Enhancing Yield and Nitrogen Utilization of Boro Rice with Urea Super Granules

ABSTRACT

A field experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during *boro* season to assess the comparative performance of prilled urea (PU) and urea super granule (USG) on the growth, yield, and nitrogen uptake of BRRI dhan29. The experiment was laid out in a randomized complete block design with three replications. The treatment combinations were T_1: Control, T_2: PU at 7 days after transplanting (DAT)+27 DAT+47 DAT, T_3: PU at 10 DAT+30 DAT+50 DAT, T_4: PU at 15 DAT+35 DAT+55 DAT, T_5: USG at transplanting, T_6: USG at 7 DAT, T_7: USG at 10 DAT and T_8: USG at 10 DAT+30 DAT where PU and USG were applied @ 216 kg N ha^{-1}. PU was applied as surface broadcasting whereas USG was placed at 6-8 cm depth by hand between four hills at every alternate row. The results revealed that all the treatments showed better performances than control (T1). Results found that yield components, yield, and nitrogen uptake of BRRI dhan29 responded significantly to deep placement of USG than PU. Treatment T_6 (USG at 7 DAT) produced the highest grain and straw yields of 6.56 t ha^{-1} and 6.95 t ha^{-1} respectively. Treatment T_6 (USG at 7 DAT) also showed the highest grain yield increase (57.16%) and straw yield increase (52.37%) over control. The highest grain, straw, and total N uptake of 87.28, 32.71 and 120 kg ha^{-1} respectively were obtained in the treatment T_6 (USG at 7 DAT). The overall results clearly indicate that deep placement of USG at 7 DAT in rice field increases rice yield and efficient uptake of the applied N. So, treatment T_6 (USG at 7 DAT) could be recommended as best treatment for reducing N losses, conserving environment and improving sustainable production of rice.

Keywords: Urea super granule; prilled urea; yield; nutrient uptake; rice

1. INTRODUCTION

"Agriculture is one of the most important sectors in Bangladesh, which contributes 13.61% of the national gross domestic product (GDP), and the rice sub-sector alone contributes about 70% of the total agricultural GDP" [1,2]. "Boro rice covers about 41.7% of the total rice area and contributes 53.12% of total rice production in Bangladesh" [3]. "In recent years, the use of chemical fertilizer has been rapidly increasing to meet the continuously growing demands of increased yield from the existing land. Excessive nitrogen (N) fertilization is one of the major concerns in sustainable agriculture because it reduces N use efficiency and increases N release to the environment, resulting in pollution of the atmosphere and water systems" [4]. Therefore, it's important to focus on minimizing the cost without compromising sustainable production.

"Nitrogen is one of the major essential plant nutrients which can contribute to the increment of rice production to a greater extent. N fertilizer plays an important role in irrigated rice cultivation. In Bangladesh, the most widely used form of N is prilled urea (PU), but its efficiency is less than 50% in most crops" [5]. "Farmers apply PU in rice fields as a source of nitrogen through surface broadcasting. The efficiency of PU in rice culture is reported as only 25-30% and the rest 70-75%, is lost through different processes" [6]. "A large amount of applied N is being lost through ammonia (NH_3) volatilization, leaching, denitrification, and surface runoff" [7]. "Various studies have shown that deep-placement fertilization can be an effective alternative to broadcast fertilization" [8,9,10]. "Deep placement of N fertilizers into the anaerobic soil zone is an efficient method to minimize volatilization loss of applied nitrogen" [11]. "Denitrification losses can also be reduced by the deep placement of nitrogen fertilizer" [12]. "Deep placement of urea in the form of urea super granule (USG) has been reported to increase nitrogen use efficiency by limiting N transformations and losses" [9,13]. "The nature and properties of USG are similar to that of PU, but its granule size is bigger and condensed with some conditions for slow hydrolysis. Deep placement of USG minimizes the concentration of NH_4^+-N in floodwater compared to broadcast application of PU. USG can save 30-50% more nitrogen than PU due to its increased absorption rate, improved soil health, and ultimately increased N uptake and rice yield" [13,14,15]. "It has been shown that deep placement of USG can also be used to improve nitrogen use efficiency and increase grain yields in the rice cropping system" [16]. Application of USG can efficiently reduce the emission of greenhouse gases and water pollution [17]. "Recent research in Bangladesh reported 20% higher rice yields and positive net economic benefits from the deep placement of USG compared to the broadcast application of PU" [13,18]. "Application of USG enhances water management and line transplanting, thus simplifying weeding and pest control" [17]. "It has been reported that 1% increase in adoption of USG contributes to a significant increase in farm productivity when other factors remain the same" [17]. In Bangladesh, a lack of effective application methods strongly influences farmers decisions to adopt USG-based N management. Although a good number of studies have already been carried out in Bangladesh on N management of rice, there is a gap in data on deep placement of N fertilizers for maximizing rice yield. Considering the above facts, the present study was undertaken to study the comparative performance of PU and USG on the yield components, yield, and N uptake of boro rice (cv. BRRI dhan29).

