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A comparative appraisal of urea super granule application in raised bed and prilled urea application in conventional planting for transplanted boro rice (Oryza sativa)

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Abstract

Utilization of urea super granule (USG) with raised bed cultivation system for transplanted boro (winter, irrigated) rice production is a major concern now days. A field experiment was conducted in the chuadanga district of Bangladesh to compare the two cultivation methods: deep placement of USG on raised bed with boro rice, and prilled urea (PU) broadcasting in conventional planting. Results showed that USG in raised bed planting increased grain yields of transplanted boro rice by up to 18.18% over PU in conventional planting. Deep placement of USG in raised bed planting increased the number of panicle m^{-2}, number of grains $panicle^{-1}$ and 1000-grains weight of boro rice than the PU in conventional planting. Better plant growth was observed by deep placement of USG in raised bed planting compared to PU in conventional planting. Sterility percentage and weed infestation were lower on USG in raised bed planting compared to the PU in conventional planting methods. Forty seven percent irrigation water and application time could be saved by USG in raised bed planting than PU in conventional planting. Deep placement of USG in bed saved N fertilizer consumption over conventional planting. Water use efficiency for grain and biomass production was higher with deep placement of USG in bed planting than the PU broadcasting in conventional planting methods. Similarly, agronomic efficiency of N fertilizer by USG in bed planting was significantly higher than the PU broadcasting in conventional planting. This study concluded that deep placement of USG in raised bed planting for transplanted boro rice is a new approach to achieve fertilizer and water use efficiency as well as higher yield and less water input compared to existing agronomic practices in Bangladesh.

Key words: Agronomic efficiency; bed planting; prilled urea; urea super granule; rice.

1 Introduction

Boro rice is one of the major cereal food grains in Bangladesh, which is transplanted in winter season (December to February).Total area under boro crop has been estimated at 4.81 million hectares in the year 2011-12 (BBS 2011-12). Total boro production of 2011-12 has been estimated at 18.759 million metric tons as compared to18.617 million metric tons in 2010-11 which is 0.77 percent higher than that of previous year (BBS.2011-12).This type of rice has been cultivated traditionally in river basin deltas of Bangladesh. This practice is spreading even to those non-traditional areas where irrigation is available. More important advantage is the lower winter temperature during the earlier crop growth. This facilitates the accumulation of photo-syntheses, thereby increasing carbon: nitrogen ratio (Singh, 2002). Farmers apply urea in rice field mainly on the soil surface. As urea is a highly water-soluble and quick release fertilizer, its application to the soil surface may result in a significant loss in various ways (as ammonia volatilization, denitrification, surface run-off and leaching) thus, reducing its efficiency. It is reported that the efficiency of urea nitrogen in wetland rice is only about 30% of the applied urea and even less in many cases (Prasad and De Datta, 1979).

However, the nature and magnitude of nitrogen loss largely depends upon the sources of nitrogenous fertilizer and its methods of application. According to Craswell and De Datta (1980), broadcast application of urea on surface soil causes losses up to 50% but point placement of urea super granules (USG) in 10 cm depth results negligible loss.

In recent years, a deep understanding on mechanisms causing poor N utilization help to develop cultural practices to improve nitrogen use efficiency (NUE) in lowland rice. Urea super granule (USG), a physical modification of ordinary urea, is considered a slowly available N fertilizer and found efficient when properly deep placed (Savant and Stangel, 1990). Urea super granule (USG), a slow releasing nitrogenous fertilizer is being marketed in Bangladesh as a source of nitrogen. Agronomic , economic, and environment advantages of deep point placement of USG have been well established (Cao *et al.,* 1984; Welselaar 1985 ; Insffer 1985, 1986 ; Kumar *et al.,* 1989 ; Chalam *et al.,* 1989; Sarvanan *et al.,* 1988 ; Stangel 1989 ; Savant *et al.*,1991 , 1992 ; Shukla *et al.,* 1993 ; Misra *et al.,* 1995). Experimental results showed that with USG, it is possible to save 20% - 40% of the urea N for the same grain yield, compared with conventional urea application (Yamada *et al.,* 1979; Kumar *et al.*,1989). Deep placement of urea super granule had increased grain yields and improved N use efficiency in research plots and farmers fields (Deftardar and Savant 1995, Singh *et al.,* 1995). Improved N recovery and efficiency of USG has been well documented in lowland rice, but its market availability and placement methods pose problem (Mohanty *et al*., 1999).

