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Efficacy of Deep Placement of Nitrogen Fertilizers on N Use Efficiency and Yield of Boro Rice (cv. BRRI Dhan29)

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ABSTRACT

The efficiency of nitrogen (N) fertilizers in rice culture is low due to their losses in different ways. An experiment was, therefore, 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 N fertilizers on N use efficiency and yield of BRRI dhan29 under alternate wetting and drying (AWD) condition. The soil was silt loam in texture having pH 6.07, organic matter content 1.10%, total N 0.055%, available P 3.6 ppm, exchangeable K 0.22 me% and available S 11.76 ppm. The experiment was laid out in a randomized complete block design with three replications. There were eight treatment combinations including T1 (Control), T2 (PU, 130 kg N/ha), T3 (USG, 130 kg N/ha), T4 (USG, 104 kg N/ha), T5 (USG, 78 kg N/ha), T6 (NPK briquette, 129 kg N/ha) and T7 (NPK briquette, 102 kg/ha) and T8 (NPK briquette, 78 kg N/ha). All the treatments except T6, T7 and T8 received 25 kg P and 64 kg K /ha as TSP and MoP, respectively. Treatments T6, T7, T8 received NPK briquette fertilizer. Prilled urea (PU) was applied in three equal splits. Urea super granule (USG) and NPK briquettes were applied at 10 day after transplanting (DAT) and the briquettes were placed at 8-10 cm depth in the centre of four hills in alternate rows. The results demonstrate that all the yield components except 1000-grain weight responded significantly to the deep placement of N fertilizers in the form of USG and NPK briquette. The grain and straw yields of BRRI dhan29 were also influenced significantly due to deep placement of N fertilizers under AWD condition. The highest grain yield (6163 kg/ha) was recorded for T3 [USG, 130 kg N/ha] which was statistically similar with T4 (USG, 104 kg N/ha). The highest straw yield (6415 kg /ha) was also found in T3 [USG, 130 kg N/ha]. The lowest grain yield (3266 kg/ha) and straw yield (3637 kg/ha) were found in T1 (Control). The N uptake by BRRI dhan29, N use efficiency and apparent N recovery also showed significant response to the application of PU, USG and NPK briquettes. The maximum N use efficiency of 28.88% was noted in T5 followed by T4 with the value of 26.46% and the minimum value of 17.55% was observed in T2. The results revealed that the deep placement of N fertilizers accelerated the N uptake, N recovery and N use efficiency by BRRI dhan29. Based on grain yield and cost-benefit analysis, it can be concluded that application of 130 kg N/ha as USG is useful for the profitable cultivation of boro rice, BRRI dhan29.

Keywords:

Deep placement, N fertilizers, N use efficiency, BRRI dhan 29, Yield

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INTRODUCTION

Rice is the most important food crop in the developing countries of Asia, where population densities are very high and overall dietary levels are not adequate. In South and Southeast Asia, rainfed and irrigated transplanted rice occupy nearly two-thirds of the rice-growing area and produces more than 80% of the paddy rice (Savant, 1991). Nitrogen is the most limiting nutrient in crop production all over the world. Rice is grown in Bangladesh under diverse ecosystems including deep water, rainfed and irrigated conditions in three distinct seasons of boro, aman and aus. Among the above mentioned rice groups, transplanted boro rice holds the major share of production.

Irrigation regimes in wetland rice are diverse and can be customized by farmers to facilitate maximum water supply. Irrigation regimes include continuous flooding (CF), alternate wetting and drying (AWD), dry seeded rice, aerobic rice, partial submergence, sprinkler irrigation, etc. The AWD technique is recently introduced by IRRI for rice to reduce water consumption (Belder *et al.*, 2004). AWD is a technique by which rice crop can be produced with low amount of water. This method will reduce cost of production by using small amount of water. This method is essential for any developing country like Bangladesh. On the other hand, deep placement of USG effectively increases N use efficiency (31.7%) compared to conveniently applied prilled urea (Jaiswal and Singh, 2001). Deep placement of N fertilizers is the most effective method for reducing the loss of N in flood water and also minimizing the loss by different processes. 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.*, 1990a, c; Savant and Stangel, 1990; Jaiswal and Singh, 2001; Das et al., 2015). Although a large

number of researches have already been carried out in Bangladesh and foreign countries, the data on N use efficiency with alternate wetting and drying (AWD) method in rice are still lacking. Hence the present study was undertaken to see the effect of deep placement of N fertilizers on the yield and N use efficiency of BRR1 dhan29.

