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Article

Effect of deep placement of N fertilizers on nitrogen use efficiency and yield of BRRI dhan29 under flooded condition

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Abstract: An experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during boro season of 2016 to evaluate the effect of deep placement of nitrogen (N) fertilizers on N use efficiency and yield of BRRI dhan29 under continuous 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 between four hills at every alternate row. The results demonstrate that all the yield components except 1000-grain weight and yields of BRRI dhan29 responded significantly to the deep placement of N in the form of USG and NPK briquettes under continuous flooded condition. The highest grain yield of 6561 kg ha^{-1} was recorded in T_3 [USG, 130 kg N ha^{-1}] which was statistically similar to that ofT_4 [USG, 104 kg N ha^{-1}].The highest straw yield of 6876 kg ha^{-1} was obtained in T_3 [USG, 130 kg N ha^{-1}]. The lowest grain yield (3094 kg ha^{-1}) and straw yield (3364 kg ha^{-1}) were found for T_1 (Control). 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 PU. 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 [30.75 kg grain increase per kg N applied) and the lowest value was found in T_8 [130 kg N ha^{-1} from PU]. Based on yield, N use efficiency and cost-benefit analysis, an application of 104 kg N ha^{-1} as USG can be recommended as the best treatment for achieving satisfactory yield of boro rice (cv. BRRI dhan29) at BAU farm and at adjacent areas under AEZ 9 (Old Brahmaputra Floodplain).

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

1. Introduction

Bangladesh is an agricultural country. Its economy mainly depends on agriculture. About 80% people are involved in agriculture directly or indirectly. Rice is the major staple food for more than 164 million Bangladeshis. Rice is grown under diverse irrigated, rainfed and deep water conditions in the three distinct seasons namely Aus, Aman and Boro in Bangladesh. Out of total rice production in this country about 43% come from Boro and the rest comes from Aman and Aus crops, respectively (BBS, 2011). For cultivation of rice, farmers of Bangladesh solely depend on urea fertilizer and 50% of the total demand is fulfilled by import which costs a huge amount of foreign currency (BBS, 2008a). 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. The volatilization loss of prilled urea (PU) is very high and farmers lose a huge amount of money for N fertilizer. Therefore, attention must be given to minimize the production cost in a search for increasing crop yield. On the other hand, water shortage during the boro season in Bangladesh is a growing problem due to climatic change and upstream water regulation of the major rivers in Bangladesh. In the wetland rice soils, rice plants take N mainly as ammonium (NH_4^+), requiring less energy to assimilate into amino acids than nitrate. Ammonia volatilization losses in the flooded soils range from negligible to almost 60% of the applied N (De Datta, 1985; Xing and Zhu, 2000). Deep placement of N fertilizers into the anaerobic soil zone is an effective method to reduce volatilization loss. Again, the deep placement of USG and NPK briquette minimizes the concentration of NH_4-N in floodwater compared to broadcast application of PU. Jahan *et al.* (2014) reported that application of USG in combination with poultry manure was more effective in producing higher rice yield and at the same time reduce water pollution. Bhuiyan *et al.* (1998) reported that deep point placement of USG produced significantly higher grain yield of rice than split application of PU. Islam *et al.* (2011) carried out an experiment on the effectiveness of NPK briquette on rice in tidal flooded soil condition. They found that NPK briquettes, USG and PU treated plots produced statistically similar grain yields. They also observed that NPK briquette can save 33 kg N ha^{-1} compared to PU. Afroz *et al.* (2013) conducted a field experiment at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during Boro season to investigate the effects of PU, USG, and NPK briquettes on growth and yield of BRRI dhan28 and found that USG performed better in increasing grain yield of rice compared to 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. Although a good number of researches has already been carried out in Bangladesh and abroad generating good data 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. In this study, the effect of deep placement of N fertilizer on N use efficiency and yield of boro rice under continuous flooding condition were examined. Hence the present study was undertaken with the following objectives: to study the effect of deep placement of N fertilizers on the yield component and yield of BRRI dhan29 and to investigate the effect of deep placement of N fertilizers on the N uses efficiency of BRRI dhan29.