Our previous study showed that water use efficiency and grain production were higher in fertilizer broadcasting in raised bed planting compared to fertilizer broadcasting in conventional planting of aman rice (Bhuyan *et al.,* 2012a). Another study showed that foliar split nitrogen fertilizer application in raised bed for transplanted aman rice produced higher yield than conventional cultivation method (Bhuyan *et al.,* 2012b). Our another study showed that split foliar nitrogen application increased water use efficiency and productivity of boro rice in raised bed over conventional methods (Bhuyan *et al.,* 2013). Our study showed that rice bed planting and foliar fertilization increased agronomic efficiency of fertilizer compared to conventional planting (Bhuyan *et al.,* 2014a).In addition, our previous study showed that fertigation with bed planting Increased yield and agronomic efficiency of boro rice (Oryza sativa) compared with conventional planting (Bhuyan *et al.,* 2014b). However, no study was undertaken to determine the effect of USG in bed planting for boro (winter, irrigated) rice as compared to the PU broadcasted in conventional planting method. Therefore, this study was undertaken to determine the role of USG on bed planting for boro rice as compared to the PU in conventional planting method. The hypothesis of this study is that the USG technique on raised bed planting achieves higher boro rice yields than the PU in conventional planting.

2 Materials and methods

2.1 Location and climate of the experimental site

The field experiment was carried out in a farmer's field, Chuadanga district of Bangladesh, during boro season (November-March) of 2012. Experimental site was located at 11.5m above mean sea level. Geographically, it was located at $23^{0}39'$N latitude and $88^{0}49'$E longitudes. The Meteorological data for the cropping season were recorded at the local weather office, Chuadanga district of Bangladesh. The rainfall received during the crop growth period of crop totaled 128 mm. The mean maximum and minimum temperatures were recorded at 34.28^{0}C and 22.03^{0}C respectively for the cropping season. The relative humidity ranged between 63.8% in the month of March and 71.5% in the month of February. Climate is most dominating factor influencing the sustainability of crop in a particular region. The yield potential of the crop depends on the climate. The most important factor influencing growth, development and yield of crop are solar radiation, temperature and rainfall (Upadhaya, 2005).

2.2 Basic soil properties of the experimental field

The soil was silt-loam with 0.88% and 0.11% organic carbon and total nitrogen, respectively and also 5.68 ppm, 0.15 meq, 12.10 ppm, 0.22 ppm of available phosphorus, exchangeable potash, available sulphur and zinc, respectively with a pH of 7.30.

2.3 Experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD). The entire experimental area was divided into three blocks representing three replications to reduce soil heterogenic effects and each block was divided into three unit plots with raised bunds as per treatments. The size of each unit plot was 4 m X 3.5 m. Plots were separated from one another by aisles of 0.25m.Unit blocks were separated from one another by 1 m drains. Treatments were randomly distributed within the blocks. The combinations of treatments were deep placement of urea super granule (USG) in raised bed and prilled urea broadcasted in conventional planting.

2.4 Deep placement of Urea super granule (USG) in raised bed planting

In bed planting within a week after transplanting rice, the USG briquettes are (2.7 gm weight) inserted into the top soil of bed by hand, being placed to a depth of 7-10 cm deep placement in the middle of alternating squares of four hills of rice (BRRI, 2009).

