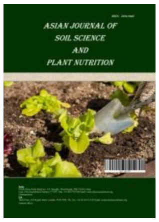

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Effects of Prilled Urea, Urea Briquettes and NPK Briquettes on the Growth, Yield and Nitrogen use Efficiency of BRRI Dhan48

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nitrogen is one of the most deficient plant nutrients in Bangladesh soils. The use nitrogenous fertilizer especially urea is a commonly used fertilizer for rice production but its efficiency very low about 30-40% under traditional broadcast method A field experiment was carried out in the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during Aus rice growing season of 2014 to investigate the effects of prilled urea, urea briquettes and NPK briquettes on the growth, yield, and nitrogen use efficiency of BRRI dhan48. There were six treatments as T_1 [check ($N_0P_{16}K_{42}$], T_2 [Urea briquette (one-3.4 g) ($N_{52}P_{16}K_{42}$)], T_3 (Urea briquette (one-2.7 g ($N_{78}P_{16}K_{42}$)], T_4 [NPK briquette (one-3.4g)($N_{51}P_{13}K_{32}$], T_5 [Prilled urea ($N_{78}P_{16}K_{42}$)] and T_6 [NPK briquettes(two-2.4 g briquettes ($N_{78}P_{15}K_{42}$)]. The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments and four replications. Prilled urea was applied in two equal splits application; at 8 days after transplanting (DAT) and the second dose after 38 DAT, while for urea briquettes and NPK briquettes were deep placed (8-10 cm depth) at 8 DAT between four hills at alternate rows. Water samples were collected for every 7 consecutive days and analyzed for NH_4-N. The results showed that the NH_4-N concentration in floodwater reached to maximum on day 2 in PU treated plots and then decreased with time, while the urea briquettes

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and NPK briquettes treated plots slowly produced NH_4-N over the growth period. The highest grain yield of 4.75 t ha^{-1} (69% over control) was obtained in the treatment T_3 [Urea briquette (one-2.7g) ($N_{78}P_{16}K_{42}$)]. The treatment T_3 also produced the highest straw yield of 5.49 t ha^{-1}. The maximum apparent N recovery and the maximum N use efficiency were found in the treatment T_4 [NPK briquette (one-3.4g) ($N_{51}P_{13}K_{32}$)]. It appeared that the deep placement of urea briquettes and NPK briquettes reduced N-losses and enhanced the recovery of applied N as well as N use efficiency in comparison with PU application.

Keywords: Prilled urea; urea briquette; NPK briquette; rice yield; nitrogen use efficiency; NH4-N.

1. INTRODUCTION

Rice is a dominant cereal crop in many south East Asian countries including Bangladesh, India, China, Japan and Vietnam. In Bangladesh, rice is grown in three seasons per year in about 11.89 million hectares of land, which covers almost78% of the agricultural land [1]. Fertilizers an essential input for boosting rice yield and farmers are using different chemical fertilizers to supply nitrogen, phosphorus, potassium, sulphur and zinc [2]. But the grain yield per hectare is lower compared to other major rice growing countries of the world. Every year 2- 3% increase in rice production must be maintained to ensure the self-sufficiency in rice in Bangladesh [3]. Proper amount and method of fertilizer application is one of the effective means for maximizing yield of a crop. Nitrogen fertilizer is the most important nutrient input for rice production and plays an important role in increasing rice yield because of the close relationship between rice yield and plant N uptake [4]. Farmers of Bangladesh generally use PU in rice field (about 2.46 million MT annually and more than 50% of the total demand of urea is imported for which the Government had been spending a huge amount of foreign currency each year [5]. In rice cultivation Nitrogen (N), Phosphorus (P) and Potassium (K) fertilizers are applied to the soil as conventional broadcast method during transplanting as a result a significant part of those applied fertilizers goes beyond plant uptake by volatilization, denitrification, run-off, leaching and fixation. This situation results in lower rice yield and ultimately reduces efficiency of applied urea fertilizer [6].

A number of strategies have been put forward to increase the efficiency of applied fertilizers through proper timing, rate, deep placement and modified forms of fertilizers. Among the strategies, deep placement of fertilizer is one of the most effective methods in reducing loss of nitrogen through volatilization loss and as nitrous oxide from the rice fields [7,8]. In deep placement method, large granules or briquettes of fertilizers are placed at 8-10 cm depth of the soil surface which results in slow and steady supply of nitrogen throughout the growth period of the rice. Urea deep placement (UDP) reduces N losses by up to 50% when compared with the conventional broadcast application of prilled urea [7,6]. In many paddy soils, more nitrogen is recovered from the deep placed fertilizer compared to broadcast PU (Yan et.al. 2008) [7]. Deep placement of urea briquettes for rice crop saves 30–35% urea compared to broadcast urea in splits and increases yield by 15–20 % [2,9], with higher N use efficiency (kg grain per kg N) [10,11].