2. Materials and Methods

2.1. Experimental site and soil

The experimental site is located at 24.75ºN latitude and 90.5ºE longitude which falls under the AEZ of Old Brahmaputra Floodplain. The experiment was set up in typical rice growing silt loam soil at the Soil Science Field laboratory, Bangladesh Agricultural University, Mymensingh during boro season of 2016. The soil was silt loam in texture having pH 6.27, organic matter content 1.95%, total N 0.14%, available P 3.16 ppm, exchangeable K 0.09 me% and available S 10.5 ppm. The experimental area has sub-tropical climate which is characterized by adequate rainfall associated with moderately low temperature during aman season.

2.2. Treatments

There were altogether eight different treatment combinations which include: T_1: Control, T_2: PU, 130 kg N ha-^{1}, T_3: USG (100%) = 130 kg N ha^{-1} (one 2.7 g + one 1.8 g briquette), T_4: USG (80%) = 104 kg N ha^{-1} (two1.8g briquette), T_5: USG (60%) = 78 kg N ha^{-1} (one 2.7 g briquette), T_6: NPK (100%) = 129 kg N ha^{-1} (two 2.4 g + one 3.4g briquette), T_7: NPK (80%)=102 kg N ha^{-1} (two 3.4g briquette), T_8: NPK (60%)=78 kg N ha^{-1} (two 2.4g briquette)

2.3. Layout of the experiment

The experiment was laid out in a randomized complete block design (RCBD), where the experimental area was divided into 3 blocks representing three replications to reduce the heterogenic effects of soil. There were 8 different treatment combinations. Each block was subdivided into 8 plots and the treatments were randomly distributed to the unit plots in each block. Thus the total number of unit plot was 24. The size of each plot was 4 m x 5 m and plots were separated from each other by ails (30 cm). There was 1 m drain between the blocks that separated the blocks from each other.

2.4. Land preparation

The land was prepared by ploughing and cross ploughing with power tiller followed by country plough. Then the land was laddered with traditional tools. All kinds of weeds and stubbles were removed from the field before final ploughing and levelling. Then the land was laddered with traditional tools. After puddling, the plots were made according to the design by making ails around each plot.

2.5. Application of fertilizers

The fertilizers were applied as per treatment. All the treatments except T_6, T_7 and T_8received 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 NPKbriquettes. 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 between four hills at alternate rows. Before application of N fertilizers, the water in the rice plots was drained out.

2.6. Transplanting of seedling

Seedlings were carefully uprooted from seedling nursery bed and transplanted in the plots on 2 February, 2016 maintaining a spacing of 20 cm× 20 cm.

2.7. Intercultural operations

Intercultural operations were done as and when necessary for ensuring and maintaining the favourable environment for normal growth and development of crop. Irrigation was provided to the plots from deep tube well to maintain continuous flooding condition during the growing period of the crop. The experimental plots were infested with some obnoxious weeds, which were controlled by uprooting and removing as many as three times from the field.

2.8. Harvesting, threshing and weighing

The crop was harvested at maturity. From each plot the area of $4m^2$was harvested and the crop bundled separately. The harvested crop was threshed plot wise. Grain and straw yields were recorded and moisture percentage was calculated after sun drying.

2.9. Digestion of plant samples for total nitrogen determination

For the determination of nitrogen, 0.l g of oven dry ground plant sample(both grain and straw separately) was taken in a micro-kjeldahl flask. 1.1 gcatalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se = 100: 10:1), 2 ml 30% H_2O_2 and 3mlH_2SO_4 were added into the flask. The flask was swirled and allowed to stand for about 30 minutes. Then heating 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.

2.10. Determination of N from plant samples

Nitrogen contents in the digests were determined by the similar method as described in case of soil analysis. One gram of oven dry ground sample was taken into micro-kjeldahl flask to which 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se = 100: 10: 1), 2ml 30% H_2O_2 and 3 ml H_2SO_4 were added. The flasks were swirled and allowed to stand for about 30 minutes. Then heating (380°C) was continued until the digest was clear and colorless. After cooling, the content was taken into 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. This 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 5drops of mixed indicator of bromocresol green ($C_{21}H_{14}O_5Br_4S$) and methyl redsolution. Finally the distillate was titrated with standard 0.01 N H_2SO_4untilthecolor changed from green to pink (Bremner and Mulvaney, 1982). The amount of N was calculated using the following formula:

$$\% N = \frac{(T-B) \times N \times 0.014 \times 100}{S}$$

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.

