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Article

Nitrogen use efficiency and yield of BRRI dhan46 as influenced by deep placement of N fertilizers under 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 2015 to evaluate the effect of deep placement of N fertilizers on nitrogen use efficiency and yield of BRRI dhan46 under flooded condition. 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 experiment was laid out in a randomized complete block design with three replications. There were eight treatment combinations including T_1 (Control), T_2 (PU, 104kgN/ha), T_3 (USG, 104kgN/ha), T_4 (USG, 78kg N/ha), T_5 (USG, 52kg N/ha), T_6 (NPK briquette, 104kgN/ha) and T_7 (NPK briquette, 78kg N/ha) and T_8 (NPK briquette, 52kg N/ha). All the treatments except T_6, T_7 and T_8 received 20 kg P and 50 kg K/ha as TSP and MoP, respectively. Treatments T_6, T_7, T_8 received NPK briquettes fertilizer. Prilled urea was applied in three equal splits. USG and NPK briquettes were applied at 10 DAT and the briquettes were placed at 8-10 cm depth in the center of four hills in alternate rows. The yield attributes, and grain and straw yields of BRRI dhan46 responded significantly to the application of PU, USG and NPK briquettes under flooded condition. The highest yields of grain (5828 kg/ha) and straw (6116 kg/ha) were recorded in T_3 and the lowest values of grain and straw yields (3522 and 3783 kg/ha, respectively) were found in the control. Deep placement of N fertilizers also enhanced the N use efficiency, N uptake and apparent recovery by BRRI dhan46. The maximum N use efficiency (22.17 kg grain increase per kg N applied) was found in T_3 and the minimum value (9.31 kg grain increase per kg N applied) was recorded in T_8. The results reveal that the deep placement of USG (104 kg N/ha) accelerated the N uptake, N recovery and N use efficiency by BRRI dhan46 as compared to other treatments. Therefore, application of 104 kg N/ha as USG may be recommended for profitable cultivation of aman rice, BRRI dhan46.

Keywords: N fertilizer; deep placement; N use efficiency; BRRI dhan29; yield

1. Introduction

In Bangladesh majority of food grains come from rice. About 80% of cropped area of this country is used for rice production, with annual production of 43.50 million metric tons from 11.20 million ha of land. The average yield of rice in Bangladesh is 3.90t/ha. Rice is grown in Bangladesh under diverse ecosystem-irrigated, rainfed, and deep water conditions in three distinct seasons namely aus, aman and boro. Rice yield is stagnating recent years even though normal recommended practices have been followed. The low available nitrogen in soil, low nutrient holding capacity of the soil and heavy leaching of the nutrients from the soil due to high rainfall of this region have been identified as the limiting factors for getting higher yield of rice.Urea is the nitrogenous

fertilizers widely used by millions of rice farmers across the globe both for irrigated and rainfed rice. Many farmers still practice broadcasting method of urea application to fertilize paddy plants standing in flooded water. This practice is highly inefficient about two-thirds of the fertilizer is lost as greenhouse gas or becomes a groundwater pollutant. A technology called fertilizer deep placement (FDP) is followed in Bangladesh, which ensures 40% more efficiency of urea utilization. IFDC, a public international organization addressing critical issues such as international food security, has joined hands with Bangladesh Ministry of Agriculture, the Rice Research Institute and the private sector (small private entrepreneurs) to develop FDP technology based upon urea supergranules (when used with urea fertilizer, FDP is called UDP- urea deep placement). Urea deep Placement is a simple but a very effective technology which involves the placement of 1-3 grams of urea supergranules or briquettes at a 7-10 centimeters (cm) soil depth shortly after the paddy is transplanted. Deep placement of USG effectively increases N use efficiency (31.7%) compared to conveniently applied prilled urea (Jaiswal and Singh, 2001). Deep placement of USG and NPK briquette in wetland rice cultivation has the advantages of protecting nitrogen from loss by ammonia volatilization and denitrification. In many paddy soils, more nitrogen is recovered from the deep-placed N fertilizers than from broadcast prilled urea (PU) (Dupuy *et al.*, 1990; Savant and Stangel, 1991; Jaiswal and Singh, 2001). The loss of nitrogen (N) can be very high in rice fields, particularly in the irrigated rice cropping systems with very poor water control. Previous studies have reported very low (30%) fertilizer N use efficiency by broadcasting in irrigated cropping systems (Alimata *et. al.*, 2015). Deep placement of Urea Super Granule (USG), NPK briquette increases N fertilizer use efficiency in wetland rice. USG dissolves slowly in the soil providing a steady supply if available nitrogen throughout the growing period of the crop. Using USG to transplant aman rice in Bangladesh can offer a compelling example of the effective approach for managing urea fertilizer that will in not only can improve efficiency but also a greater yield with less urea fertilizer. 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 and NPK briquette. Islam (2012) observed that NPK briquettes deep placement increased straw yield when compared with urea broadcast during boro season at three locations with equivalent rate at same PK levels.Deep placement of N fertilizers under continuous flooding condition introduces a new dimension in N fertilization regime. Although a large number of researches have already been carried out in Bangladesh and foreign countries, the data on N use efficiency in rice are still lacking. Hence the present study was undertaken with the following objectives: to evaluate the effect of deep placement of N fertilizers on the yield attributes and yield of BRRI dhan46 under continuous flooded condition and to investigate the N use efficiency of BRRI dhan46 as influenced by deep placement of N fertilizers.

