistically similar to T_2 (PU, 104 kg N ha^{-1}) and T_6 (NPK briquette, 104 kg N ha^{-1}). The lowest grain yield of 3265 kg ha^{-1} was observed in T_1 (Control). The percent increase of grain yield over control ranged from 56.19 to 83.18% (Figure 1). The maximum increase over control was found in T_3 (USG, 104 kg N ha^{-1}) and the minimum increase was noted in T_8 (Table 2). Based on grain yield the treatments may be ranked in the order of T_3> T_6> T_2> T_4> T_5> T_7> T_8> T_1. Deep placement of USG at the rate of 104 kg ha^{-1} performed better in increasing grain yield of rice as compared to PU and NPK briquette. These findings are well corroborated with Kapoor *et al.* (2008) and Islam *et al.* (2011) who also observed increased rice yield due to application of USG and NPK briquettes. Islam *et al* (2017) also reported grain yield increase of BRRI dhan46 as a consequence of deep placement of N fertilizers.

Straw yield

Straw yield of BRRI dhan49 responded significantly to different treatments under study. The highest straw yield of 6381 kg ha^{-1} was found in T_3 (USG, 104 kg N ha^{-1}) which was statistically similar with T_2, T_4 and T_6. The lowest straw yield of 4280 kg ha^{-1} was observed in T_1 (Control). Nearly 30.06 to 49.09% increase in straw yield over control was recorded due to application of N either broadcast or deep placed (Figure 1). As like as the grain yield, the maximum increase of straw yield over control was found in T_3 (USG, 104 kg N ha^{-1}). Based on straw yield the treatments may be ranked in order of T_3> T_2> T_6> T_4> T_5> T_7> T_8> T_1. Deep placement of USG @ 104 kg N ha^{-1}) performed better than other treatments in increasing straw yield under flooded condition. These results are in agreement with Islam *et al*. (2017) and Shaha *et al.* (2018) who also found straw yield increase of rice due to deep placement of N fertilizers.

Table 2. Yield of BRRI dhan49 as influenced by the application of PU, USG and NPK briquettes

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1 (Control)	3265d	4280d
T_2 (PU, 104 kg N ha^{-1})	5700ab	6244ab
T_3 (USG, 104 kg N ha^{-1})	5981a	6381a
T_4 (USG, 78 kg N ha^{-1})	5533b	6057ab
T_5 (USG, 52 kg N ha^{-1})	5400bc	5900bc
T_6 (NPK briquette, 104 kg N ha^{-1})	5722ab	6166ab
T_7 (NPK briquettes, 78 kg N ha^{-1})	5400bc	5866bc
T_8 (NPK briquettes, 52 kg N ha^{-1})	5100c	5566c
CV%	4.28	3.83
SE(±)	130	129

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

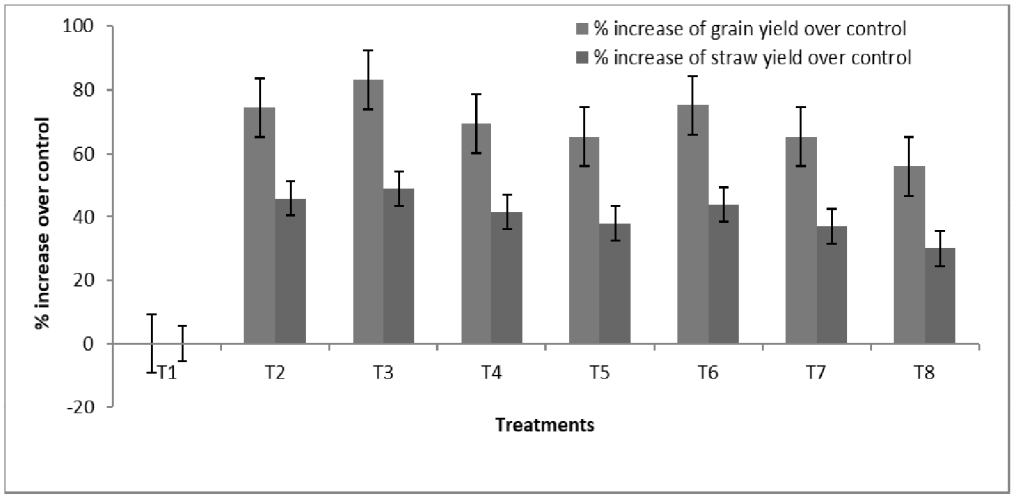

Fig. 1. Bar diagram showing %yield increase over control of BRRI dhan49 as influenced by the application of PU, USG and NPK briquettes

Apparent N recovery (ANR)