The use of urea prilled briquettes and NPK briquettes has often been advocated to minimize nitrogen losses in irrigated rice ecosystem. Although some trials with urea briquette and NPK briquette application in rice have been carried out in Bangladesh, but the quantitative data on deep placement of urea briquette and NPK briquette for BRRI dhan48 rice cultivar is limited. Considering the above facts, the experiment was carried out to evaluate the benefits of deep placement of urea briquettes and NPK briquettes over broadcast application of PU in terms of growth, yield, N uptake, N recovery and N use efficiency of BRRI dhan48.

2. MATERIALS AND METHODS

2.1 Experimental Setup

The experiment was conducted during the Aus rice growing season (May to August) of 2014 to evaluate the effects of PU, urea briquettes and NPK briquettes on the growth, yield, and nitrogen use efficiency of BRRI dhan48. The PU, urea briquettes and NPK briquettes were purchased from the local market of Mymensingh district. The soil of the experimental site belongs to the Sonatala series under the Agro Ecological Zone (AEZ) of Old Brahmaputra Floodplain. Texturally the soil was silt loam having pH 6.3, organic matter content 1.90%, total N content 0.13%, $NaHCO_3$ available P 3.18 ppm, K 0.08 me% and $CaCl_2$ extractable S 10.7 ppm. The experiment was laid out in a Randomized Complete Block Design (RCBD) with six treatments and four replications. The treatments were T_1 [Check ($N_0P_{16}K_{42}$)], T_2 [Urea briquette (one-1.8g) ($N_{52}P_{16}K_{42}$)], T_3 [Urea briquette (one-2.7g) ($N_{78}P_{16}K_{42}$)], T_4 [NPK briquette (one-3.4g) ($N_{51}P_{13}K_{32}$)], T_5 [PU ($N_{78}P_{16}K_{42}$)] and T_6 [NPK, two-2.4 g briquettes ($N_{78}P_{16}K_{42}$)]. All the treatments received 16 kg P and 42 kg K ha^{-1} from Triple Super Phosphate (TSP) and Muriate of Potash (MoP), respectively except T_4 and T_6. Sulphur at 20 kg ha^{-1} was applied to all plots as basal dose from gypsum. BRRI dhan48, a high yielding variety of Aus rice was used as a test crop. Thirty-day old rice seedlings were transplanted in the plots maintaining a spacing of 20 cm x 20 cm. Prilled Urea was supplied in two equal splits; the first dose was applied at 8 days after transplanting (DAT) and the second dose after 30 days of the first split. Urea briquettes and NPK briquettes were applied at 8 DAT and were placed at 8-10 cm depth within four hills at alternate rows. Intercultural operations (viz. irrigation, weeding, pest control etc.) were done as and when necessary.

2.2 Crop Harvest and Chemical Analysis

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, effective tillers $hill^{-1}$, panicle length, filled grains $panicle^{-1}$ and 1000-grain weight were recorded. The N content in rice grain and straw was determined by Semi-micro Kjeldahl method [12]. 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 Duncan's New Multiple Range Test (DMRT) [13].

The apparent N recovery was calculated by the following formula-

$$ANR\ (kg\ ha^{-1}) = (UN{+}N - UN0N)/FN$$

Where, UN+N is total N uptake (kg ha^{-1}) with grain and straw; UN0N is the N uptake (kg ha-1) in control; FN is amount of fertilizer N applied (kg ha^{-1})

The nitrogen use efficiency 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^{-1})

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Growth and yield attributes parameters of BRRI dhan48G