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 aman season of 2015.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

The experiments composed of eight treatments which include: T_1: Control, T_2: PU, 104 kgN/ha, T_3: USG (100%) = 104 kg N/ha (two 1.8 g briquette), T_4: USG (75%) = 78 kg N/ha (one 2.7 g briquette). T_5: USG (50%) = 52 kgN/ha (one 1.8g briquette), T_6: NPK (100%) = 104 kgN/ha (two 3.4 briquette), T_7: NPK (75%) = 78 kgN/ha (two 2.4 briquette), T_8: NPK (50%) = 52 kgN/ha (one 3.4 briquette).

2.3. Lay out 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 the replications to reduce theheterogenic 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 4m×3m and plots were separated from each other by ails 30cm. There was 1 m drain between the blocks that separated the blocks from each other. The layout of the experiment has been shown in Figure1.

2.4. Land preparation

The land was prepared by ploughing and cross ploughing with power tiller followed by country plough and laddering at suitable times. The land was then cleaned by collecting and removing the weeds, stubble and previous crop residues. 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_8 received 20 kg P, 50 kg K and 18 kg S 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 dressed 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 nursery bed and transplanted in the plots on 3 August, 2015 maintaining spacing of 20 m×20 m.

2.7. Intercultural operations

Intercultural operations were done as and when necessary for ensuring and maintaining the favorable environment for normal growth and development of crop. Weeding and irrigation were performed.

2.8. Harvesting, threshing and weighing

The crop was harvested at maturity on 17 December 2015. 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. Determination of N from plant samples

Total N was determined by micro-Kjeldahl method where1g 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), 2 mL 30% H_2O_2 and 3 mL H_2SO_4 were added. After swirling the flask, it was allowed to stand for about 30 minutes. Then the flask were heated (380 ºC) until the digest became 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 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. For this, 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 and 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:

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

Where, T = Sample titration value (mL) of standard H_2SO_4, B = Blank titration value (mL) of standard H_2SO_4, N = Strength of $H_2SO_4$and S = Weight of soil sample in g.

2.10. Apparent recovery of applied N (ANR)

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

ANR (kg /ha) = (UN+N – UN0N) /FN

Where, UN+N is total N uptake (kg with grain and straw), UN0N is the N uptake (kg /ha) in control and FN is amount of fertilizer N applied (kg /ha).

2.11. Nitrogen use efficiency

Nitrogenuse 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 efficiency N was calculated by the following formula:

NUE = (GY+N – GY0N) /FN

Where, GY+N = grain yield in treatment with N application, GY0N = grain yield in treatment without N application, FN = amount of fertilizer N applied (kg /ha).