MATERIALS AND METHODS

Experimental site and soil

The experimental site is located at 24.75° N latitude and 90.5° E 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 the boro season of 2016. The soil was silt loam in texture having pH 6.07, organic matter content 1.10%, total N 0.055%, available P 3.6 ppm, exchangeable K 0.22 me% and available S 11.76 ppm. The main characteristics of the climate of the experimental area are inadequate rainfall associated with moderately low temperature during Kharif-1 season (16 October 2015 – 15 March 2016).

Treatments

There were altogether eight different treatments which include: **T₁**: Control, **T₂**: PU, 130 kg N ha⁻¹, **T₃**: USG (100%) = 130 kg ha⁻¹ (one 2.7 g + one 1.8 g briquette), **T₄**: USG (80%) = 104 kg ha⁻¹ (two 1.8 g briquettes), **T₅**: USG (60%) = 78 kg ha⁻¹ (one 2.7 g briquette), **T₆**: NPK (100%) = 129 kg ha⁻¹ (two 2.4 g + one 3.4g briquette), **T₇**: NPK (80%) = 102 kg ha⁻¹ (two 3.4 g briquettes), **T₈**: NPK (60%) = 78 kg ha⁻¹ (two 2.4 g briquettes).

Lay out of the experiment

The experiment was laid out in a randomized complete block design (RCBD), where the experimental site was divided into 3 blocks representing the replications to reduce the heterogenic effects of soil. There were altogether 8 treatment combinations. A total of 24 plots were prepared for the experiment and

the treatments were distributed to the unit plots in each block. The size of each plot was 5m x 4m and plots were separated from each other by ails. There was 1 m drain between the blocks that separated the blocks from each other.

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.

Fertilizer application

The fertilizers were applied as per treatment. All the treatments except T₁ received 25 kg P, 64 kg K and 20 kg S/ha as TSP, MoP and Gypsum, respectively. In T₆, T₇ and T₈ P and K were given from NPK briquettes. First split of PU, USG and NPK briquettes were applied after 9 days of transplanting. The second and third splits of piled urea were applied after 34 and 54 days of transplanting. The USG and NPK briquettes were placed at 8-10 cm depth between four hills at alternate rows.

Transplanting of seedlings

Seedlings were carefully uprooted from seedling nursery bed and transplanted in the plots on 6 February, 2016. Seedling to seedling spacing was 20 cm x 20 cm and line to line spacing was also 20 cm x 20 cm.

Intercultural operations

Irrigation and weeding were done as per requirement to provide and maintain the favorable condition for normal plant growth and development of crop.

Harvesting, threshing and weighing

The crop was harvested at maturity. From each plot, the area of 6m² 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 adjusted at 14% for grain. The straw yield was expressed as sun dry basis.

Determination of N from plant samples

Total N was determined by micro-Kjeldahl method where 1 g of oven dry ground sample was taken into micro-Kjeldahl flask to which 1.1 g catalyst mixture (K₂SO₄: CuSO₄.5H₂O: Se = 100:10:1), 2 mL 30% H₂O₂ and 3 mL H₂SO₄ were added. After swirling the flask, it was allowed to stand for about 30 minutes. Then the flask was heated (380°C) 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% H₃BO₃ solution and 5 drops of mixed indicator of bromocresol green (C₂₁H₁₄O₅Br₄S) and methyl red solution and the distillate was titrated with standard 0.01 N H₂SO₄ 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 H₂SO₄, B = Blank titration value (mL) of standard H₂SO₄, N = Strength of H₂SO₄, S = Weight of soil sample in g.

