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Original article

Effect of nitrogen source and water management on rice yield and nitrogen use efficiency

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A B S T R A C T

We conducted two experiments using prilled urea and urea super granule to examine the effects of nitrogen source and water stress on rice yield and nitrogen use efficiency. The experimental treatments were 0, 25, 50, 75 and 100 kg N ha^{-1} (experiment 1). The water stress treatments were: no fertilizer + continuous standing water, water stress before first urea top dress, water stress before second urea top dress, water stress before third urea top dress, water stress before first, second and third urea top dress and all fertilizers+continuous standing water (experiment 2). The experiment was laid out in a randomized complete block design with four replications. BRRI dhan49 was used as planting material. Urea super granule at 75 kg N ha^{-1} was enough for rice production in aman season and save 25 kg N ha^{-1} which was equivalent to 55 kg urea. During application of prilled urea water stress before third top dress performed better than continuous standing water in terms of grain yield and nitrogen use efficiency.

1. Introduction

Nitrogen is the most important and key nutrient for rice production all over the world for its huge requirements and instability in soil. It is the most limiting element for increasing rice productivity in the tropical countries like Bangladesh. Prilled urea (PU), high nitrogen concentration (46%) fertilizer, is used widely for agricultural production. The efficiency of PU in rice field is about 25-30 percent and rest of 70-75 percent is lost for many reasons after application (BRRI, 2008). It is a quick releasing nitrogenous fertilizer that usually broadcasted in splits, can cause considerable loss as ammonia volatilization, denitrification, surface run off and leaching etc (De Datta, 1978). Thus, more than 40% of N lost through ammonia gas when urea was applied on soil surface (Catchpoole et al., 1983; Nommik, 1973). As a result, the loss of ammonia after urea application may lead to poor growth of rice. Deep placement of urea super granule (USG) and slow release nitrogen can reduce ammonia loss (Mikkelsen et al, 1978). Deep placement of USG reduces denitrification process and minimizes urea concentration in irrigation water, thus reduce nitrogen loss and improve nitrogen use efficiency by 20-25 percent for better grain production (Pillai, 1981). Slow release nitrogenous fertilizer increased the yield and N uptake by rice due to less loss of nitrogen from the soil (Ramaswamy, et al. 1987). Moreover, placement of USG in the root zone is the most effective method for increasing the nitrogen use efficiency and rice yield (Prasad et al. 1982). Slow releasing nitrogenous fertilizer dissolve slowly in the soil providing a steady supply of available nitrogen throughout the growing period of the crop. BRRI (2008) reported that USG was superior source of N over PU. More than 90% of the rice in the world is produced and used in Asia. In Asia, more than 80% of the fresh water resources are used in agriculture and half of that is used for rice production (Parsi-Nejad et al., 2003). In transplanted and wet-seeded rice, keeping the soil continuously around saturation reduced yields on average by 5% and water inputs by 35% and increased water productivity by 45% as compared with flooded conditions (Tabbal et al., 2002). Traditional transplanted rice with continuous standing water needs relatively high water inputs. By applying appropriate irrigation management during growing season of rice, a large volume of water can be saved which may help to bring more area under irrigation particularly where there are limited water resources (Bouman et al., 2005).

Therefore, we conducted two field experiments using PU and USG as nitrogen source. The objectives of the studies were i. to examine the effects of nitrogen source and water stress on rice yield and ii. to increase the nitrogen use efficiency.