The apparent N recovery (ANR) indicates the absorption efficiency of applied N. The ANR by BRRI dhan49 has been presented in Fig. 2. Mean apparent recovery of N by BRRI dhan49 ranged from 42.58 to 67.44% in different treatments. The maximum value of ANR was obtained with the application of USG in treatment T_5 (USG, 52 kg N ha^{-1}) followed by T_3 (USG, 104 kg N ha^{-1}), T_8 (NPK briquette, 52 kg N ha^{-1}), T_4 (USG, 78 kg N ha^{-1}), T_7 (NPK briquettes, 78 kg N ha^{-1}) and T_6 (NPK briquettes, 104 kg N ha^{-1}). The minimum value was found in T_2 (PU, 104 kg N ha^{-1}). The data show that the deep placement of USG and NPK briquettes increased the recovery of applied N as compared to broadcast application of NPK fertilizers in flooded condition. The results of the present study support the findings of Islam *et al.* (2017) and Shaha *et al.* (2018) who demonstrated that application of N in the form of USG and NPK briquette increased the apparent N recovery of rice as compared to PU.

Nitrogen use efficiency (NUE)

Agronomic nitrogen use efficiency (NUE) 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. Nitrogen use efficiency represents the responses of rice plant in terms of grain yield to N fertilizer. The maximum value of NUE (41.05 kg grain increase per kg N applied) was obtained in T_5 (USG, 52 kg N ha^{-1}) followed by T_8 (35.28 kg grain increase per kg N applied), T_4 (29.08 kg gain increase per kg N applied), T_7 (27.37 kg gain increase per kg N applied), T_3 (26.12 kg gain increase per kg N applied) and T_6 (23.63 kg gain increase per kg N applied). The minimum value was found in T_2 (23.41 kg gain increase per kg N applied). The data clearly indicate that the deep placement of USG and NPK briquettes enhanced the NUE as compared to broadcast application of prilled urea (Fig. 2). Das *et al.* (2015), Islam *et al.* (2017) and Shaha *et al.* (2018) also reported that deep placement of N fertilizers enhanced the N use efficiency of rice.

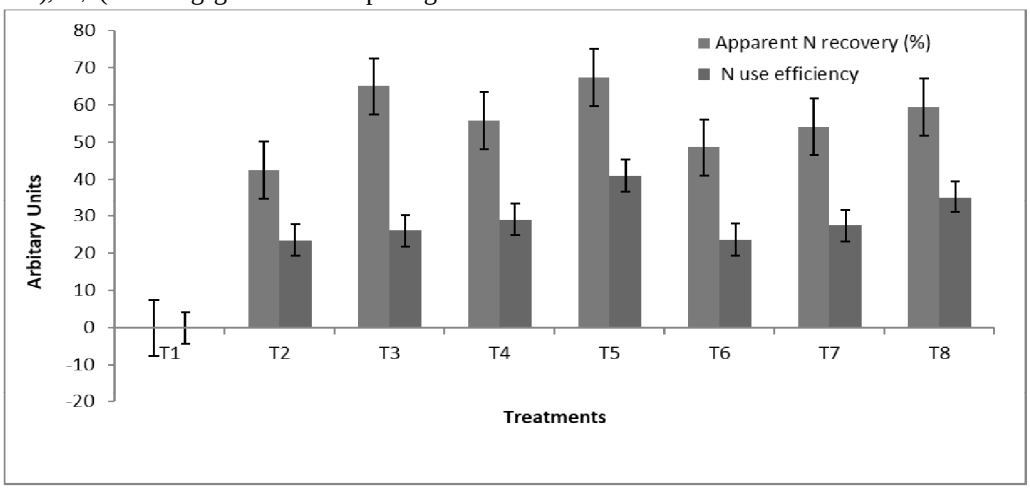

Fig. 2. Bar diagrams showing the effect of PU, USG and NPK briquettes on apparent N recovery (%) and N use efficiency (NUE) of BRRI dhan49

Conclusions

The overall results indicate that the highest grain yield of BRRI dhan49 was found in T_3 (USG, 104 kg N ha^{-1}) which was statistically similar with T_2 (PU, 104 kg N ha^{-1}) and T_6 (NPK briquettes, 104 kg N ha^{-1}). The maximum N uptake was also observed in T_3. On the contrary, treatment T_5 showed the maximum apparent N recovery and maximum N use efficiency as compared to other treatments. The recovery of applied N obtained from T_3 was approximately similar to T_5. The deep placement of USG and NPK briquettes enhanced the recovery of applied N and N use efficiency in comparison with broadcast application of PU fertilizers. As a consequence, the grain yield of BRRI dhan49 was increased to a significant extent. Based on grain yield and apparent N recovery, the treatment T_3 (USG, 104 kg N ha^{-1}), can be recommended for the production of aman rice, BRRI dhan49.

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