2. MATERIAL AND METHODS

The experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh, during the boro (winter) season. The experimental site is located at 24.75°N latitude and 90.5°S longitude at a mean elevation of 18m above the sea level belonging to Non-calcareous Dark Gray Floodplain Soils under the Old Brahmaputra Floodplain agro-ecological region [19]. The climate is sub-tropical with distinct seasonal variations. The land is moderately well-drained with sufficient sunshine. The physico-chemical properties of initial soil samples have been presented in Table 1.

Table 1: Physicochemical properties of soil with their methods of determination

Soil Properties	Values	Method of Determination
% Sand	21	Hydrometer method [20]
% Silt	63	
% Clay	16	
Textural class	Silt loam	
Soil pH	6.09	Glass electrode pH meter method

		[21]
Organic matter (%)	1.61	Wet oxidation method [22]
Total N (%)	0.117	Micro-Kjeldahl method [23]
Available P (mg kg^{-1})	5.19	Olsen method [24]
Exchangeable K (meq %)	0.092	NH_4OAc (1N) extraction method [25]
Available S (mg kg^{-1})	9.52	$CaCl_2$ turbidity method [26]

There were eight treatment combinations such as T1: Control (no PU or USG), T2: PU at 7 DAT+27 DAT+47 DAT, T3: PU at 10 DAT+30 DAT+50 DAT, T4: PU at 15 DAT+35 DAT+55 DAT, T5: USG at transplanting, T6: USG at 7 DAT, T7: USG at 10 DAT and T8: USG at 10 DAT+30 DAT where PU and USG were applied @ 216 kg N ha-1. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each block was subdivided into eight plots. The treatments were randomly distributed to the unit plots in each block. The total number of plots was 24 (8 x 3). The unit plot size was 4m x 2.5m. Block to block and plot to plot distances were maintained as 1.0 m and 0.5 m, respectively. There were 0.5 m drains between the blocks. The treatments were randomly distributed to each block.

The land was prepared by ploughing and cross ploughing with power tiller followed by laddering. All kinds of weeds and stubbles were removed from the field during final land preparation. BRRI dhan29 was used for this experiment. Thirty-five-day old seedlings of BRRI dhan29 were carefully uprooted from the seedbed and transplanted to the experimental plots. Three seedlings were placed in each hill, maintaining a spacing of 10cm× 10cm.

Each treatment received P, K, S and Zn as basal doses at the rate of 20, 65, 18 and 2 kg ha^{-1} respectively, in the form of triple super phosphate (TSP), muriate of potash (MoP), gypsum, and zinc oxide following the Fertilizer Recommendation Guide [27]. Prilled urea was applied in three splits at different days in the T2, T3 and T4 experimental plots. Urea super granule (USG) was applied at different days at T5, T6, T7 and T8 experimental plots. One USG of 1.8 g was placed at 8-10 cm depth between four hills at alternate rows by hand. Different intercultural operations, such as irrigation, weeding, and pest control etc., were done as and when necessary.

