



## Effect of Different Forms and Levels of Urea Fertilizer on Rice (*Oryza sativa* L) and Mineral Nitrogen Status in Soil

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### ABSTRACT

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Field experiment was conducted to determine the effect of prilled urea (PU) and urea super granule (USG) with their different nitrogen levels N<sub>1</sub>: 70, N<sub>2</sub>: 100 (recommended dose) and N<sub>3</sub>: 130% on rice and NH<sub>4</sub><sup>+</sup>-N/NO<sub>3</sub><sup>-</sup>-N in post-harvest soil. Experiment was laid out in a randomized completely block design with three replications at Bangladesh Institute of Nuclear Agriculture (BINA) Farm, Mymensingh, Bangladesh during 2015-16. Higher yield attributing characters (plant height, effective tiller panicle<sup>-1</sup>, panicle length) were achieved from USG × N<sub>2</sub> treatment. USG, N<sub>2</sub> (100% N) and USG × N<sub>2</sub> produced the highest grain (3.60, 3.64, 3.78 t ha<sup>-1</sup>) and straw yield (3.55, 3.45, 3.70 t ha<sup>-1</sup>) respectively. Though USG × N<sub>3</sub> treatment produced the highest effective tiller, panicle length and unfilled grain but USG × N<sub>2</sub> treatment produced maximum grain yield of rice due to higher filled grain. In respect of mineral nitrogen, Ammonium -N (NH<sub>4</sub><sup>+</sup>-N) was decreased with the increase in soil depth but opposite result was found in nitrate-nitrogen (NO<sub>3</sub><sup>-</sup>-N) in soil. Deep placement of USG fertilizer released NH<sub>4</sub><sup>+</sup>-N slowly and steadily compared to prilled urea in soil. As a result, one time fertilizer application of USG is better than three times broadcast application of PU in terms of crop yield, nitrogen status in different depth of soil and labour cost. Future research needs to develop the effective USG fertilizer applicator for deep placement in soil during crop production.

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### Introduction

Rice is the staple food for the people of Bangladesh. The total area and production of rice in Bangladesh are about 11.7 million hectares and 31.8 million metric tons, respectively (BBS, 2017). Increase in rice production is needed of rising population demand is to be met. However, cultivable natural land resources are limited. Therefore, much of this increase must come from improved yield per hectare. Nitrogen is the most important key input among the essential nutrients for rice production. Farmers of Bangladesh are practiced surface broadcasting of PU (prilled urea) to meet up the N demand for rice crop. But by this method of application, a large portion of the N is wasted – lost through leaching, run-off, volatilization (atmospheric evaporation) and de-nitrification. Excessive N fertilization is one of the major concerns in sustainable agriculture for its decreased N-utilization efficiency by crops and increased N release to the environment, resulting atmosphere and water systems pollution (Zhu et al. 1997). Researchers reported that broadcast application of PU on surface soil causes loss it up to 50% (Crasswell and Datta, 1980). In this regard, researchers have tried many ways to

achieve the newly defined goal of fertilizer use by improving fertilizer nutrient use efficiency and minimizing environmental impacts. Khalil et al. (2009) reported that the volatilization loss of PU is very high and farmers lose a huge amount of money for N fertilizer and proposed that to control this loss, deep placement of fertilizer may be a good option to minimize production cost as well as to increase yield. Bandaogo et al. (2015) reported that deep point placement of USG produced significantly higher grain yield of rice than split application of PU for irrigated rice cultivation. Split application of N fertilizer (one basal fertilizer and two top-dressings) is the conventional fertilization method for rice, and the basal fertilizer application is usually applied by broadcasting. However, higher prices (controlled released fertilizer) and extra labour inputs (topdressing) have restricted the spread of these technologies. In addition, labour prices have increased year by year in Bangladesh because farmers have got older and people have left the land. This has meant that both farmers and the government are more willing to accept simplified fertilization patterns, such as one-time

fertilization, as long as they do not lead to yield reductions. The effects of a one-time fertilizer deep placement application on rice have been reported in South and Southeast Asia (Mazid et al., 2016; Savant and Stangel, 1990). A good number of research works were conducted on N management and N use efficiency in rice but still there is a gap in data on deep placement of N fertilizers for maximizing rice yield and N use efficiency. In Bangladesh, broadcast application of fertilizers is still the common practice for lowland rice. Therefore, attention must be given to minimize the production cost in a search for increasing crop yield. Keeping in mind, the present investigation was undertaken to evaluate the efficiency of USG and PU with their different levels on rice and soil.