2.11. Nitrogen uptake

To calculate N uptake with grain and straw the following equation was used

Nitrogen uptake (kg ha^{-1}) = (Gy × N_{Gr})/ 100 + (Sy × N_{st})/100

Where, Gy = Grain yield (kg ha^{-1}), Sy = Straw yield (kg ha^{-1}), N_{Gr} = N content in grain (%), N_{st} = N content in straw (%)

2.12. Apparent recovery of applied n fertilizer (ANR)

ANR is defined as kg of N taken up per kg of fertilizer applied.

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 and FN is amount of fertilizer N applied (kg ha^{-1})

2.13. Nitrogen use efficiency (NUE) of applied N fertilizer

NUE is defined as kg grain yield increase kg^{-1} N applied

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

Where Gy_{+N} = Grain yield in treatment with N application, Gy_{ON} = Grain yield in treatment without N application, FN = Amount of fertilizer N applied (kg ha^{-1})

2.14. Statistical analysis

The analyses of variance for different crop characters as well as for different nutrient concentrations of the treatments were made and the mean differences were adjudged by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Yield attributes of BRRI dhan29

Plant height of BRRI dhan29 responded significantly due to application of PU, USG and NPK briquettes (Table 1). All the treatments gave significantly higher plant height over the control (T_1). Plant height ranged from 62.66 cm to 88.16 cm. The tallest plant of 88.16 cm was found in T_3 [USG, 130 kg N ha^{-1}]. Statistically similar plant height was recorded in T_4 [USG, 104 kg N ha^{-1}] and T_6 [NPK briquette, 129 kg N ha^{-1}] with the value of 82.86 and 82.03 cm respectively. The shortest plant of 62.66 cm was observed in T_1 [control].A significant variation in the number of effective tillers $hill^{-1}$ of BRRI dhan29 was observed due to PU, USG and NPK briquettes application. All the treatments increased the effective tillers $hill^{-1}$ significantly over the control (T_1). The maximum number of effective tillers $hill^{-1}$(15.00) was found in T_3 [USG, 130 kg N ha^{-1}]. Statistically similar effective tillers $hill^{-1}$ was recorded in T_2 [PU, 130 kg N ha^{-1}], T_4 [USG, 104 kg N ha^{-1}] and T_6 [NPK briquette, 129 kg N ha^{-1}] with the value of 13.80, 14.10 and 13.96, respectively. The minimum effective tillers $hill^{-1}$ of 5.66 was obtained in control. The application of PU, USG and NPK briquette showed a positive effect on panicle length of BRRI dhan29 over control. The largest panicle (23.43 cm) was found in T_3 [USG, 130 kg Nha^{-1}]. Statistically similar panicle length was found in T_2 [PU, 130 kg N ha^{-1}], T_4 [USG, 104 kg N ha^{-1}] and T_6 [NPK briquette, 129 kg N ha^{-1}] with the value of 21.56, 22.03, 21.76 cm, respectively. The smallest panicle (17.66 cm) was observed in T_1 (control).Grains $panicle^{-1}$ of BRRI dhan29 was influenced profoundly due to the application of PU, USG and NPK briquettes. The number of grains $panicle^{-1}$ varied from 81.33 to 145.00. The highest number of grains $panicle^{-1}$ (145.00) was found in T_3 [USG, 130 kg N ha^{-1}], which was statistically similar with T_2 [PU, 130 kg Nha^{-1}], T_4 [USG, 104 kg N ha^{-1}] and T_6 [NPK briquette, 129 kg N ha^{-1}] in producing grains $panicle^{-1}$ with the value of 133.40, 136.30 and 134.90, respectively. The lowest value of grains $panicle^{-1}$ was found in T_1 (control). The 1000-grain weight of BRRI dhan29 varied insignificantly due to application of PU, USG and NPK briquettes. The 1000-grain weight of rice ranged from 20.36 to 24.70g. Although there were some numerical differences in 1000-grain weight among the treatments but the effect of the treatments was not significant.