Nitrogen uptake

After the completion of chemical analysis, nitrogen contents were calculated. Nitrogen uptake was calculated by the following formula:

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

Apparent recovery of applied N (ANR)

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

$$\text{ANR (kg ha}^{-1}\text{)} = (\text{UN}_{+\text{N}} - \text{UN}_{0\text{N}}) / \text{FN}$$

Where, $\text{UN}_{+\text{N}}$ is total N uptake (kg with grain and straw), $\text{UN}_{0\text{N}}$ is the N uptake (kg ha^{-1}) in control, FN is the amount of N fertilizers applied (kg ha^{-1}).

Nitrogen use efficiency

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 efficiency N was calculated by the following formula:

$$\text{NUE} = (\text{GY}_{+\text{N}} - \text{GY}_{0\text{N}}) / \text{FN}$$

Where, $\text{GY}_{+\text{N}}$ = grain yield in treatment with N application, $\text{GY}_{0\text{N}}$ = grain yield in treatment without N application, FN = amount of fertilizer N applied (kg ha^{-1}).

Economic analysis

A partial budget was estimated. Marginal benefit cost ratio (MBCR) was used as a tool of partial budget analysis. Added cost and added benefit were calculated. Besides, the gross return was calculated on the basis of farm prices of rice grain and straw prevailed during the harvesting period. Marginal benefit cost ratio (MBCR) is the ratio of marginal or added benefit and cost. To compare different fertilizer treatments with control the following equation was used as outlined by Rahah et al. (2007).

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

Statistical analysis

All the data were statistically analyzed by F-test and the mean differences were adjudged by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez; 1984)

RESULTS AND DISCUSSION

Yield attributes

Plant height of BRR1 dhan29 responded positively to 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 69.37 to 89.30 cm across the treatments. The tallest plant of 89.30 cm

was recorded in T_6 [NPK briquette, 129 kg N/ha] which was identical to all other treatments except control. The shortest plant of 69.37 cm was recorded in T_1 (Control). The highest panicle length of 25 cm was recorded in T_3 [USG, 130 kg N/ha]. The second highest panicle length of 23.23 cm was found in T_4 [USG, 104 kg N ha^{-1}] which was statistically similar with T_2 [PU, 130 kg N/ha], T_5 [USG, 78 kg N/ha], T_6 [NPK briquette, 129 kg N/ha], and T_7 [NPK briquette, 102 kg N/ha]. The lowest panicle length of 18.00 cm was observed in T_1 . The maximum number of effective tillers hill^{-1} (12.33) was found in T_3 [USG, 130 kg N/ha]. Statistically similar effective tillers hill^{-1} was recorded in T_6 [NPK briquette, 129 kg N/ha], T_4 [USG, 104 Kg N/ha], T_2 [PU, 130 kg N ha^{-1}] and T_8 [NPK briquette, 78 kg N/ha] with the values of 12.33, 11.33, 11.00, 10.67, respectively. The minimum effective tillers hill^{-1} of 8.67 was observed in T_1 (Control). The number of grains panicle^{-1} varied from 69.33 to 121.00. The highest grains panicle^{-1} (121.00) was recorded in T_3 [USG, 130kg N/ha] which was identical to T_6 [NPK briquette, 129 kg N/ha] with the value of 118.33. The lowest grains panicle^{-1} (69.33) was recorded in T_1 (Control). The 1000-grain weight of BRR1 dhan29 varied insignificantly due to application of PU, USG and NPK briquettes (Table 1). The numerical difference in 1000-grain weight found in various treatments was quite low. The 1000-grain weight ranged from 32.66 g in T_7 [NPK briquette, 102 kg/ha] to 36.03 g in T_2 [PU, 130 kg N/ha]. Although all the treatments produced higher 1000-grain weight over control but the variation was insignificant. The results obtained from the present study are well corroborated with the findings of Islam *et al.* (2014) and Jahan *et al.* (2014) who demonstrated that yield attributes of rice were influenced by the application of urea briquette as compared to PU.