## Materials and Methods

Application of urea super granule is an innovative technology to reduce the nitrogen fertilizer losses from rice field. A field experiment on rice was conducted at the Bangladesh Institute of Nuclear Agriculture Institute (BINA) farm, Mymensingh, Bangladesh to compare the effect of PU and USG with their different doses on yield, yield attributing characters and mineral nitrogen ( $\text{NH}_4^+\text{-N}$  &  $\text{NO}_3^-\text{-N}$ ) content in different depths of post-harvest soil. Initial soil samples were collected at a depth 0-15 cm from the surface to determine physical and chemical properties following standard methods. Fresh soil samples were collected from 0-15, 15-30, 30-45 and 45-60 cm depths for the determination of mineral nitrogen content in soil. The soils of the experimental field belongs to sandy loam having pH 6.50, organic carbon 0.84%, total nitrogen 0.08%,  $0.5 \text{ mol L}^{-1} \text{ NaHCO}_3$ -extractable P 15 mg/kg, and  $1 \text{ mol L}^{-1} \text{ NH}_4\text{OAc}$  - extractable K 14 mg/kg and bulk density  $1.28 \text{ g cm}^{-3}$ . Initial soil mineral nitrogen ( $\text{NH}_4^+\text{-N}$  &  $\text{NO}_3^-\text{-N}$ ) content was determined using Kjeldahl method using 2N KCl extracting solution (Keeney, 1982). Factorial experiment was laid out in a RCBD with three replications. PU and USG with three levels of N dose were  $\text{N}_1=30\%$  less than recommended dose of N as PU and USG,  $\text{N}_2=\text{recommended N dose as PU and USG}$  and  $\text{N}_3=30\%$  higher than recommended dose of N as PU and USG. BINAdhan-7 was the test crop. Recommended dose of urea was used  $165 \text{ kg ha}^{-1}$ . Full dose of TSP, MoP, gypsum and  $\text{ZnSO}_4$  were applied to the soil during final land preparation at the rate of 25 kg P, 35 kg K and 1.3 kg Zn  $\text{ha}^{-1}$ , respectively. USG was applied at 10 days after transplanting. PU was applied in three splits such as at 10, 25 and 45 days after transplanting. Prilled urea was applied as broadcast and USG was placed for every four hills at 6-8 cm depth in puddle soil by hand and leveled immediately after placement. Other cultural practices such as weeding and pesticide application were done as necessary. A certain amount of post harvest fresh soil placed in 2N KCl solution for extracting mineral nitrogen of soil (Keeney, 1982).  $\text{NH}_4^+\text{-N}$  &  $\text{NO}_3^-\text{-N}$  were determined by direct distillation of the KCl extracted solution with magnesium oxide and Devarda's alloy, respectively. Data were recorded on plant height, effective tiller per plant, panicle length, filled grain per panicle, unfilled grain per panicle, grain - straw yield and mineral nitrogen status in post-harvest soil. Five plants were selected for calculation of the above mentioned yield attributing characters of rice. For recording total

aboveground biomass, one square meter was harvested stacked for uniform drying and then weighed. Then total grain and straw weight was recorded and converted into  $\text{kg ha}^{-1}$ . Collected data were analyzed statistically following the two way ANOVA technique with the help of MSTAT-C software. The mean differences among the treatments were adjusted by least square difference (LSD) (Steel and Torrie, 1984).