The tallest plant of 84.5 cm was found in treatment T_6 which was identical to treatment T_4 with the value of 82.6 cm (Table 1). The shortest plant of 70.6 cm was observed in T_1 treatment. These results are in agreement with Halder [14] who also found highest plant height of BR27 rice with the application of NPK briquette ($N_{78}P_{16}K_{42}$). The highest number of effective tillers $hill^{-1}$ of 12.9 was found in treatment T_6 which was statistically similar to all other treatments except T_1. The treatments may be ranked in the order of $T_6>T_4>T_3>T_2>T_5>T_1$ in terms of effective tiller $hill^{-1}$. The tallest panicle (22.3 cm) was found in treatment T_2 which was identical with T_6 treatment and the shortest panicle (20.3 cm) was observed in T_1 treatment. The treatments T_3 and T_4 were statistically similar for panicle length. These results are in agreement with Afroz et al. [15] who observed an increase in panicle length with the application of urea briquettes compared to PU. The number of filled grains $panicle^{-1}$ varied from 49.7 in T_1 (Check) treatment to 60.4 in T_3 treatment. The treatments T_3 and T_6 were statistically identical in number of filled grains $panicle^{-1}$. These results support the findings Islam et al. [16] observed that significantly higher number of filled grains $panicle^{-1}$ was in NPK briquettes and urea briquettes treated plots. The 1000-grain weight of BRRI dhan48 varied significantly due to application of PU, urea briquettes and NPK briquettes. The 1000-grain weight ranged from 22.4 g in treatment T_1 to 23.8 g in T_3 treatment. The treatments T_4 and T_6 are statistically identical to each other. These results are in consistent with Islam et al. [16] who also observed insignificant effect of PU, urea briquettes and NPK briquettes on 1000-grain weight of rice.

3.1.2 Grain yield

Effect of PU, urea briquettes and NPK briquette showed a positive effect on grain yield of BRRI dhan48 (Table 2). The highest grain yield was found in treatment T_3 which was statistically identical to that found in treatment T_6. The treatments T_4 and T_6 were also statistically identical. The grain yields obtained from different treatments may be ranked in the order of $T_3>T_6>T_4>T_2>T_5>T_1$. The increase in grain yield over control ranged from 28.5 to 69.0% where the highest increase was obtained in T_3 treatment where 78 kg N ha^{-1} was applied as urea briquette. Islam et al. [16] carried out an experiment on the effectiveness of urea briquette and NPK briquette on rice in tidal flooded soil condition. They found that NPK briquettes and urea briquettes treated plot produced statistically similar grain yield. Durguda et al. [17] also reported that higher grain yield in rice with Di-Ammonium Phosphate (DAP) briquettes compared to urea. Another study also reported that urea briquettes increased grain yield (up to 5 to 20%) of rice over split application of urea [18]. Grain yield, recovery efficiency of N, agronomic efficiency of N and partial factor productivity of N significantly increased with optimizing the application location of N [19].

3.1.3 Straw yield

The straw yield of BRRI dahn48 significantly increased due to the application of PU, urea briquettes and NPK briquette fertilizers (Table 2). The highest straw yield of 5.49 t ha^{-1} was obtained in T_3 treatment and the lowest yield of 3.31 t ha^{-1} was found in T_1 treatment. The highest straw yield found in T_3 treatment was statistically identical to those of T_6 and T_4 treatments. The straw yield found in T_2 was statistically identical to T_5. The treatments were ranked in the order of $T_3> T_6> T_4> T_2> T_5> T_1$ for straw yield of BRRI dhan48. Urea briquettes and NPK briquette fertilizers performed better in producing straw yields as compared to PU. Regarding the percent increase of straw yield, maximum straw yield increase (65.9%) was noted in T_3 treatment and the minimum value (31.7%) was found in T_5 treatment. These results support the findings of Khan et al. (2007) who reported that the application of NPK and organic manures significantly increased straw yield of rice. Urea briquettes also significantly improved straw yield of rice and reduced volatilization loss of ammonia relative to the application of PU [20].

3.1.4 Nitrogen content in grain and straw

The N content in grain and straw of BRRI dhan48 was influenced significantly by the application of PU, urea briquettes and NPK briquettes (Table 3). The highest N content of 1.428% was observed in T_3 treatment and the lowest N content of 1.113% was noted in T_1 treatment. The N content in the straw ranged from 0.402% in T_1 treatment to 0.655% in T_3 treatment. Application of chemical fertilizers increased the N content in rice grain markedly in T_3 treatment. The results revealed that N content in rice grain was higher than that of straw. A significant increase in N content in rice grain and straw due to the application of urea briquette has been reported by many investigators [15,7,21].

3.1.5 Nitrogen uptake by grain and straw

Results in Table 3 indicate that the N uptake both by grain and straw of BRRI dhan48 varied significantly due to application of PU, urea briquettes and NPK briquettes. The N uptake by grain ranged from 31.34 to 67.69 kg ha^{-1} and that by straw from 13.34 to 36.20 kg ha^{-1}. The highest N uptake by grain (67.69 kg ha^{-1}) and by straw (36.20 kg ha^{-1}) was recorded in T_3 treatment and the lowest of 31.34 kg ha^{-1} by grain and 13.34 kg ha^{-1} by straw in T_1 treatment. The total N uptake both by grain and straw was influenced significantly by different treatments (Table 3). The highest total N uptake (103.9 Kg ha^{-1}) was observed in T_3 treatment and the lowest value (44.68 Kg ha^{-1}) was found in T_1 treatment. The highest total N uptake by rice with deep placement of urea briquettes also reported by Afroz et al. [15] and Jahan et al. [22]. Recovery efficiency of N, agronomic efficiency of N and partial factor productivity of N significantly increased with optimizing the location of application of N [19].