Table 1. Effect of deep placement of nitrogen as USG, and NPK briquettes on the 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)	62.66 f	5.66 e	19.70 c	81.33 d	20.36
T_2 [PU, 130 kg N ha-^{1})]	81.13 c	13.80 b	21.56 b	133.40 a b	22.70
T_3 [USG, 130 kg N ha^{-1}]	88.16 a	15.00 a	23.43 a	145.00 a	24.70
T_4 [USG, 104 kg N ha^{-1}]	82.86 b	14.10 b	22.03 b	136.30 a b	23.20
T_5 [USG, 78 kg N ha^{-1}]	74.60 d	12.66 c	19.83 c	122.70 b c	20.86
T_6 [NPK briquette, 129 kg N ha^{-1}]	82.03 b c	13.96 b	21.76 b	134.90 a b	22.96
T_7 [NPK briquette, 102 kg N ha^{-1}]	73.80 d	12.56 c	19.63 c	121.33 b c	20.66
T_8 [NPK briquette, 78 kg N ha^{-1}]	66.40 e	11.30 d	17.66 d	109.26 c	20.60
CV (%)	1.02	3.10	2.73	7.04	01.61
SE (±)	0.45	0.22	0.33	4.99	0.21

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

3.2. Grain yield of BRRI dhan29

Deep placement of N in the form USG and NPK briquettes showed a positive effect on grain yield of BRRI dhan29 (Table 2). It was found that the grain yield ranged from 3094 to 6561 kg ha^{-1}. The highest grain yield of 6561 kg ha^{-1} was recorded in T_3 [USG, 130 kg N ha^{-1}] and the lowest value of 3094 kg ha^{-1} was recorded in T_1 (control). The highest grain yield obtained with the treatment T_3 [USG, 130 kg N ha^{-1}] was statistically similar toT_4 [USG, 104 kg N ha^{-1}] with the value of 6292 kg ha^{-1}. The grain yields obtained with the treatments T_2 [PU, 130 kg N ha^{-1}], T_5 [USG, 78 kg N ha^{-1}], T_6 [NPK briqutte, 129 kg N ha^{-1}] were statistically similar. The increase in grain yield over control ranged from 43.77 to 112.06 to where the highest increase was obtained due to T_3 [USG, 130 kg N ha^{-1}] and the lowest one was obtained with T_8 [NPK briquette, 78 kg N ha^{-1}] as shown in Table 2. The grain yields obtained from different treatments may be ranked in the order of T_3> T_4>T_5>T_6>T_7>T_8>T_2>T_1. Urea super granule followed by NPK briquettes performed better in increasing grain yield of BRRI dhan29 as compared to PU.

3.3. Straw yield of BRRI dhan29

The straw yield of BRRI dhan29 was also influenced significantly due to the deep placement of USG and NPK briquettes as shown in Table 2. The straw yield obtained from different treatments ranged from 3364 kg ha^{-1} to 6876 kg ha^{-1}. The highest straw yield of 6876 kg ha^{-1} was obtained in T_3 [USG, 130 kg N ha^{-1}] and the lowest value of 3364 kg ha^{-1} was noted in T_1 (Control). The straw yield produced by the treatment T_3 [USG, 130 kg N ha^{-1}] was identical with T_4 [USG, 104 kg N ha^{-1}]. The straw yield obtained with the treatments T_2 [PU, 130 kg N ha^{-1}], T_5 [USG, 78 kg N ha^{-1}] and T_6 [NPK briqutte, 129 kg N ha^{-1}] were statistically similar. The treatments may be ranked in the order of T_3> T_4>T_5>T_6>T_2> T_7>T_8> T_1 in terms of straw yield. Regarding the percent increase of straw yield, maximum straw yield increase (104.40%) was noted in T_3 and the minimum increase (47.06%) was found in T_8 as demonstrated in Table 2.

Table 2. Effect of deep placement of nitrogen in the form of USG and NPK briquettes on the grain and straw yields of BRRI dhan29.