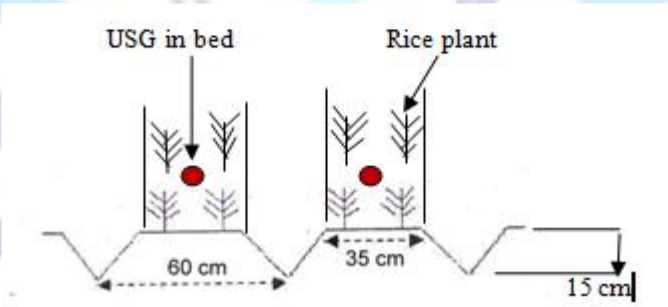

Figure 1: Deep placement of USG in raised bed planting

2.5 Prilled urea (PU) broadcasted in conventional planting

Prilled urea (PU) broadcasted at the following rates: N=120, P=14, K=36, S=1.0 kg ha^{-1} applied as urea, triple super-phosphate (TSP), murate of potash (MP), gypsum and zinc sulphate ($ZnSO_4$), respectively. Whole of TSP, MP, gypsum and $ZnSO_4$ were applied at the final land preparation as basal dose in the plots with conventional treatment. The prilled urea (PU) was broadcasted in three equal splits at 15, 30 and 50 days after transplanting (DAT) in conventional planting.

Figure 2: Prilled urea (PU) broadcasted in conventional planting

2.6 Experimental procedure

Raised bed was prepared manually for the experiment. It can also be prepared through raised bed planting machine. Paddy rice crops were transplanted in two rows on top of the raised bed and irrigation water was applied within the furrows between the beds. Water moves horizontally from the furrows into the beds. The height of the beds was maintained 15 cm; top was 35 cm with 6 beds per plot (Fig. 1). The furrow width was 25 cm. Two 45 days old seedlings hill^{-1} of BRRI 28, a popular boro (winter, irrigated) rice variety, were transplanted. The row to row and hill to hill spacing were 25 cm and 20 cm for both beds and flat. Only two rows of rice were planted on each raised bed and plant density was much higher in the conventional treatment. Manual weeding was done twice in the transplant boro rice field during growth period. The plots were weeded at 15 and 30 DAT. Weed samples from each plot were collected at time of weeding for comparing weed population and dry biomass yield of different treatments.

2.7 Plant growth parameter observation

Ten randomly selected and tagged plants were used for the measurement of plant height at an interval of 15 days from 15th day after transplanting and ending with just flowering. It will be measured from base to tip of the upper leaves of the main stem. Number of tiller per plant was counted from one meter row lengths. Leaf area (cm^2) of the functional leaves obtained from samples drawn for a dry matter accumulation study, were measured by an automatic leaf area meter .The leaf area of the plants units^{-1} was then worked out by the following formula:

Leaf area index (LAI) = Leaf area/Ground area

2.8 Yield parameter observation

Observations regarding the effective tiller per row length were recorded just before harvesting the crop and the average values were used to obtain the effective tiller per meter row length. The length of panicle was taken from the 10 panicles from each plot which were randomly selected just before harvesting and the mean was calculated. The number of filled and unfilled grains was counted to determine the number of grains per panicle. One thousand grains were counted from the grain yield of each plot and weighted with the help of an automatic electronic balance. Grain yield and straw yield were taken at harvesting from each plot .A digital grain moisture meter was used record the moisture of the grain .Finally the grain yield was adjusted at 14% moisture using the formula as suggested by Paudel (1995).

Grain yield (t/ha) at 14% moisture = (100-MC) x plot yield (ton) x 10000(m^2)/ (100-14) x plot area (m^2)

Where, MC is the moisture content in the percentage of the grains.

The harvest index was computed by dividing grain yield with the total dry matter yield as per the following formula:-

H.I. = (grain yield)/ (grain yield+ straw yield)

2.9 Irrigation water measurement

Irrigation water was measured by using a delivery pipe and water pan. A plastic delivery pipe was connected from the water pump to the experimental field. A water pan, with a 300-liter volume, was filled by irrigation through the delivery pipe and the time required to fill was recorded. Then the plots with different methods of planting were irrigated through the delivery pipe and the times required were recorded. The amount of irrigation water applied to the different plots was calculated as follows:

Amount of water applied per plot=

$$\frac{\text{Volume of water pan (L)} \times \text{Time required to irrigate the plot (sec)}}{\text{Time required filling the water pan (sec)}}$$

2.10 Water use efficiency calculation

Water use efficiency for grain and biomass production was calculated by the following equations:

Water use efficiency for grain production (kg ha^{-1}cm^{-1})