2. Materials and methods

To full fill the objectives we executed two experiments. A field experiment was conducted with two nitrogen source during July to December, 2010 (aman season). The experimental treatments were 0, 25, 50, 75 and 100 kg N ha-1 from prilled urea (PU) and urea super granule (USG). Urea super granules were placed in 5-8 cm depth at 7 days after transplanting in the centre of four hills in alternate rows. For 25 kg N ha^{-1}, one USG balls was placed at the centre of every four hills, two balls for 50 kg N ha^{-1}, three balls for 75 kg N ha-1 and four balls for 100 kg N ha-1. Second experiment was conducted at net house during July to December, 2011. The treatments were: T1 = No fertilizer + continuous standing water (control), T2 = Water stress before first urea top dress (15 days after transplanting, DAT), T3 = Water stress before second top dress (30 DAT), T4 = Water stress before third urea top dress (45 DAT), T5 = Water stress before first, second and third urea top dress and T6 = all fertilizer + continuous standing water (no water stress). The experiment was laid out in a randomized complete block design with four replications having plot size 4 × 2.5 m. Forty-day old seedling of variety BRRI dhan49 was transplanted at 20 × 20 cm spacing with 2-3 seedling hill-1. The field was a medium high land of clay soils having pH was 7.1. The soil physical and chemical properties are shown Table 1. Prilled urea was applied in three equal splits, one-third at 15 DAT, one-third at 30 DAT and rest one-third at 45 DAT. Fertilizers as triple super phosphate, muraite of potash and gypsum were applied as basal at the rate of 100, 70 and 60 kg ha^{-1} respectively. Intercultural operations were done as and when necessary. The crop was harvested was at maturity stage. The harvested crops were threshed, cleaned and processed plot wise. Yield and yield components data were collected accordingly. Record data were analyzed statistically using MSTAT package and difference among the treatment means were adjust by DMRT.

3. Results and discussion

3.1. Experiment 1

3.1.1. Yield components

Source and different nitrogen rates had significant effect on number of panicles m^{-2}. Panicle number increased with the increases of nitrogen rates irrespective of urea source. Urea super granule (USG) treated plots produced more number of tillers irrespective of rates (Figure 1). Significantly the highest number of panicle m-2 was obtained when USG was applied at 100 kg N ha^{-1} which was about 11% higher than prilled urea (PU) at 100 kg ha^{-1}. About 19 and 24% more panicles m^{-2} was recorded from PU and USG applied plots at 25 kg ha^{-1} than control plots, respectively. Again, USG treated plots produced about 7, 6 and 14% more panicles m^{-2} than PU at 25, 50 and 100 kg N ha^{-1}, respectively. The slow releases of nitrogen from USG ensured long time supply of N to the rice plants and help to produce higher panicles m^{-2}. The results obtained for bearing tillers m^{-2} were in conformity with the findings of Jee and Mahapatra (1989) who have mentioned that the deep placement of USG produced significant higher number of bearing tillers m^{-2} than PU application at harvest. The lowest number of bearing tillers hill^{-1} was observed in control plots.

Table 1
Physical and chemical properties of soil in experimental site.

Parameters	**Mean**
pH	7.01
Organic C (%)	1.2
Total N (%)	0.19
Available P-Olsen (mg kg-1)	30.0
Available K (meq 100 g-1)	1.12
Available Zn (mg kg-1)	1.99
Exch. K (meq 100 g-1)	1.34
Soil texture	
Clay (%)	58.3
Silt (%)	33.0
Sand (%)	8.7
Textural class	Clay soil