## Results and Discussion

### *Effect of PU and USG on yield and yield attributing characters*

Yield and yield attributing characters differed significantly due to variation in urea forms (Table 1). The highest plant height (87.96 cm) was found with the use of USG. The minimum plant height was found in PU treated plots. The treatment USG produced the maximum number of effective tiller  $\text{hill}^{-1}$  (10.97). Maximum panicle length was obtained from USG treatment and the minimum panicle length was observed in PU treatment. The filled grain number ranged from 89.38 in PU to 89.64 in USG. The treatment USG produced higher unfilled grain number than PU treatment. Yield attributing characters (plant height, effective tiller per hill, panicle length, unfilled and filled grain number) were produced 2.78, 5.68, 6.35, 0.29 and 5.16% higher than PU treatment. USG treatment achieved higher grain and straw yield than PU treatment. These results are in agreement with Wu et al. (2017) who found increased productive panicle with the application of USG (Rahman et al., 2016; Bhuyan et al., 2016).

### *Effect of N Dose on Yield and Yield Attributing Characters*

The response of rice plants to application rates in terms of yield and yield attributing characters are as presented in Table 1. Maximum plant height (87.30 cm) was found in  $\text{N}_3$  (130% of recommended dose of N as urea) treatment. The minimum plant height was achieved in  $\text{N}_1$  (70% recommended dose of N as urea) treatment. The effective tiller number per hill ranged from 10.33 in  $\text{N}_1$  to 10.89 in  $\text{N}_2$  treatment. The lowest effective tiller number per hill was found in  $\text{N}_3$  (130% of recommended dose of N as urea) treatment. Filled grain is an important factor for rice yield. Maximum filled grain was achieved in  $\text{N}_2$  treatment. The lowest filled grain number per panicle was found in  $\text{N}_1$  treatment.  $\text{N}_2$  (100% of recommended dose of N as urea) increased 9% grain yield over  $\text{N}_1$  (70% of recommended dose of N) as urea treatment. These results are in agreement with the findings with Guo et al. (2017). It was observed that recommended dose of N as USG produced 13% higher grain yield of rice than PU with 70% of recommended dose of urea. Wu et al. (2017) reported that grain yield of rice significantly influenced by USG application. Point of placement of USG to 10 cm depth can save 30% nitrogen as PU urea, increase absorption rate, improve soil health, reduce leaching loss, surface run-off, de-nitrification, volatilization due to high localized urea/ $\text{NH}_4$  concentration develop followed by an increase in soil pH through enzyme-catalyzed hydration (Dhane et al., 1989; Jiang et al., 2005; Bautista et al., 2001; Ding et al., 2002; Savant et al., 1981).

Table 1. Effect of PU and USG and their N doses on yield and yield attributing characters of rice

Treatment	PH	ETP	PL	FGP	UGP	GY	SY	IGY
	(cm)	(no.)	(cm)	(no.)	(no.)	(t ha <sup>-1</sup> )	(t ha <sup>-1</sup> )	(%)
Urea form (U)								
PU	85.58	10.38	23.00	89.38	19.78	3.41	3.28	-
USG	87.96	10.97	24.46	89.64	20.80	3.60	3.55	6
N dose								
N <sub>1</sub>	85.80	10.33	23.30	85.00	17.90	3.34	3.39	-
N <sub>2</sub>	87.20	10.89	23.97	92.60	20.73	3.64	3.45	9
N <sub>3</sub>	87.30	10.80	23.92	90.93	22.23	3.54	3.40	6
Interaction								
PU×N <sub>1</sub>	84.93	10.07	22.67	84.53	19.13	3.33	3.42	-
PU×N <sub>2</sub>	85.80	10.80	23.33	92.80	19.33	3.50	3.19	5
PU×N <sub>3</sub>	86.00	10.27	23.00	90.80	20.87	3.41	3.22	2.4
USG×N <sub>1</sub>	86.67	10.60	23.93	85.47	16.67	3.34	3.32	-
USG×N <sub>2</sub>	88.60	10.99	24.60	92.40	22.13	3.78	3.70	13
USG×N <sub>3</sub>	88.60	11.33	24.83	91.07	23.60	3.68	3.58	3
LSD <sub>0.05</sub>								
U	2.40	0.70	1.40	0.30	1.12	0.22	0.30	
N	3.42	1.75	1.19	4.87	2.36	0.54	0.45	
U×N	4.84	2.48	1.69	6.89	3.34	0.76	0.64	