= grain yield (kg ha^{-1})/total water required (cm)

Water use efficiency for biomass production (kg ha^{-1}cm^{-1})

= [grain yield (kg ha^{-1}) + straw yield (kg ha^{-1})]/ total water required (cm)

2.11 Agronomic efficiency of N fertilizer calculation

Agronomic efficiency (AE) of N fertilizer was calculated by the following equation:

AE= GY_{NA}-GY_{N0}/N_R

Where $GY_{NA=}$ Grain yield (kg /ha) with addition of nutrient

GY_{N0}= Grain yield (kg/ha) without addition of nutrient

N_R= Rate of added nutrient (kg/ha)

2.12 Statistical analysis

The experiment was conducted using randomized complete block design with three replications for each treatment. Data was analyzed following standard statistical procedures and means of treatments were compared based on the least significant difference test (LSD) at the 0.05 probability level. Microsoft Excel was used for tabulation and simple calculation, and presentation of tables for different comparisons.

3 Results

3.1 Grain yield and yield components

The yield increased by 18.18% when urea super granule (USG) was used in bed planting over prilled urea (PU) broadcasting in conventional method (Table 1). A similar finding was also found for the panicles, grains per panicle and 1000 gm grain wt. These results were significantly ($P \le 0.05$ for grain yield and 1000 g grain, $P \le 0.01$ for panicle) different when compared to conventional method. The USG in bed planting had 32 panicle number m^{-2}, 18 grain number per panicle and 4.33g in 1000 grain wt more than PU in conventional method.

Table 1: Grain yield and yield components with respect to USG in raised bed and fertilizer broadcasting in conventional planting

Method of Fertilizer application	Yield and yield components			
	panicles m^{-2} (no)	Grains panicle^{-1} (no)	1000 grain wt (gm)	Grain yield (t ha^{-1})
USG in bed planting	472a	124a	25.33a	5.20a
Prilled urea broadcasting in conventional planting	430b	106b	21.00b	4.40b
LSD at 5%	9.44	4.63	2.35	0.41
Level of significance	**	**	*	*

Where * and ** represents probability of ≤ 0.001 and ≤ 0.01 respectively. Values were means of three replicates. In a column figures with same letter do not differ significantly whereas figures with dissimilar letter differ significantly ($P \le 0.01$).

3.2 Other Plant attributes

Planting method affected plant height, panicle length, non-bearing tillers m^{-2}, sterility percentage, straw yield and harvest index of rice. Plant height, panicle length and harvest index were higher by USG in bed planting than PU in conventional method (Table 2). On the contrary, non-bearing tillers m^{-2}, and sterility percentage were higher PU broadcasting in conventional method than the USG in bed planting. Likewise, lower number of non bearing tillers m^{-2} was recorded by the USG in bed planting treatments than the PU in conventional method. The USG in bed planting significantly ($P \le 0.05$) reduced the sterility percentage compared to the PU in conventional planting. In bed planting sterility was lower. The lower sterility may be accountable for higher grains in bed planting.

Table 2: Plant biomass with respect to USG in raised bed and fertilizer broadcasting in conventional planting.

Method of Fertilizer application	Plant height (cm)	Panicle length (cm)	Non-bearing tiller (no-m^{-2})	Sterility (%)	Straw yield (tha^{-1})	Harvest index
USG in bed planting	89.93a	25.08a	62b	13.24b	5.25a	0.49a

Prilled urea broadcasting in conventional planting	87.34a	24.10a	102a	16.21a	4.92b	0.47a
LSD at 5%	2.34	2.74	2.62	1.14	0.23	0.01
Level of significance	n.s.	n.s.	**	*	*	n.s.

Where *, ** and n.s represents probability of ≤ 0.001, ≤ 0.01 and < 0.05 respectively. Values were means of three replicates. In a column figures with same letter do not differ significantly whereas figures with dissimilar letter differ significantly (*P* ≤ 0.01).

3.3 Tiller production

Transplanting of boro (winter, irrigated) rice under different planting methods affected the number of tillers m^{-2} of rice. The increasing trend of tiller m^{-2} was continued to 40 days after transplanting for both planting method. At 40 days after transplanting both planting method attained the highest number of tiller m^{-2} and then started declining up to 100 days after transplanting (Table 3).