3. Results and Discussion

3.1. Yield attributes of BRRI dhan46

Plant height of BRRI dhan46 responded significantly to the deep placement of N fertilizers in the form of USG and NPK briquette (Table 1). All the treatments gave significantly higher plant height compared to T_1 (Control). The plant height ranged from 92.6 to 107.8 cm across the treatments. The tallest plant of 107.8 cm was recorded in T_3 (USG, 104 kg N/ha) which was identical to all other treatments except T_2 (PU, 104kgN/ha) and the shortest plant of 92.6 cm was recorded in T_1 (Control). A significant variation in the number of effective tillers/hill of BRRI dhan46 was observed in response to PU, USG and NPK briquettes. All the treatments increased the effective tillers/hill significantly over the control (T_1). The maximum number of effective tillers/hill of 14.0 was found in T_3 (USG, 104 kg N/ha) which was identical to T_6 (NPK briquette, 104 kgN/ha) and the smallest effective tillers/hill (7.5) was observed in T_1 (control). The application of PU, USG and NPK briquette showed a positive effect on panicle length of BRRI dhan46 over control. The highest panicle length of 26.9 cm was recorded in T_3 (USG, 104 kg N/ha). The smallest panicle length (16.7cm) was observed in T_1 (control). The effect of PU, USG and NPK briquette on grains/panicle of BRRI dhan46 was significant over control. The number of grains/panicle varied from 72.7 to 135.6. The highest grains/panicle (135.6) was recorded in T_3 (USG, 104 kg N/ha) followed by T_6 (NPK briquette, 104 kgN/ha) which was statistically similar with all other treatments except control. The lowest grains/panicle (72.7) was observed in T_1 (control). The 1000-grain weight of BRRI dhan46 varied insignificantly due to application of PU, USG and NPK briquettes. The numerical difference in 1000-grain weight found in various treatments was quite low. The 1000-grain weight ranged from 33.70g to 32.09g. Although all the treatments produced higher 1000-grain weight over control, the effect of the treatments was not significant.

Table 1. Effect of deep placement of N fertilizers on the yield components of BRRI dhan46.

Treatments	Plant height (cm)	Tillers /hill (no.)	Panicle Length (cm)	Grains /panicle	1000-grain weight (g)
T_1(Control)	92.6c	7.5f	16.7c	72.7c	32.48
T_2(PU, 104kgN/ha)	97.6bc	10.4e	21.2b	106.3b	32.33
T_3(USG, 104kg N/ha)	107.8a	14.0a	26.9a	135.6a	33.70
T_4(USG, 78kg N/ha)	104.6ab	11.8cd	21.6b	108.4b	33.41
T_5(USG, 52kg N/ha)	104.4ab	10.7de	20.5b	114.4b	33.56
T_6(NPKbriquette, 104kg N/ha	106.8a	13.0ab	21.9b	118.3b	33.42
T_7 (NPK briquette, 104kg N/ha)	104.6ab	12.3bc	20.9b	115.1b	32.62
T_8 (NPK briquette, 52kg N/ha)	101.5ab	11.8cd	21.2b	110.7b	32.09
CV (%)	3.91	5.53	3.80	6.91	3.36
SE (±)	2.315	0.366	0.469	4.39	0.638

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

Significant response of the grain yield of BRRI dhan46was found due to the deep placement of N fertilizers in the form of USG and NPK briquette (Table 2). The grain yield ranged from 3522 to 5828 kg/ha where the highest grain yield was recorded in T_3 (USG, 104kg N/ha) and the lowest value was observed in T_1 (control). The maximum grain yield increase over control (65.47%) was found in T_3 (USG, 104kg N/ha) and the minimum increase (13.74%) was noted in T_8 (NPK briquette, 52kg N/ha). Based on grain yield the treatments may be ranked in the order of $T_3 > T_6 > T_2 > T_4 > T_7 > T_5 > T_8 > T_1$. USG performed better in increasing grain yield of rice as compared to PU and NPK briquette.

3.3. Straw yield

Straw yield of BRRI dhan46also responded significantly to different treatments under study (Table 2). The highest straw yield (6116kg/ha) was found in T_3 (USG, 104kg N/ha). The straw yield produced by the treatments T_2, T_4 and T_6 with the value of 5090, 5194 and 5166 kg/ha was statistically similar. The lowest straw yield of 3783 kg/ha was observed in T_1 (control). Nearly 13.03 to 61.67% increase in straw yield over control was recorded due to application of N either broadcast as PU or deep placed as USG and NPK briquette. Like the grain yield, the maximum straw yield increase over control (61.67%) was noted in T_3 (USG, 104kg N/ha). Based

on straw yield the treatments may be ranked in the order of T_3> T_4> T_6> T_2> T_7>T_5>T_8>T_1. USG (104Kg N/ha) performed better than other treatments in increasing straw yield under continuous flooding condition.