Grain yield

Significant response of the grain yield of BRR1 dhan29 to the deep placement of N fertilizers

was found as depicted in Table 2. The grain yield ranged from 3266 kg/ha to 6163 kg/ha across the treatments. The highest grain yield of 6163 kg/ha was recorded in T₃ [USG, 130kg N/ha) which was statistically similar with T₄ [USG, 104 kg ha⁻¹] and the lowest value was observed in T₁ (control). The grain yield obtained with the treatments T₂ [PU, 130 kg N ha⁻¹] and T₆ [NPK briquette, 129 kg ha⁻¹] was identical. The percent increase of grain yield over control ranged from 60.25 to 88.70%. The maximum grain yield increase (88.70%) over control was found in T₃ [USG, 130 kg N/ha] and the minimum increase (60.25%) was noted in T₈ (NPK briquette, 78 kg ha⁻¹) (Figure 4.1). Based on grain yield the treatments may be ranked in the order of T₃> T₄> T₆> T₂> T₅>T₇>T₈>T₁. USG performed better in

increasing grain yield of rice as compared to PU and NPK briquette. These results figure out the 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 in agreement 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 BRR1 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 deep placement of N fertilizers on the yield components of BRR1 dhan29

Treatments	Plant height (cm)	Panicle length (cm)	Effective tillers hill ⁻¹ (No.)	Grains Panicle ⁻¹ (No.)	1000-grain weight (g)
T ₁ (Control)	69.37b	18.10d	8.66c	69.33e	34.57
T ₂ (PU, 130 kg N ha ⁻¹)	84.53a	22.53bc	11.00ab	109.67d	36.03
T ₃ (USG, 130 kg N ha ⁻¹)	86.07a	25.00a	12.33a	121.00a	33.93
T ₄ (USG, 104 kg N ha ⁻¹)	85.40a	23.23b	11.33ab	115.33bc	34.77
T ₅ (USG, 78 kg N ha ⁻¹)	85.90a	22.30bc	10.00bc	112.00cd	35.47
T ₆ (NPK briquette, 129 kg ha ⁻¹)	89.30a	23.20b	12.33a	118.33ab	34.83
T ₇ (NPK briquette, 102 kg ha ⁻¹)	87.27a	22.07bc	9.33bc	115.00bcd	32.67
T ₈ (NPK briquette, 78 kg ha ⁻¹)	86.20a	21.30c	10.67abc	110.67cd	33.60
CV (%)	4.31	3.04	10.27	2.62	3.80
SE (±)	2.10	0.39	0.63	1.65	0.76

The figure(s) having common letter(s) in a column do not differ significantly at 5% level of significance. CV = Coefficient of variation; SE = Standard error of means.

Straw yield

Straw yield of BRR1 dhan29 responded significantly to different treatments under study. The highest straw yield (6415kg/ha) was found in T₃ [USG, 130 kg N/ha] which was identical to that obtained with T₄ [USG, 104 kg ha⁻¹] and T₆ [NPK briquette, 129 kg ha⁻¹] with the value of 5963 and 6075 kg/ha, respectively. The lowest straw yield (3637 kg /ha) was observed in T₁ (control). 53.78 to 76.38 % increases in straw yield over control was recorded due to

application of N either as broadcast or deep placed as depicted in Figure 4.1. Like the grain yield, the maximum straw yield increase (76.38%) over control was found in T₃ [USG, 130kg N/ha]. Based on straw yield the treatments may be ranked in order of T₃> T₆> T₄> T₂> T₅>T₇>T₈>T₁. The findings of the present study support the findings of Islam *et al.*, (2014) and Das *et al.* (2015) who reported that straw yield of boro rice was increased due to application of USG and NPK briquette.