3.1.6 Apparent N recovery

The apparent N recovery by BRRI dhan48 rice is presented in Table 4. Mean apparent recovery of N by rice ranges from 27.6% to 76.8% in different treatments. The maximum value of apparent N recovery was obtained with the application of NPK briquette ($N_{51}P_{13}K_{32}$) in T_4 treatment followed by T_3, T_6 and T_2 treatments. The minimum value was found in T_5 treatment. The results clearly indicate that the deep placement of urea briquettes and NPK briquettes increased the recovery of applied N compared to broadcast application of N fertilizer. The reasons for high recovery of applied N in urea briquettes and NPK briquettes treated plots could be the deep placement of urea briquettes and NPK briquettes in rice field that resulted in continuous supply of available N throughout the growth period of rice, which ultimately gave the maximum N uptake by rice.

Table 1. Effects of PU, urea briquettes and NPK briquettes on the growth and yield components of BRRI dhan48 rice cultivar

Treatments	Plant height (cm)	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Grains panicle^{-1} (No.)	1000-grain weight (g)
T_1	70.6c	9.0b	20.3c	49.7b	22.4c
T_2	81.0ab	11.3a	22.3a	54.6ab	22.9bc
T_3	81.1ab	12.1a	21.7ab	60.4a	23.8a
T_4	82.6a	12.4a	22.1ab	57.7ab	23.4ab
T_5	77.5b	11.0a	21.0bc	57.2ab	23.2b
T_6	84.5a	12.9a	22.2a	60.2a	23.5ab
CV (%)	3.41	10.89	3.14	9.06	2.16
SE (±)	1.354	0.6227	0.3390	2.5655	0.2525
Significance level	**	**	**	*	**

Figures in a column having common letters do not differ significantly at 5% level of significance; CV (%) = Coefficient of variation; SE = Standard error of means; = P<0.05; * * = P<0.01; NS = Not significant*

Table 2. Effects of PU, Urea briquette and NPK briquettes on the grain and straw yields of BRRI dhan48

Treatments	Grain yield (t ha^{-1})	% Increase over control	Straw yield (t ha^{-1})	% Increase over control
T_1	2.81d		3.31d	
T_2	3.67c	30.6	4.65bc	40.5
T_3	4.75a	69.0	5.49a	65.9
T_4	4.36b	55.2	5.18ab	56.5
T_5	3.61c	28.5	4.36c	31.7
T_6	4.63ab	64.8	5.40a	63.1
CV (%)	5.80		9.56	
SE (±)	0.115		0.226	
Significance level	**		**	

*Figures in a column having common letters do not differ significantly at 5% level of significance; CV (%) = Coefficient of variation; SE = Standard error of means; ** = P<0.01*

Table 3. Effects of PU, urea briquettes and NPK briquettes on N content and uptake of BRRI dhan48

Treatments	N content (%)		N uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1	1.113b	0.402c	31.34e	13.34c	44.68d
T_2	1.331ab	0.577ab	48.87cd	27.14b	76.01b
T_3	1.428a	0.655a	67.69a	36.20a	103.89a
T_4	1.310ab	0.515bc	57.31bc	26.54b	83.86b
T_5	1.239ab	0.493bc	44.74d	21.50b	66.23c
T_6	1.411a	0.650a	65.30ab	35.04a	100.34a
CV (%)	11.05	14.42	10.72	16.83	7.32
SE (±)	0.0721	0.0396	2.8165	2.2410	2.8970
Significance level	*	**	**	**	**

*Figures in a column having common letters do not differ significantly at 5% level of significance; CV (%) = Coefficient of variation; SE = Standard error of means; * = P<0.05; ** = P<0.01*

Table 4. Effects of PU, urea briquettes and NPK briquettes on apparent N recovery and nitrogen use efficiency of BRRI dhan48

Treatment	N applied (kg ha^{-1})	Grain yield (kg ha^{-1})	Total N uptake (kg ha^{-1})	ANR (%)	NUE (kg grain per kg N applied)
T_1	0	2810d	44.68d		
T_2	52	3670c	76.01b	60.3	16.5
T_3	78	4750a	103.89a	75.9	24.9
T_4	51	4360b	83.86b	76.8	30.4
T_5	78	3610c	66.23c	27.6	10.3
T_6	78	4630ab	100.34a	71.4	23.3