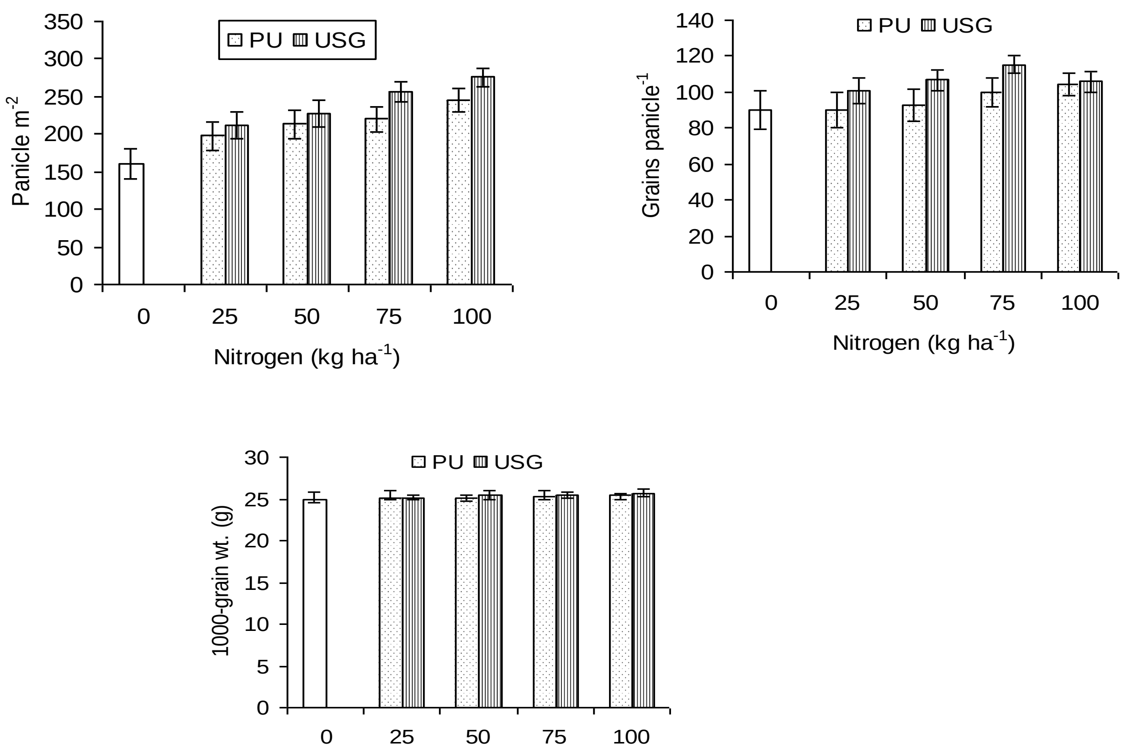

Fig. 1. Effect of source of nitrogen on yield component of rice. PU = Prilled urea, USG = Urea super granule, The vertical bars represent the standard error.

The forms of nitrogen fertilizers had significant effect on filled grains panicle^{-1}. Deep placement of USG gave higher number of filled grains panicle^{-1} while PU gave lower number of filled panicle^{-1} (Figure 1). Rama et al. (1989) reported that the number of grains panicle^{-1} was significantly higher due to deep placement of USG than PU application. The doses of nitrogen showed significant influence on number of filled grains panicle^{-1}. Application of USG 75 kg N ha^{-1} produced highest umber of filled grains panicle^{-1}. The lowest number of grains panicle^{-1} produced by control and PU at 25 kg N ha^{-1}. Mandal and Swamy (2003) obtained increases grains panicle^{-1} with increased level of nitrogen up to 120 kg N ha^{-1}.

Forms of nitrogen fertilizer did not exert significant influence on 1000-grain weight. But, numerically higher 1000-grain weight was measured with USG while lower with PU application (Figure 1). Singh and Yadav (1985) also observed that 1000-grain weight did not differ significantly due to different forms of urea viz. PU, USG and sulphur coated urea. Doses of nitrogen did not show significant effect on 1000-grain weight. But, 1000-grain weight increased with the increase of nitrogen doses. The highest 1000-grain weight was obtained with 100 kg N ha^{-1} while lowest with control and PU at 25 kg N ha^{-1} application. This result is similar with those of Chowdhury et al. (1993) who found that 1000-grain weight increased with the increasing rate of nitrogen upto 120 kg N ha^{-1}.