The crop was harvested at full maturity. Data on growth and yield contributing characteristics of rice, such as plant height, number of effective tillers $hill^{-1}$, panicle length, number of filled grains $panicle^{-1}$ and thousand grain weights were recorded. Grain and straw yields were recorded on the basis of 14% moisture content.

After sun drying, straw and grain samples were kept in an oven at 70+2ºC for about 72 hours. Later, samples were ground by a grinding mill. The ground samples were kept in paper bags and stored in a dessicator for further use. The prepared samples were analyzed for N concentration following the standard method [23]. The grain and straw N uptake were calculated from the N content and yield using the following formula;

$$NU = (NC \times Y)/100$$

Where, NU= nitrogen uptake (kg ha^{-1}), NC= nitrogen concentration (%), and Y= yield (kg ha^{-1}).

All data were statistically analyzed to get the level of significance using the MSTAT–computer package program [28], and the mean differences were ranked by Duncan's New Multiple Range Test (DMRT) at the 5% level of probability [29].

3. RESULTS AND DISCUSSION

All the yield contributing characteristics of BRRI dhan29 were significantly influenced by different nitrogen fertilizer applications compared to the control (Table 2). All the doses of urea super granule (USG) produced taller plants than the respective doses of prilled urea (PU). The tallest plant of 91 cm was found in treatment T6 (USG at 7 DAT), whereas the maximum plant height recorded from PU application was 87.66 cm obtained from T4 (PU at 15 DAT+35 DAT+55 DAT). All the treatments resulted in an increasing effect on the number of effective tiller $hill^{-1}$ over control. All the treatments with the application of USG performed better than treatments with application of PU except T4 (PU at 15 DAT+35 DAT+55 DAT). The highest number of effective tillers $hill^{-1}$ (11.0) was found in treatment T6 (USG at 7 DAT). Adequate nitrogen favors cellular activities during the formation and development of plants which leads to an increase in tiller numbers. Panicle length was significantly influenced by the application of PU and USG. The results revealed that application of USG increased the panicle length of rice compared with PU. The highest panicle length was found in T6 (USG at 7 DAT). However, all the treatments with USG and PU showed statistically similar results except T2 (PU at 7 DAT+27 DAT+47 DAT) and T1 (control). Filled grains $panicle^{-1}$ was significantly increased due to the application of PU and USG compared to the control. The number of filled grains $panicle^{-1}$ varied from 97.06 to 143.7. The highest value of filled grains $panicle^{-1}$ was found in T6 (USG at 7 DAT). 1000-grain weight was also significantly increased due to the application of different nitrogen fertilizers. 1000-grain weight ranged from 21.53 g to 22.66 g and the highest 1000-grain weight was found in T7 (USG at 10 DAT). 1000-grain weight was not significantly affected by split application of PU and deep placement of USG. Islam et al. [30] similarly reported that "all the yield components except the 1000-grain weight of BRRI dhan29 responded significantly to the deep placement of N in the form of USG". Bony et al. [31] reported that "the highest number of total tillers $hill^{-1}$ and grains $panicle^{-1}$ were obtained from USG @ 3.6 g/4 hills in every alternate row applied at 5cm depth". These results are also in agreement with the findings of Islam et al. [32], Jahan et al. [33], and Miah et al. [34] who reported that "yield attributes of rice were influenced by the application of urea briquette as compared to PU".

Table 2. Effect of PU and USG on various yield contributing characters of BRRI dhan29

Treatments	Plant height (cm)	Effective tillers hill^{-1} (No.)	Panicle Length (cm)	Filled grains panicle^{-1} (No.)	1000-grain weight (g)
T_1	74.33 b	4.93 c	20.86 c	97.06 c	21.53 b
T_2	86.33 a	9.53 b	21.33 bc	116.10 b	22.03 ab
T_3	86.33 a	9.57 b	22.13 ab	136.40 a	22.38 a
T_4	87.66 a	10.06 ab	22.06 ab	122.10 b	22.23 a
T_5	88.00 a	10.53 ab	22.66 a	140.40 a	22.36 a
T_6	91.00 a	11.00 a	22.86 a	143.70 a	22.55 a
T_7	90.66 a	10.46 ab	22.66 a	134.80 a	22.66 a
T_8	89.00 a	10.13 ab	22.40 ab	133.80 a	22.50 a
SE (±)	1.47	0.407	0.354	3.24	0.205
CV (%)	2.94	7.40	2.77	4.39	1.59