Table 3: Effect of tiller production by USG in raised bed and fertilizer broadcasting in conventional planting.

Method of Fertilizer application	Tiller (no. m^{-2}) at days after transplanting								
	20	30	40	50	60	70	80	90	100
USG in bed planting	64b	223a	247a	213a	168a	164a	159a	152a	149a
Prilled urea broadcasting in conventional planting	76a	209b	240a	200a	162b	149b	141b	139b	135a
LSD at 5%	2.07	2.62	9.44	9.66	2.42	4.14	9.44	2.62	9.44
Level of significance	**	**	n.s.	n.s.	*	**	*	**	n.s.

Where *, ** and n.s represents probability of ≤ 0.001, ≤ 0.01 and < 0.05 respectively. Values were means of three replicates. In a column figures with same letter do not differ significantly whereas figures with dissimilar letter differ significantly (*P* ≤ 0.01).

3.4 Leaf Area index

Planting method affected the leaf area index (LAI) of transplanted boro rice recorded at different days after transplanting (DAT) (Table 4). The highest leaf area index was achieved at 60 DAT by USG in bed planting method. After 60 DAT the leaf area index started declining and continued to do so until100 DAT by USG in bed planting. Table 4 shows that at early stages of crop growth, the leaf area index by USG in bed planting treatments was lower than conventional planting. The highest LAI was achieved by PU in conventional planting at 80 DAT. After 80 DAT the LAI started to decline and continued to 100 DAT by PU in conventional method.

Table 4: Effect of leaf area index by USG in raised bed and fertilizer broadcasting in conventional planting

Method of Fertilizer application	LAI at different DAT				
	20	40	60	80	100
USG in bed planting	0.41a	2.64a	5.89a	5.42a	4.06a
Prilled urea broadcasting in conventional planting	0.42a	2.50a	5.03b	5.08a	3.85b
LSD at 5%	0.09	0.46	0.09	1.07	0.07
Level of significance	n.s.	n.s.	**	n.s.	**

Where ** and n.s represents probability of ≤ 0.01 and < 0.05 respectively. Values were means of three replicates. In a column figures with same letter do not differ significantly whereas figures with dissimilar letter differ significantly (*P* ≤ 0.01).

3.7 Weed population

Weed population and dry biomass were greatly influenced by different planting methods of transplanted boro rice. The USG in bed planting (162 number m^{-2}) method reduced weeds population resulting in lower dry biomass than PU in conventional planting (389 number m^{-2}). The PU in conventional method (344.98 kg ha^{-1}) had significantly (*P* ≤ 0.01) higher dry biomass than raised bed planting (152.14kg ha^{-1}).

3.8 Irrigation water

Different planting methods affected the irrigation water requirement (Table 5). The PU in conventional planting received a higher amount of water at every irrigation and the total amount was 149 cm. The total amount of irrigation water received by USG in bed planting was 100.96 cm. Results showed that total water savings by USG in raised bed planting compared to PU in conventional method was 47.58%.

Table 5: Irrigation water savings by USG in raised bed and fertilizer broadcasting in conventional planting

Method of Fertilizer application	Irrigation required (cm)	Rainfall (cm)	Total Irrigation required (cm)	Water saved over conventional method (%)
USG in bed planting	88.16b	12.8a	100.96b	
Prilled urea broadcasting in conventional planting	136.20a	12.8a	149.00a	47.58%
LSD at 5%	2.85	0.85	2.62	
Level of significance	**	n.s.	**	

Where ** and n.s represents probability of ≤ 0.01 and < 0.05 respectively. Values were means of three replicates. In a column figures with same letter do not differ significantly whereas figures with dissimilar letter differ significantly (*P* ≤ 0.01).