% ANR = Apparent nitrogen recovery; NUE = Nitrogen use efficiency

3.1.7 Nitrogen use efficiency

Nitrogen use efficiency (NUE) represents the response of rice plant in terms of grain yield to N fertilizer. The range of NUE varied from 10.3 to 30.4 kg grain per kg N applied (Table 4). The highest value of NUE (30.4 kg grain increase per kg N applied) was obtained in T_4 treatment followed by T_3 (24.9 kg grain increase per kg N applied), T_6 (23.3 kg grain increase per kg N applied), T_2 (16.5 kg grain increase per kg N applied) treatments and the lowest value (10.3 kg grain increase per kg N applied) was found in T_5 treatment. These results indicate that application of urea briquettes and NPK briquettes in rice field decreases the losses of N that leads to efficient uptake and utilization of applied N by rice. These results support the findings of Jahan et al. [22] who found increased N use efficiency by the application of urea briquettes alone or in combination with poultry manure. Islam et al. [16] also reported enhanced N use efficiency by the deep placement of NPK fertilizers.

3.2 Discussion

Urea fertilizers are being used mainly by the farmers of Bangladesh as the main source of nitrogen. Generally, urea is applied as broadcast method. But, the efficiency of applied N from urea fertilizer is very low which is attributed to losses like volatilization, denitrification, leaching and surface run-off. These losses can be reduced by management practices deep placement of N fertilizers and proper water management practices. Among those, deep placement of fertilizers (urea briquette and NPK briquette) into the anaerobic soil zone is an effective method to reduce loss of N [19]. The present study was conducted to evaluate the effects of deep placement of N fertilizers and broadcast application of PU on yield, nutrient uptake, and N use efficiency of BRRI dhan48. Growth and yield contributing characters like plant height, effective tillers hill^{-1}, panicle length, filled grains panicle$^{-1,}$ 1000 grain weight were influenced by different treatments. The tallest plant of 84.5cm was found in T_6 which was identical to T_4 with the value of 82.6 cm. The shortest plant of 70.6 cm was observed in treatment T_1. The highest number of effective tillers hill^{-1} of 12.9 was found in treatment T_6 which was statistically similar to all other treatments except T_1. The highest number of grains panicle^{-1}was found in T_3 which was identical with T_6 and the lowest number of grains panicle^{-1} (49.7) was found in T_1(Check) treatment. The maximum 1000-grain weight was found in T_3 which was statistically similar to T_4 and T_6. The grain yield of BRRI dhan48 has been significantly increased due to the deep placement of N fertilizers. The highest grain yield was recorded for T_3 [Urea briquettes, $N_{78}P_{16}K_{42}$] which was superior to broadcast application of PU treatment T_5 (78 kg N ha^{-1} as PU). These results indicate positive effects of deep placement of N fertilizers on rice yield. The increase in rice yield as observed in the present study is due to the continuous supply of nitrogen from urea briquettes and NPK briquettes throughout the growing period of rice and due to minimum loss of nitrogen. These findings are well corroborated with the Islam et al. [16], Afroz et al. [15], Huda et al. [7] those who observed increased rice yield due to application of urea briquettes and NPK briquettes. The N uptake and recovery of applied N by rice increased when nitrogen was deep placed in the form of urea briquette and NPK briquette. The highest N uptake and recovery of applied N by rice held with the deep placement of urea briquette and NPK briquette whereas the lowest uptake took place with the broadcast application of N in the form of PU. Accordingly, the maximum N use efficiency was also obtained from the deep placement of NPK briquette and urea briquette. These results clearly indicate that the deep placement of urea briquette and NPK briquette decreases the loss of N, resulting increased grain yield of rice and higher N use efficiency compared to broadcast application of N in the form of PU.

4. CONCLUSION

Deep placement of nitrogen fertilizers in the form of urea briquette or NPK briquette minimizes N losses and enhances N use efficiency. It also improves the growth and yield of rice. Application of urea briquettes and NPK briquettes showed better performance in comparison with broadcast application of PU. The highest grain and straw yields were found in the treatment consisting of urea briquette ($N_{78}P_{16}K_{42}$). Nitrogen recovery and nitrogen use efficiency were much higher when N was applied as NPK briquette ($N_{51}P_{13}K_{32}$). Hence, application of urea briquette and NPK briquette fertilizers can be suggested for achieving sustainable yield of BRRI dhan48 with a minimum loss of NPK.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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