Table 2. Effect of deep placement of N fertilizersas USG and NPK briquette on the grain and straw yields of BRRI dhan46.

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)
T_1 (Control)	3522e	3783d
T_2 (PU, 104kgN/ha)	4857b	5090b
T_3 (USG, 104kg N/ha)	5828a	6116a
T_4 (USG, 78kg N/ha)	4666b	5194b
T_5 (USG, 52kg N/ha)	4091cd	4562c
T_6 (NPK briquette, 104kg N/ha	4870b	5166b
T_7 (NPK briquette, 104kg N/ha)	4339c	4625c
T_8 (NPK briquette, 52kg N/ha)	4006d	4276c
CV (%)	3.83	3.95
SE (±)	100.112	110.634

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

Application of PU, USG and NPK briquette influenced the N content of both grain and straw of BRRI dhan46 significantly over control (Table 3). The grain N concentration ranged from 1.02 to 1.40 %. The highest N content of 1.40% was recorded in T_3 (USG, 104kg N/ha) and the lowest N content of 1.02% was observed in T_1 (Control). In case of straw, The N content ranged from 0.51% in T_3 (USG, 104 kg N/ha) to 0.64% in T_1 (Control). Deep placement of USG was more efficient in increasing the N content both grain and straw of BRRI dhan46. The results reveal that the N content in rice grain was higher than that of straw.

3.5. Nitrogen uptake

The N uptake both by grain and straw of BRRI dhan46 was influenced significantly by the application of PU, USG and NPK briquettes under continuous flooding condition (Table 3). The highest N uptake by grain (81.81(kg/ha) was observed in T_3 (USG, 104kg N/ha) and the lowest N uptake (35.83(kg/ha) was found in T_1 (control). On the other hand, the treatments T_4 (USG, 78kg N/ha) and T_6 (NPK briquette, 104 kg N/ha) were statistically similar in their effects on nitrogen uptake by grain. In straw, the N uptake ranged from 19.29 to 39.05 kg/ha whereas the maximum N uptake was recorded in T_3 (USG, 104 kg N/ha) and the minimum uptake in T_1 (Control). The second highest N uptake by straw was 28.70 kg/ha which was found in T_4 (USG, 78 kg N/ha). The total N uptake by BRRI dhan46 ranged from 55.12 to 120.86 kg/ha. The highest total N uptake was recorded in T_3 (USG, 104 kg N/ha) and the treatment T_6 (NPK briquette, 104 kgN/ha) gave the second highest total N uptake. On the other hand, treatments T_2 (PU, 104kgN/ha) and T_4 (USG,78kg N/ha) gave statistically similar total N uptake. The total N uptake by BRRI dhan46due to different treatments may be ranked in the order of T_3> T_6> T_4>T_2>T_7>T_6>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 dhan46.

Treatments	N content (%)		N uptake (Kg/ha)		Total
	Grain	Straw	Grain	Straw	
T_1 (Control)	1.02f	0.510b	35.83f	19.29d	55.12e
T_2 (PU, 104kgN/ha)	1.12de	0.560b	54.62c	28.42b	83.04b
T_3 (USG, 104kg N/ha)	1.40a	0.640a	81.81a	39.05a	120.86a
T_4 (USG, 78kg N/ha)	1.21bc	0.553b	56.57bc	28.70b	85.27b
T_5 (USG, 52kg N/ha)	1.15cd	0.520b	47.23de	23.82c	71.05cd
T_6 (NPK briquette, 104kg N/ha	1.25b	0.533b	61.31b	27.58b	88.89b
T_7 (NPK briquette, 104kg N/ha)	1.18bcd	0.517b	51.34cd	23.88c	75.21c
T_8 (NPK briquette, 52kg N/ha)	1.05ef	0.537b	41.92ef	22.84c	64.76d
CV (%)	3.62	5.87	6.49	0.569	1.282
SE (±)	0.0246	0.0185	2.016	0.931	2.093

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 (ANR) indicates the absorption efficiency of applied N. The ANR by BRRI dhan46 has been presented in (Table 4). Mean apparent recovery of N by BRRI dhan46 ranged from 18.50 to 63.20% in different treatments. The maximum value of ANR was obtained with the application of USG in T_3 (USG,104kg N/ha) followed by T_4 (USG,78kg N/ha) and the minimum value was found in T_8 (NPK briquette, 52kgN/ha). 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 under continuous flooding condition.