PH: Plant height, ETP: Effective tiller plant<sup>-1</sup>, PL: Panicle length, FGP: Filled grain panicle<sup>-1</sup>, UGP: Unfilled grain panicle<sup>-1</sup>, GY: Grain yield, SY: Straw yield, IGY: Increase grain yield, LSD<sub>0.05</sub>=least significance difference at 5% level of probability, PU=prilled urea, USG=urea super granule, N<sub>1</sub>=30% less than recommended dose of N as PU and USG, N<sub>2</sub>=recommended N dose as PU and USG and N<sub>3</sub>= 30% higher than recommended dose of N as PU and USG.

#### Interaction Effect of PU, USG and Their N Dose on Yield and Yield Attributing Characters

The response of rice plants to different urea sources and application rates in terms of yield and yield attributing characters are as presented in Table 1. Plant height, effective tiller per plant, panicle length, filled grain, unfilled grain, grain-straw yield differed significantly to the interaction between urea form and their doses of N (Table 1). In case of plant height, the tallest plant height (88.60 cm) was observed in the interaction treatments USG & N<sub>2</sub> and USG & N<sub>3</sub> and the lowest plant height (84.93 cm) was obtained in the interaction between PU and N<sub>1</sub>. The highest number of effective tiller per hill (11.33), panicle length (24.83 cm), unfilled grain (23.60) was obtained from the interaction between USG and N<sub>3</sub>. Maximum grain (3.78 t ha<sup>-1</sup>) and straw (3.70 t ha<sup>-1</sup>) yield were obtained from the interaction between USG and N<sub>2</sub> treatment.

#### Effect of PU and USG and Their N Dose on Mineral Nitrogen in Soil

Mineral nitrogen content differed significantly due to urea fertilizer form and its dose (Figure 1). Maximum NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N was released from PU treated plots and the minimum NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N released from USG treated plots. USG produced NH<sub>4</sub><sup>+</sup>-N slowly and steadily due to deep placement by keeping most of urea nitrogen in the soil, close to plant roots. This resulted in continuous supply of available nitrogen throughout the growth period of rice plant, which ultimately gave the higher grain yield. The above results are well correlated with the findings of Sarker et al. (2012) reported that deep placement of USG was more effective over PU and N loss was also minimal. They also reported that USG can save 10-20% N fertilizer instead of traditional PU fertilizer. The higher dose (130% recommended dose as urea) of N fertilizer produced the

maximum amount of NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N followed by N<sub>1</sub> treatment. Minimum NH<sub>4</sub><sup>+</sup>-N and NO<sub>3</sub><sup>-</sup>-N was released from the recommended dose of nitrogenous fertilizer (Figure 2). Maximum NH<sub>4</sub><sup>+</sup>-N was obtained from 0-15 cm depth of soil followed by 15-30 cm depth of soil. The amount of NH<sub>4</sub><sup>+</sup>-N was decreased with the increase of soil depth. The lowest NH<sub>4</sub><sup>+</sup>-N content was found in 45-60 cm depth of soil. On the other hand, minimum NO<sub>3</sub><sup>-</sup>-N content was found in 0-15 cm depth of soil. The highest NO<sub>3</sub><sup>-</sup>-N content increased with the increase of soil depth. This might be happened due to ionic nature of NH<sub>4</sub><sup>+</sup>-N and water soluble nature of NO<sub>3</sub><sup>-</sup>-N. In this regard, clay and organic matter can absorb NH<sub>4</sub><sup>+</sup>-N in soil NO<sub>3</sub><sup>-</sup>-N can leach out with soil water from surface to lower depth of soil. Frequently use of PU helped to increase NH<sub>4</sub><sup>+</sup>-N content in post-harvest soil. But the dynamics of N was not similar during entire growth period of rice by PU fertilizer. NO<sub>3</sub><sup>-</sup>-N dissemination was higher in PU treated plots than USG treated plots. Analysis of cost efficiency results of PU and USG are presented (Figure 3). During fertilizer application, maximum time consumed (36 hr/ha) in PU treated plots and the minimum time (32 hr/ha) used in USG treated plot. PU fertilizer was applied in three splits such as at 10, 25 and 45 days after transplanting of rice seedlings whereas the USG was applied one time at 10 days after transplanting of rice seedlings. Labour cost due to fertilizer application is presented (Figure 3). More or less similar results were found in respect of labour cost of PU and USG fertilizer application. Maximum labour cost was found in PU application due to three times application. The minimum labour cost was observed in USG treated plots due to due to single application. Therefore, using of USG instead of PU could save money (10%) over PU fertilizer as well as profitable for rice production (Mohanty et al., 1999; Islam et al., 2019).