3.9 Water use efficiency

Water use efficiency for grain and biomass production by USG in bed planting was 51.50 kg $ha^{-1}cm^{-1}$ and 103.50 kg $ha^{-1}cm^{-1}$, respectively (Table 6). The water use efficiency for grain production and biomass production in the conventional planting was 29.53 kg $ha^{-1}cm^{-1}$ and 62.55kg $ha^{-1}cm^{-1}$, respectively. Therefore water use efficiency for grain production and biomass production in raised bed planting was 74.39% and 65.46% higher than PU in conventional planting.

Table 6: Water use efficiency by USG in raised bed and fertilizer broadcasting in conventional planting.

Method of Fertilizer application	Efficiency savings by USG in raised bed and fertilizer broadcasting in conventional planting.	
	Water use efficiency for grain production (kg $ha^{-1}cm^{-1}$)	Water use efficiency for biomass production (kg $ha^{-1}cm^{-1}$)
USG in bed planting	51.50a	103.50a
Prilled urea broadcasting in conventional planting	29.53b	62.55b
LSD at 5%	2.44	2.68
Level of significance	**	**

Where ** represent probability of ≤ 0.01. Values were means of three replicates. In a column figures with same letter do not differ significantly whereas figures with dissimilar letter differ significantly (*P* ≤ 0.01).

3.10 Agronomic efficiency of N fertilizer

Agronomic efficiency of N fertilizer in raised bed planting was 42.6 % (Table 7) while agronomic efficiency for PU in conventional planting was 22.56%. Agronomic efficiency of N fertilizer by USG in raised bed was significantly (*P* ≤ 0.01) higher than the PU in conventional planting method.

Table7: Agronomic efficiency of fertilizer by USG in raised bed and fertilizer broadcasting in conventional planting.

Method of Fertilizer application	Agronomic efficiency of fertilizer (%)
USG in bed planting	42.69a
Prilled urea broadcasting in conventional planting	22.56b
LSD at 5%	2.67
Level of significance	**

Where ** represent probability of ≤ 0.01. Values were means of three replicates. In a column figures with same letter do not differ significantly whereas figures with dissimilar letter differ significantly ($P \leq 0.01$).

3.11 Advantages of USG application over PU

Urea super granule (USG) was applied in bed 59 kg N ha^{-1} and prilled urea (PU) broadcasted in conventional planting 95 kg N ha^{-1}. So, USG in bed saved 61% N fertilizer compared to PU in conventional planting (Table 8). Economic benefit in USG application instead of PU was also assessed and the result was presented in (Table 9). It appears that 78.26 kg of urea could be saved by using USG. Using USG, 11.87 US dollar could be saved since price of USG was higher and additional labor cost for USG application was 25 USD ha^{-1}. The main benefit as gained was additional yield of 0.80 t ha^{-1} (18.18% higher) and the additional benefit was USD 175 ha^{-1}.

Table 8: Nitrogen (N) fertilizer applied in raised bed and conventional planting

Method of Fertilizer application	Added N fertilizer (Kg ha^{-1})	N fertilizer saved by USG in bed planting over Prilled urea broadcasting in conventional planting (%)
USG in bed planting	59	61
Prilled urea broadcasting in conventional planting	95	

Table 9: Comparative advantages of USG use over PU application

Items	Total amount (kg)	US dollar
Urea applied in bed in USG form (kg ha^{-1})	128.26 (@0.31 USD/ kg)	39.76
PU applied in conventional planting (kg ha^{-1})	206.52 (@0.25 USD/ kg)	51.63
US dollar saved from urea (US dollar ha^{-1})	11.87	11.87
Additional labor cost for USG application (US dollar ha^{-1})	10 labor (@2.5 USD labor^{-1})	25
Yield of USG plot (t ha^{-1})	5.20 (18.18%)	
Yield of PU plot (t ha^{-1})	4.40	
Additional yield from USG plot (t ha^{-1})	0.80 (@ 218.75 USD /ton)	175
Additional benefit from USG plot (US dollar ha^{-1})		161.87