Treatments	Grain yield (kg ha^{-1})	Increase over control (%)	Straw yield (kg ha^{-1})	Increase over control (%)
T_1(control)	3094 e		3364 e	
T_2[PU,130 kg N ha-^{1}]	5593 b c	80.77	5752 c	70.99
T_3 [USG, 130 kg N ha^{-1}]	6561 a	112.06	6876 a	104.40
T_4 [USG, 104 kg N ha^{-1}]	6292 a b	103.36	6737 a b	100.27
T_5 [USG, 78 kg N ha^{-1}]	5704 b c	84.36	6046 b c	79.73
T_6 [NPK briquette, 129 kg N ha^{-1}]	5573 b c	80.12	6030 b c	79.25
T_7 [NPK briquette, 102 kg N ha^{-1}]	5161 c d	66.81	5735 c	70.48
T_8 [NPK briquette, 78 kg N ha^{-1}]	4439 d	43.47	4947 d	47.06
CV (%)	8.11		7.23	
SE (±)	248		237	

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

3.4. Nitrogen content by BRRI dhan29

Application of PU, USG and NPK briquettes showed significant variation in nitrogen content of grain and straw of BRRI dhan29. The grain N content varied from 0.87%to 1.21%. The highest N content of 1.21% was observed in T_3 [USG, 130 kg N ha^{-1}] and the lowest N content of 0.87% was noted in T_1 (control) as shown in Table 3. The N content in straw of BRRI dhan29 rice also varied significantly due to different treatments. The application of N fertilizers increased the N content in rice straw markedly in T_3 [USG, 130 kg N ha^{-1}]. Deep placement of USG was more efficient in increasing the N content both in grain and straw of BRRI dhan29. The results reveal that the N content in rice grain was higher than that of straw.

3.5. Nitrogen uptake by BRRI dhan29

The N uptake both by grain and straw of BRRI dhan29 was increased significantly due to application of PU, USG and NPK briquettes. The N uptake by grain ranged from 27.11 kg ha^{-1} to 79.41 kg ha^{-1} (Table 3). The highest N uptake by grain (79.41 kg ha^{-1}) was obtained in T_3 [USG, 130 kg N ha^{-1}]and the lowest N uptake by grain (27.11 kg ha^{-1}) was found in T_1 (control).On the other hand, the treatments T_2 [PU,130 kg N ha^{-1}], T_5 [USG, 78 kg N ha^{-1}] and T_6 [NPK briquette, 129 kg N ha^{-1}] were statistically similar in their effects on nitrogen uptake by grain. Application of deep placement of USG increased the N uptake in rice grain. The N uptake by straw ranged from 19.27 kg ha^{-1} to 49.61 kg ha^{-1}. The highest N uptake by straw (49.61 kg ha^{-1}) was obtained in T_3 [USG, 130 kg N ha^{-1}] and the lowest straw N uptake (19.27 kg ha^{-1}) was found in T_1 (control). Straw N uptake by T_2 [PU, 130 kg N ha^{-1}], T_4 [USG, 104 kg N ha^{-1}], T_5 [USG, 78 kg N ha^{-1}] and T_6 [NPK briquette, 129 kg N ha^{-1}] were statistically similar in their effects on N uptake by rice straw. The total N uptake was also influenced significantly by different treatments. The highest total N uptake (129.03 kg ha^{-1}) was observed in T_3 [USG, 130 kg N ha^{-1}] and the lowest value (46.39kg ha^{-1}) was found in T_1 (control). On the other hand, treatments T_2 [PU, 130 kg N ha^{-1}], T_4 [USG, 104 kg N ha^{-1}], T_5 [USG briquette, 78 kg N ha^{-1}], T_6 [NPK briquette, 129 kg N ha^{-1}] and T_7 [NPK briquette, 102 kg N ha^{-1}] gave statistically similar total N uptake. The total N uptake by BRRI dhan29 due to different treatments may be ranked in the order of $T_{3>}T_4>T_6>T_5>T_7>T_{2>}T_{8>}T_{1.}$