T1: Control; T2: PU at 7 DAT+27 DAT+47 DAT, T_3: PU at 10 DAT+30 DAT+50 DAT, T4: PU at 15 DAT+35 DAT+55 DAT, T5: USG at transplanting, T6: USG at 7 DAT, T7: USG at 10 DAT and T8: USG at 10 DAT+30 DAT. In a column, the figure(s) having same letter(s) do not differ significantly at 5% level of probability by DMRT, SE = Standard error of means, CV = Co-efficient of variation.

The grain and straw yields of BRRI dhan29 were significantly affected due to the application of different N fertilizers (Table 2). Application of PU and USG showed a positive effect on grain and straw yields of rice. The highest grain and straw yields of 6.56 t ha^{-1} and 6.95 t ha^{-1} were recorded in T6 (USG at 7 DAT), whereas the lowest grain and straw yields of 2.81 t ha^{-1} and 3.31 t ha^{-1} were found in the control treatment. The treatments T5 (USG at transplanting), T7 (USG at 10 DAT) and T8 (USG at 10 DAT+30 DAT) were statistically identical in producing grain yields of 6.24 t ha^{-1}, 6.13 t ha^{-1}, and 5.96 t ha^{-1}, respectively. The percentage increase in grain and straw yield over control ranged from 48.25 to 57.16 and 41.62 to 52.37, respectively (Figure 1, 2). The highest grain and straw yields increase over control (57.16% and 52.37%, respectively) were observed in treatment T6, where USG was applied at 7 DAT. The percentage of grain and straw yields increase over control was higher with the application of USG at different combinations (T5, T6, T7 and T8) than percentage of yield increase observed with the application of PU. This might be due to the spontaneous supply of nitrogen from USG throughout the growing period of rice and the minimum loss of nitrogen caused by the deep placement of USG. Several studies reported similar results that deep placement of USG in the root zone increased grain and straw yields significantly than that of PU [30,34,35,36]. Islam et al. [37] reported "the highest grain and straw yields of BRRI dhan29 with the application of USG in combination with poultry manure".

Table 3: Effect of PU and USG on grain and straw yield of BRRI dhan29

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)
T_1	2.81 f	3.31 c
T_2	5.43 e	5.72 b
T_3	5.84 cd	5.81 b
T_4	5.76 d	5.67 b
T_5	6.24 b	6.70a
T_6	6.56 a	6.95 a
T_7	6.13 bc	6.82 a
T_8	5.96 bcd	5.99 b
SE (±)	0.105	0.134
CV (%)	3.24	3.96

T1: Control; T2: PU at 7 DAT+27 DAT+47 DAT, T_3: PU at 10 DAT+30 DAT+50 DAT, T4: PU at 15 DAT+35 DAT+55 DAT, T5: USG at transplanting, T6: USG at 7 DAT, T7: USG at 10 DAT and T8: USG at 10 DAT+30 DAT. In a column, the figure(s) having same letter(s) do not differ significantly at 5% level of probability by DMRT, SE = Standard error of means, CV = Co-efficient of variation.