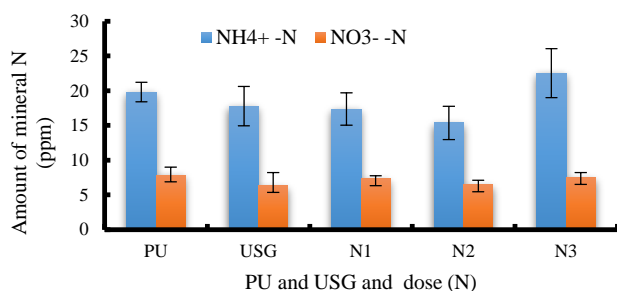


Figure 1. Effect of PU, USG and their different dose of N on mineral nitrogen content in soil

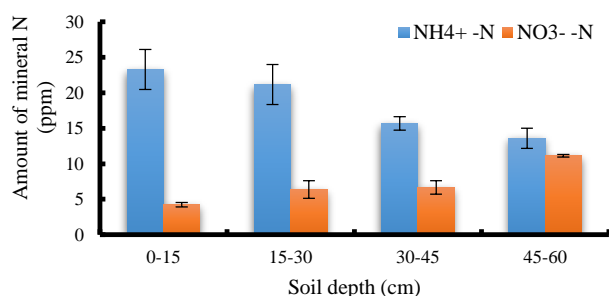


Figure 2. Effect of urea fertilizer on mineral nitrogen in different depths of soil

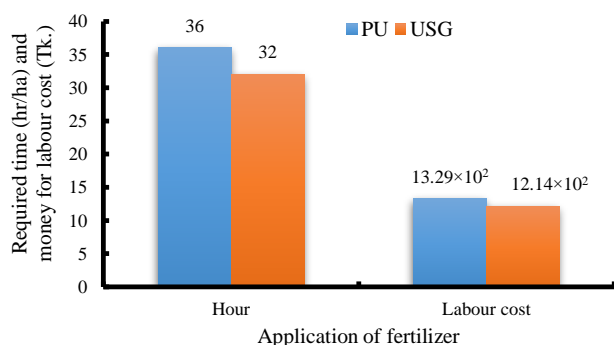


Figure 3. Cost efficiency of PU and USG application for rice production

## Conclusion

These results clearly showed that deep placement of fertilizer can significantly increase rice grain yield and N use efficiency in irrigated rice, which reduces pollution and topdressing times compared to the traditional farmer practice. Fertilizer deep placement practice is a promising technique that can be adopted by farmers growing rice in irrigated schemes once an effective simple fertilization machine has been produced in Bangladesh. However, future research needs to investigate the most appropriate urea application sites and fertilization levels for different soil types, determine the effects of a combined NPK root zone fertilizer application on rice growth, and to develop fertilizer deep placement application equipment.

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## Conflict of Interest

There is no competing interest among the authors of this research article.

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