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)	0.87 f	0.57 e	27.11 e	19.27 d	46.39 d
T_2[PU, 130 kg N ha-^{1}]	1.02 e	0.62 b	57.29 c	36.03 b	93.32 b
T_3 [USG, 130 kg N ha^{-1}]	1.21 a	0.72 a	79.41 a	49.61 a	129.03 a
T_4 [USG, 104 kg N ha^{-1}]	1.07 c d	0.56 f	67.75 b	38.05 b	105.80 b
T_5 [USG, 78 kg N ha^{-1}]	1.02 e	0.57 e	58.44 c	34.94 b	93.39 b
T_6 [NPK briquette, 129 kg N ha^{-1}]	1.06 d	0.59 d	59.17 c	35.42 b	94.59 b
T_7 [NPK briquette, 102 kg N ha^{-1}]	1.12 b	0.62 c	58.01 c	35.33 b	93.35 b
T_8 [NPK briquette, 78 kg N ha^{-1}]	1.08 c	0.59 d	48.38 d	29.38 c	77.76 c
CV (%)	1.01	0.95	8.48	7.76	7.91
SE (±)	0.01	0.001	2.79	1.56	4.19

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

3.6. Apparent N recovery (ANR)

The apparent N recovery indicates the absorption efficiency of applied N. The apparent N recovery by BRRI dhan29 has been presented in Table 4. Mean apparent recovery of N by rice ranged from 36.10 to 63.57% in different treatments. The maximum value (63.57%) of apparent N recovery was obtained with the application of USG in T_3 [USG, 130 kg N ha^{-1}]followed by T_5 [USG,78 kg N ha^{-1}], T_4 [USG, 104 kg N ha^{-1}], T_7 [NPK briquette,102 kg N ha^{-1}]and T_8 [NPK briquette, 78 kg N ha^{-1}].The minimum value (36.10%) was found in T_2 [PU,130 kg N ha^{-1}]. The data clearly indicate that the deep placement of USG and NPK briquettes enhanced the recovery of applied N as compared to broadcast application of NPK fertilizers.

3.7 Nitrogen use efficiency (NUE)

Agronomic nitrogen use efficiency (NUE) is a term used to indicate the amount of rice grain (kg) produced per kg use of N. NUE represents the response of rice plant in terms of grain yield to N fertilizer. The NUE varied from 17.24 to 33.46 among the treatments (Table 4). The highest value of NUE (33.46 kg grain increase per kg N applied) was obtained in T_5 [USG, 78 kg N ha^{-1}] followed by T_4 (30.75 kg grain increase per kg N applied), T_3 (26.67 kg grain increase per kg N applied), T_7 (20.26 kg grain increase per kg N applied), and T_2 (19.22 kg grain increase per kg N applied) and the lowest value was found in T_8 (78 kg N ha^{-1} from NPK). The data clearly indicate that the deep placement of USG and NPK briquettes enhanced the NUE as compared to broadcast application of prilled urea.

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

Treatments	Apparent N recovery (%)	N use efficiency
T_1 (control)	-	-
T_2[PU, 130 kg N ha-^{1}]	36.10	19.22
T_3 [USG, 130 kg N ha^{-1}]	63.57	26.67
T_4 [USG, 104 kg N ha^{-1}]	57.13	30.75
T_5 [USG, 78 kg N ha^{-1}]	60.26	33.46
T_6 [NPK briquette, 129 kg N ha^{-1}]	37.36	19.22
T_7 [NPK briquette, 102 kg N ha^{-1}]	46.04	20.26
T_8 [NPK briquette, 78 kg N ha^{-1}]	40.22	17.24

4. Conclusions

The deep placement of N fertilizers has numerous benefits over broadcast application of PU. The overall results indicate that the highest grain yield obtained with the treatment T_3 [USG, 130 kg N ha^{-1}] was statistically similar to T_4 [USG, 104 kg N ha^{-1}] with the value of 6292 kg ha^{-1}. The highest N uptake by grain (79.41 kg ha^{-1}) and apparent N recovery (63.57%) were also obtained with T_3 [USG, 130 kg N ha^{-1}]. But the highest value of NUE (33.46 kg grain increase per kg N applied) was obtained in T_5 [USG, 78 kg N ha^{-1}] followed by T_4 [USG, 104 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 broadcast application of PU. As a consequence, the grain yield of BRRI dhan29 was increased to a significant extent. The treatment T_4 demonstrated the highest marginal benefit-cost ratio (15.48) and the lowest MBCR was obtained in T_8. Considering the above facts, the treatment T_4 [USG, 104 kg N ha^{-1}] can be recommended for profitable cultivation of boro rice, BRRI dhan29.

Conflict of interest

None to declare.

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