Note: Figures in the parentheses indicate percent increase

4 Discussions

4.1 Benefits of Deep Placement of Urea Super granules over PU in conventional planting

Economic benefit in USG application instead of PU was also assessed and the result was presented in Table 9. It appears that on average, 78.26 kg of urea could be saved by using USG. In our experiment 128.26 kg urea ha^{-1} was applied in bed planting as a form of USG and PU broadcasted 206.52 kg urea ha^{-1} in conventional planting. The market value of 128.26 kg USG was 40.08 USD (@ USD 0.31USG kg^{-1}). On the other hand the market value of 206.52 kg PU was Tk.4130.40 (@ Tk.20 PU kg^{-1}). So USG in bed planting saved expenditure for urea by 11.87 USD ha^{-1} over PU. Regardless of that, nearly

10 more labor was needed in the USG using plots compared to that of PU user plots. This contributed additional labor cost for USG application was 25USD ha^{-1} (Table 9). Our study suggested that USG in bed planting reduced expenditure for urea by 22.36% over PU in conventional planting. Similarly, IFDC innovation about deep placement of urea super granule observed that USG reduces expenditure for urea by 20%-25%. Similarly, Roy (2010) reported that yearly requirement of urea in Bangladesh is 2.9 million tons (mt) of which 80 per cent (2.3 mt) is used for rice alone. The country produces 1.7 mt and the rest is (1.2 mt) imported at a cost of 465 million USD. If all the urea could be applied in super granule form, then 1.15 mt urea could be saved. In that case only 0.05 mt urea needs to be imported and its market value is 19.375 million USD .So, it can reduced expenditure for urea nearly 445.625 million USD yearly by using USG instead of prilled urea (PU).

Deep placement of USG in bed produced grain yield 5.20 t ha^{-1} and PU in conventional planting produced 4.40 t ha^{-1} (Table 1). Deep placement of USG produced 18.18% more yield than PU in conventional planting. The main benefit as gained by USG in bed was additional yield of 0.80 t/ha (18.18% higher) and the additional benefit was Tk. 12923.90 ha^{-1} over PU in conventional planting (Table 9). Other study conducted by Savant and Stangel (1998) have shown that N loss is significantly reduced in USG, which results in a significant increase in rice grain yield under flooded conditions compared with split applied PU. Likewise, Singh and Allgood (2013) demonstrated that fertilizer deep placement (FDP) is an innovative, proven fertilizer application technology that achieves average yield increases of 18 percent while reducing fertilizer use by about one-third. This technology has resulted from IFDC-applied research to improve nitrogen-uptake efficiency. It is a simple, low-cost technology that is extremely well suited to small-scale rice production. Moreover, experiments with N-labeled peat ball fertilizer showed that deep placement of nitrogen at the panicle formation stage resulted in 86% of the nitrogen being taken up by the rice plant; surface broadcasting gave only 50% nitrogen uptake (Mitsui, 1977).

Our speculation is that deep placement of USG reduces possible losses of nutrients, particularly losses of nitrate nitrogen, between applications and uptake by the plants through gradual nutrient release. They also reduce evaporation losses of ammonia. This substantially decreases the risk of environmental pollution. However, the benefits of USG such as mitigation of nitrogen loss mechanisms, improving crop uptake to support yield improvement, and lower application of high cost fertilizers. Deep placement of USG encourages algal biological nitrogen fixation because of low floodwater nitrogen concentration;s weeding and pest control is made easier, minimizes ammonium and phosphate fixation and immobilization, reduces the number of ineffective tillers in rice plants and results in bigger panicles, and ensures nitrogen availability beyond the flowering stage when applied at an appropriate rate.