3.7. 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 response of rice plant in terms of grain yield to N fertilizer. The NUE varied from 9.31 to 22.17 kg grain increase per kg N applied among the treatments (Table 4).The highest value of NUE (22.17 kg grain increase per kg N applied) was obtained in T_3 (USG, 104kg N/ha) followed by T_4 (14.67 kg grain increase per kg N applied). The lowest NUE (9.31 kg grain increase per kg N applied) was found in T_8 (NPK briquette, 52 kg N/ha). 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.

Table 4. Effect of N supplied from PU, USG, and NPK briquettes on apparent N recovery (%) and N use efficiency (NUE) of BRRI dhan46.

Treatments	Apparent N recovery (%)	N use efficiency
T_1 (Control)	-	-
T_2 (PU, 104kgN/ha)	26.80	12.83
T_3 (USG, 104kg N/ha)	63.20	22.17
T_4 (USG, 78kg N/ha)	38.60	14.67
T_5 (USG, 52kg N/ha)	30.60	10.97
T_6 (NPK briquette, 104kg N/ha	32.50	12.96
T_7 (NPK briquette, 104kg N/ha)	25.80	10.47
T_8 (NPK briquette, 52kg N/ha)	18.50	9.31

Figures in a column having common letters do not differ significantly at 5% level of significance.
NUE=Nitrogen use efficiency
%ANR=Apparent nitrogen recover

3.8. Economic analysis

The marginal-benefit cost ratio (MBCR) 0f BRRI dhan46 as influenced by PU, USG and NPK briquettes has been presented in (Table 5). MBCR is the ratio of marginal or added benefit and cost. To compare different fertilizer treatments with control, the following equation outlined by Rahah *et al.* (2007) was used:

$$\text{MBCR}=\frac{\text{Gross income of treatment}-\text{Gross income of control}}{\text{Gross cost of production (treatment)}-\text{Gross cost of production(Control)}}$$

The cost and return analysis of BRRI dhan46 shows that the highest marginal benefit cost ratio of 6.53 was obtained in T_3 (USG, 104kg N/ha), which was followed by T_2 (PU, 104kgN/ha), T_4 (USG, 78kg N/ha) and T_6 (NPK briquette, 104 kgN/ha) with the value of 4.83, 3.77 and 3.49, respectively. The gross margin was the maximum in T_2.Considering the benefit cost ratio, T_3 might be ranked first.

Table 5. Economic analysis of BRRI dhan46 as influenced by the application of PU, USG and NPK briquettes.

Treatment	Yield (kg/ha)		Gross return (Tk)	Added cost over control (Tk/ha)	Added benefit over control (Tk/ha)	Gross margin over control (Tk/ha)	MBCR (Over control)
	Grain	Straw					
Treatments	3522	3783	63755	-	-	-	-
T_1 (Control)	4857	5090	87318	9744	23543	18671	2.41
T_2 (PU, 104kgN/ha)	5828	6116	10481	12576	41059	34771	3.26
T_3 (USG, 104kg N/ha)	4666	5194	85329	8574	21574	15858	2.51
T_4 (USG, 78kg N/ha)	4091	4562	74852	7716	11097	5953	1.44
T_5 (USG, 52kg N/ha)	4870	5166	87848	13824	24093	17181	1.74
T_6 (NPK briquette, 104kg N/ha	4339	4625	78375	9276	14620	8436	1.58
T_7 (NPK briquette, 104kg N/ha)	4006	4276	72389	8184	8633	3177	1.05

4. Conclusions

The deep placement of N fertilizers has numerous benefits over broadcast application of PU and NPK briquettes. From the results of the present study it was observed that the deep placement of USG had better performances on grain and straw yields, nitrogen recovery and nitrogen use efficiency as compared to the broadcast application of PU and NPK briquettes. Based on grain yield and N use efficiency it can be concluded that application of N @ 104 kg/ha (80% of recommended N) as USG can be used for profitable cultivation of BRRI dhan46.

Conflict of interest

None to declare.

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