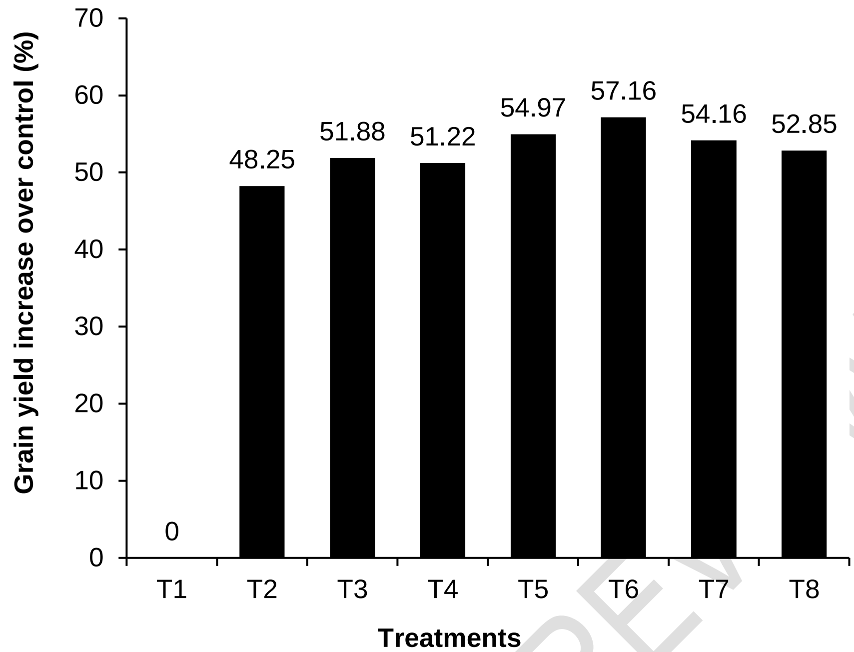

Fig. 1. Effect of PU and USG on % grain yield increase of BRRI dhan29 over control
[T1: Control (no PU or USG), T2: PU at 7 DAT+27 DAT+47 DAT, T3: PU at 10 DAT+30 DAT+50 DAT, T4: PU at 15 DAT+35 DAT+55 DAT, T5: USG at transplanting, T6: USG at 7 DAT, T7: USG at 10 DAT and T8: USG at 10 DAT+30 DAT]

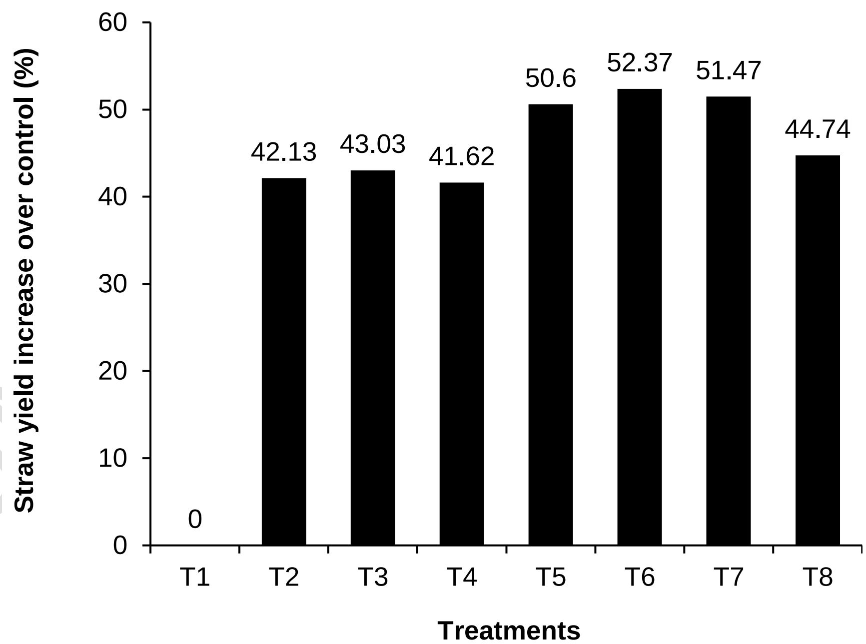

Fig 2. Effect of PU and USG on % straw yield increase of BRRI dhan29 over control

[T1: Control (no PU or USG), T2: PU at 7 DAT+27 DAT+47 DAT, T3: PU at 10 DAT+30 DAT+50 DAT, T4: PU at 15 DAT+35 DAT+55 DAT, T5: USG at transplanting, T6: USG at 7 DAT, T7: USG at 10 DAT and T8: USG at 10 DAT+30 DAT]