4.2 Deep placement of USG in bed saved N fertilizer consumption over conventional planting

In our experiment urea super granule (USG) was applied in bed 59 kg N ha^{-1} and prilled urea (PU) broadcasted in conventional planting 95 kg N ha^{-1}. So, USG in bed saved 61% N fertilizer compared to PU in conventional planting. These results are in accordance with Hasanuzzamman *et al*., (2013). They found that deep placement of urea super granule in boro rice reduced 60% N fertilizer compared to prilled urea. Likewise, Dr. Ray B. Diamond, an IFDC agronomist, demonstrated that deep-placed USG resulted in an average saving of urea fertilizer of about 35%. He also stated that in most cases, the agronomic performance of deep placed USG was superior to that of two or three split broadcast applications of prilled urea (B. Diamond). Similarly, Alam *et al.,* (2011) assessed the economic benefit in USG application instead of PU. They found that urea saved (kg ha^{-1}) by USG over PU were 55, 32, 25,129 in four research station. These findings suggested that average 60 kg of urea could be saved by using USG over PU. Islam *et al*., (2012*)* demonstrated that deep placement of USG could be a profitable N management technique. They also found that grain yield with only 55 kg N ha^{-1} in USG form as against 80 kg N ha^{-1} in the form of prilled urea was same. Deep placement of USG saved 45.45% N compared to PU. Eusuf *et al.,* (1993) reported that 58 kg USG and 87 kg PU produced almost similar grain yield. As a result using USG at the same level of crop yield can save one third of nitrogen required for conventional split application of urea. The use of N as USG has more efficiency than that of PU (Rashid *et al*., 1996). From this study, it reveals that deep placement of USG is an effective means of increasing nitrogen use efficiency of rice as compared to the traditional split application of PU. The USG with deep placement provided a zone of concentrated urea solution where the denitrifying bacteria cannot enter and therefore nitrogen is left at the root zone for uptake by the plants (Mukherjee, 1986). Deep placement of urea super granule (USG) was best suited to conditions where the predominant N loss mechanism is ammonia volatilization rather than leaching or de nitrification. Deep placement of USG thus has greater benefit over surface split application on moderate to heavy textured soils (Mohanta *et al.,* 1999). In contrast Sarder *et al*., (1988) evaluated about slow release nitrogenous sources and urea fertilizer on wetland rice. Conventional method of urea application as broadcast was compared with USG in deep placement. Results showed that point placement of urea super granules were superior to the conventional method of urea application only at the higher nitrogen rates. Urea super granules did not show any advantage over conventional method of urea application.

Our speculation is that urea super granules (USG) application in the root zone at 8-10 cm depth of soil (reduced zone of rice soil) can save nitrogen than prilled urea because of deep placement are restricted to leaching or by diffusion of ammonium to the surface. Volatilization loss of ammonia can be minimized by mixing of nitrogen fertilizers in soil rather than broadcasting on soil surface, deep placement of urea super granules (USG) in puddle rice field. Dentrification loss can be minimized by avoiding the use of NO_3 form of nitrogenous fertilizer in rice and use of deep placement of urea sugar granules (USG) in flooded rice field. To minimize N losses deep placement of nitrogen fertilizers are promising for Bangladesh. Deep placement of USG is to make the amount of N released coincide with the nitrogen requirement of growing plants, especially the tillering and heading stages, and thereby reducing N losses. We also speculated that this modified form of urea, because of its larger granule size, may go deeply into the mud simply by force throwing, and thus may be expected to be more efficiently used than PU which may contribute to reduce N loss.

5 Conclusions

This research demonstrated that USG in bed planting increased grain yield by 18.18 % for boro (winter, irrigated) rice compared to prilled urea (PU) broadcasting in conventional planting. Deep placement of USG in raised bed planting produced higher number of panicles per unit area, number of grains per panicle and 1000-grain weight for transplanted boro rice which ultimately gave the higher grain yield than the PU in conventional planting. This study also concluded that the deep placement of USG in raised bed planting proved beneficial over conventional PU technique, especially with respect to grain yield, yield attributes, agronomic efficiency and water use efficiency. Deep placement of USG in raised bed planting effectively increased N-use efficiency as compared to PU in conventional planting. Deep placement of USG in raised bed planting is considered the most effective method to decrease N losses and thereby to increase fertilizer use efficiency. This study also suggests that the deep placement of USG in raised bed planting for boro rice is feasible for water and nitrogen use efficiency and reduction in soil compaction. The USG in raised bed planting saved irrigation water by 47.58% as well as increased irrigation efficiency over PU in conventional planting. Bed planting provided less weed density and dry biomass than conventional planting. These findings concludes that water use efficiency for grain and biomass production was higher by deep placement of USG in bed planting than PU broadcasting in conventional method. The agronomic efficiency of N fertilizer was also significantly higher in USG of bed planting than the PU broadcasting in conventional planting method.

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