Table 2: Grain and straw yields of BRRI dhan29 as influenced by the deep placement of N fertilizers under alternate wetting and drying (AWD) condition

Treatments	Grain yield (kg ha ⁻¹)	% increase over control	Straw yield (kg ha ⁻¹)	% increase over control
T ₁ (Control)	3266e	-	3637c	-
T ₂ (PU 130 kg N ha ⁻¹)	5548bc	69.87	5743b	57.90
T ₃ (USG, 130 kg N ha ⁻¹)	6163a	88.70	6415a	76.38
T ₄ (USG, 104 kg N ha ⁻¹)	6018a	84.26	5963ab	63.95
T ₅ (USG, 78 kg N ha ⁻¹)	5441c	66.59	5701b	56.75
T ₆ (NPK briquette, 129 kg ha ⁻¹)	5707b	74.74	6075ab	67.03
T ₇ (NPK briquette, 102 kg ha ⁻¹)	5407c	65.55	5872b	61.45
T ₈ (NPK briquette, 78 kg ha ⁻¹)	5234d	60.25	5593b	53.78
CV (%)	1.81	-	4.50	-
SE (±)	56.92	-	145.99	-

The figure(s) having common letter(s) in a column do not differ significantly at 5% level of significance. CV = Coefficient of variation; SE = Standard error of means.

Nitrogen content

Application of PU, USG and NPK briquette influenced the N content of both grain and straw of BRRI dhan29 significantly over control (Table 3). The grain N concentration ranged from 1 to 1.27%. The highest N content of 1.27% was recorded in T₄ (USG, 104 kg N ha⁻¹) and the lowest N content of 1% was observed in T₁ (Control). In case of straw, The N content ranged from 0.72% in T₃ [USG, 130 kg N/ha] to 0.50% in T₁ (Control). Due to the deep placement of N fertilizers, the N content in grain increased remarkably in T₄ [USG, 104 kg N/ha].

Nitrogen uptake

The data presented in Table 3 indicate that N uptake both by grain and straw of BRRI dhan29 was influenced significantly by the deep placement of N fertilizers in the form of USG and NPK briquettes under AWD condition. The highest N uptake in grain (70.20 kg /ha) was observed in T₄ [USG, 104 kg N/ha] and the lowest N uptake (32.73 kg/ha) was found in T₁ [Control]. On the other hand, the treatments T₃ [USG, 130 kg N/ha] and T₇ [NPK briquette, 102 kg ha⁻¹] were statistically similar in their effects on nitrogen uptake by grain. In straw, the N

uptake ranged from 18.20 kg /ha to 46.17 kg /ha whereas the maximum N uptake was recorded in T₃ [USG, 130 kg N/ha] and the minimum uptake in T₁ (Control). The total N uptake by BRRI dhan29 ranged from 50.97 to 110.87 kg/ha. The highest total N uptake was recorded in T₃ [USG, 130 kg N/ha] and the treatment T₄ [USG, 104 kg N/ha] gave the second highest total N uptake. On the other hand, treatments T₂ [PU, 130 kg N/ha] and T₇ [NPK briquette 102 Kg N/ha] gave statistically similar total N uptake. The total N uptake by BRRI dhan29 due to different treatments may be ranked in the order of T₃>T₄>T₆>T₇>T₂>T₅>T₈>T₁. The N uptake 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 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.

Apparent N recovery (ANR)

The apparent N recovery (ANR) indicates the absorption efficiency of applied N. The ANR by

BRR1 dhan29 has been presented in Table 3. Mean apparent recovery of N by BRR1 dhan29 ranged from 36.31 to 56.36% in different treatments. The maximum value of ANR (56.36%) was obtained with the application of USG in T₅ [USG, 78Kg N/ha) followed by T₄ [USG, 104 kg N/ha] with the value of (56.35%) and the minimum value (36.31%) was found in T₂ [PU, 130 kg N/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 N fertilizer under AWD condition. The results of the present study follows the similar trend as obtained by Jahan *et al.* (2014), Afroz *et al.* (2014) and Das *et al.* (2015).

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 added N fertilizer. The maximum value of NUE (28.88 kg grain increase per kg N applied) was obtained in T₅ [USG, 78 kg N/ha) followed by T₄ (26.46 kg grain increase per kg N applied), T₈ (25.23 Kg grain increase per kg N applied), T₃ (22.28 kg grain increase per kg N applied), T₇(20.99 kg grain increase per kg N applied) and T₆ (18.92 kg grain increase per kg N applied). The minimum NUE was found in T₂ (17.55 kg grain increased with 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. 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.