The grain and straw nitrogen (N) concentrations significantly varied with different N fertilizer applications (Table 3). Grain N content ranged from 1.14% to 1.34%. The highest grain N content of 1.34% was recorded in T8 (USG at 10 DAT+30 DAT), and the lowest grain N content of 1.14% was recorded in T1 (control). Treatments with the application of USG showed a higher grain N concentration compared to PU except treatment T4 (PU at 15 DAT+35 DAT+55 DAT). The N concentration in rice straw was also significantly affected due to the application of PU and USG. The straw nitrogen content varied from 0.367% to 0.490% with the application of different treatments. The highest straw N content of 0.490% was observed in T8 (USG at 10 DAT+30 DAT), and the lowest N content of 0.367% was noted in T1 (control). Application of USG increased the N content in rice straw markedly in T8 (USG at 10 DAT+30 DAT), which was statistically identical with T3, T4, T6, and T7. Islam et al. [28] similarly reported the highest grain and straw N contents in BRRI dhan29 due to the deep placement of USG in the field. Rea et al. [36] and Ahmed et al. [38] also found the highest grain and straw N contents with the application of USG.

Nitrogen uptake by rice grain and straw was significantly influenced by the application of PU and USG (Table 3). The highest grain and straw nitrogen uptake (87.28 kg ha^{-1} and 32.71 kg ha^{-1}) was recorded in treatment T6 (USG at 7 DAT) and the lowest grain and straw nitrogen uptake of 31.85 kg ha^{-1} and 12.02 kg ha^{-1} was recorded in treatment T1 (control). Application of USG showed higher grain and straw N uptake than PU. Islam et al. [30] reported that deep placement of USG enhances N uptake in rice grain and straw. Islam et al. [37] reported increased grain and straw N uptake with the application of USG and poultry manure.

Table 4: Effect of PU and USG on nitrogen concentration and uptake by BRRI dhan29

Treatment	Content		Uptake (kg ha^{-1})		
	% N (grain)	% N (straw)	N (grain)	N (straw)	Total
T_1	1.14 d	0.367 c	31.85 d	12.02 c	43.87 e
T_2	1.26 b	0.430 b	68.57 c	24.62 b	93.20 d
T_3	1.20 c	0.450 ab	70.05 c	26.16 b	96.21 d
T_4	1.30 ab	0.460 ab	74.94 bc	26.07 b	101.00 cd
T_5	1.33 a	0.430 b	83.01 a	28.85 ab	111.90 ab

T_6	1.33 a	0.477 a	87.28 a	32.71 a	120.00a
T_7	1.30 ab	0.460 ab	79.75 ab	31.40 a	111.10ab
T_8	1.34 a	0.490 a	79.83 ab	29.40 ab	109.20 bc
SE (±)	0.018	0.014	2.39	1.53	2.94
CV (%)	2.52	5.29	5.77	10.01	5.19

T1: Control; T2: PU at 7 DAT+27 DAT+47 DAT, T_3: PU at 10 DAT+30 DAT+50 DAT, T4: PU at 15 DAT+35 DAT+55 DAT, T5: USG at transplanting, T6: USG at 7 DAT, T7: USG at 10 DAT and T8: USG at 10 DAT+30 DAT. In a column, the figure(s) having same letter(s) do not differ significantly at 5% level of probability by DMRT, SE = Standard errors of means, CV = Co-efficient of variation.

4. CONCLUSION

Application of nitrogen fertilizers significantly affected the growth, yield, and nitrogen uptake of BRRI dhan29. Deep placement of USG has numerous benefits over broadcast application of PU. Significantly higher grain and straw yields and nitrogen uptake were obtained with the deep placement of USG compared to the broadcast application of PU. Treatment T6 (USG at 7 DAT) produced the highest grain and straw yields of rice. The highest grain, straw, and total nitrogen uptake were also found in treatment T6 (USG at 7 DAT). It can be concluded that application of USG at 7 DAT is a promising practice for higher growth, yield, and nitrogen uptake of rice. So, deep placement of USG at 7 DAT may be recommended for efficient uptake of the applied N and rice yield augmentation.

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