Table 3: Effect of PU, USG and NPK briquette on N content and uptake by BRR1 dhan29

Treatments	N content (%)		N uptake (kg/ha)			%ANR	NUE
	Grain	Straw	Grain	Straw	Total		
T ₁ (Control)	1.0c	0.50d	32.73c	18.20d	50.97d	-	-
T ₂ (PU 130 kg N ha ⁻¹)	1.15abc	0.60bc	63.77ab	34.40bc	98.17abc	36.31	17.55
T ₃ (USG, 130 kg N ha ⁻¹)	1.10abc	0.72a	69.80a	46.17a	110.87a	46.08	22.28
T ₄ (USG, 104 kg N ha ⁻¹)	1.27a	0.61bc	70.20a	36.67bc	109.57a	56.35	26.46
T ₅ (USG, 78 kg N ha ⁻¹)	1.17abc	0.55cd	63.47ab	31.43c	94.93bc	56.36	27.88
T ₆ (NPK briquette, 129 kg ha ⁻¹)	1.1abc	0.64b	62.73ab	38.90b	101.67ab	39.30	18.92
T ₇ (NPK briquette, 102 kg ha ⁻¹)	1.23ab	0.57bcd	66.70a	33.70bc	100.37abc	48.43	20.99
T ₈ (NPK briquette, 78 kg ha ⁻¹)	1.03bc	0.60bc	54.07b	33.50bc	87.60c	46.96	25.23
CV (%)	10.09	7.33	10.39	9.29	7.27	-	-
SE (±)	0.07	0.03	3.64	1.83	3.95	-	-

The figure(s) having common letter(s) in a column do not differ significantly at 5% level of significance. CV = Coefficient of variation; SE = Standard error of means.

Table 4: Economic analysis of BRR1 dhan29 as the 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					
T ₁	3266	3637	59733.75	-	-	-	-
T ₂	5548	5743	99403.25	11536	39669.5	28989.5	2.51
T ₃	6163	6415	110590.25	13720	50856.5	37136.5	2.70
T ₄	6018	5963	106558.25	12050	46924.5	34348.5	2.85
T ₅	5441	5701	97812	11432	38079	26647	2.33
T ₆	5707	6075	103047.25	15224	43313.5	28089.5	1.84
T ₇	5407	5872	98183	13712	38449.25	24737.25	1.80
T ₈	5234	5593	94608.75	12368	34875	22507	1.81

Economic analysis

The marginal-benefit cost ratio (MBCR) of BRR1 dhan29 as influenced by the deep placement of N fertilizers in the form of USG and NPK briquettes has been presented in Table 4. The MBCR is the ratio of marginal or added benefit and cost. To compare different N fertilizers treatments with control, the following equation outlined by Rahan *et al.* (2007) was used:

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

The cost and return analysis of BRR1 dhan29 shows that the highest marginal benefit-cost of 2.85 was obtained from T₄ [USG, 104 kg N/ha], which was followed by T₃ [USG, 130 kg N/ha], T₂ [PU, 130 kg N/ha] and T₅ [USG, 78 kg N/ha] with the value of 2.70, 2.51 and 2.33, respectively. The gross margin was the maximum in T₃ followed by T₄, T₆, T₂ and T₇. Considering the benefit-cost ratio, T₄ might be ranked the first.

CONCLUSION

The treatment T₃ [USG, 130 kg N/ha] produced the highest grain yield of BRR1 dhan29 which was statistically similar with T₄ [USG, 104 kg/ha]. However, the T₄ produced the highest N use efficiency. This reveals that the deep

placement of N fertilizer in the form of USG under AWD condition enhanced the N use efficiency. As a result, the grain yield of BRR1 dhan29 was increased to a greater extent. Therefore, 104 kg N/ha USG can be recommended for successful cultivation of Boro rice for the efficient use of nitrogen and irrigation water.

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