3.1.2. Grain yield and nitrogen use efficiency

Grain yield was significantly influenced by the forms of nitrogen fertilizer. Results revealed that the highest grain yield was obtained by USG where split application of PU produced the lowest one. Deep placement of nitrogen as USG produced the highest number of effective tillers m^{-2}, filled grains panicle-1 that ultimately gave the highest grain yield (Figure 2). Singh and Singh (1997) also reported that among all the forms of N, USG recorded the highest grain yield than other forms of nitrogen. The doses of nitrogen showed a significant influence on grain yield. The highest grain yield was obtained with USG at 75 kg N ha$_{-1}$ which was about 24% higher than PU at 75 kg N ha^{-1}. The second highest grain yield was recorded from USG at 100 kg N ha^{-1} which was about 11% higher than PU at 100 kg N ha^{-1}. Urea super granule yielded 17 and 11% higher than PU at 25 and 50 kg N ha^{-1}. It is found that increasing of nitrogen doses increased grain yield. The lowest grain yield was obtained by control. It was observed that comparatively higher yields were obtained from higher doses of nitrogen. This is an agreement with Jadav and Sahane (1997) and Bhuiyan et al. (1998) who disclosed that grain yield increase with increased level of nitrogen. Effect of forms and doses of nitrogen showed a significant influence on grain yield. Nitrogen use efficiency significantly influenced by forms and doses of nitrogen. Urea super granules showed higher N use efficiency than PU. The prilled urea gave N use efficiency up to 36% where USG gave N use efficiency up to 63%. Urea was much quickly hydrolysis by urease to ammonia and carbon dioxide ($NH_2CONH+H_20 \rightarrow 2NH_3+CO_2$) in the soil solution, ammonium ions in the soil solution exist in equilibrium with ammonia (NH_{4+} + OH- $\rightarrow NH_2+H_2O$). More than 40% of N lost through ammonia gas when urea was applied on soil surface (Catchpoole et al., 1983; Nommik, 1973).

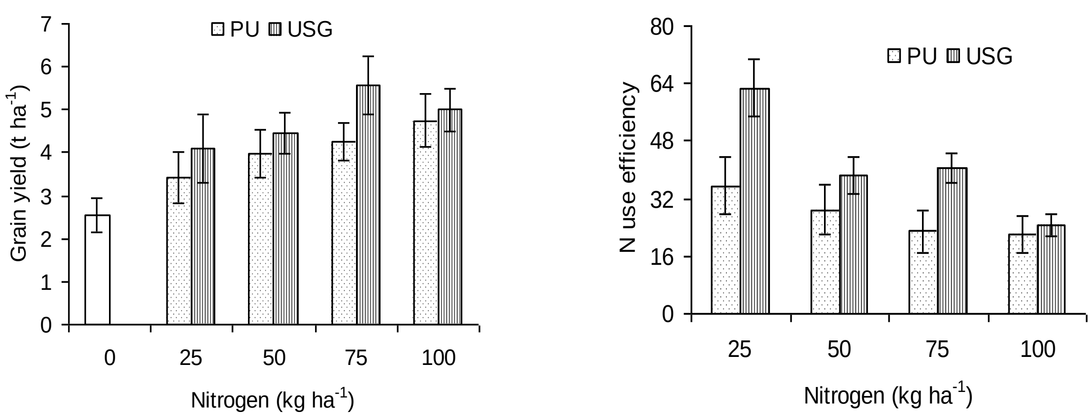

Fig. 2. Effect of source of nitrogen on rice yield and nitrogen use efficiency. PU = Prilled urea, USG = Urea super granule, The vertical bars represent the standard error.

3.2. Experiment 2

3.2.1. Yield components

Different water stress exerted significant influence on panicles m^{-2} (Figure 3). Significantly the highest number of panicle m^{-2} was recorded from water stress before third urea top dress (T4). The second highest panicle was obtained from three split of urea fertilizer at 15, 30 and 45 DAT + continuous standing water (T6). Panicle number obtained from water stress before first urea top dress (T2) and water stress before second top dress (T3) were statistically identical. Water stress before first, second and third urea top dress (T5) gave minimum panicle but higher than control, no fertilizer + continuous standing water, (T1). Water stress did not exert significant influence on grains panicle-1 (Figure 3). Numerically maximum higher number of grains panicle-1 was obtained from T6 followed by T5 and T3. More or less similar number of grains panicle-1 was recorded from T2 and T4 but lowest from T1. Weight of 1000-grains did not significantly influence by water stress treatment (Figure 3). Numerically maximum 1000-grain weight was obtained from T1 followed by T5. More or less similar 1000-grain weight was recorded from T2, T3, T4 and T6.

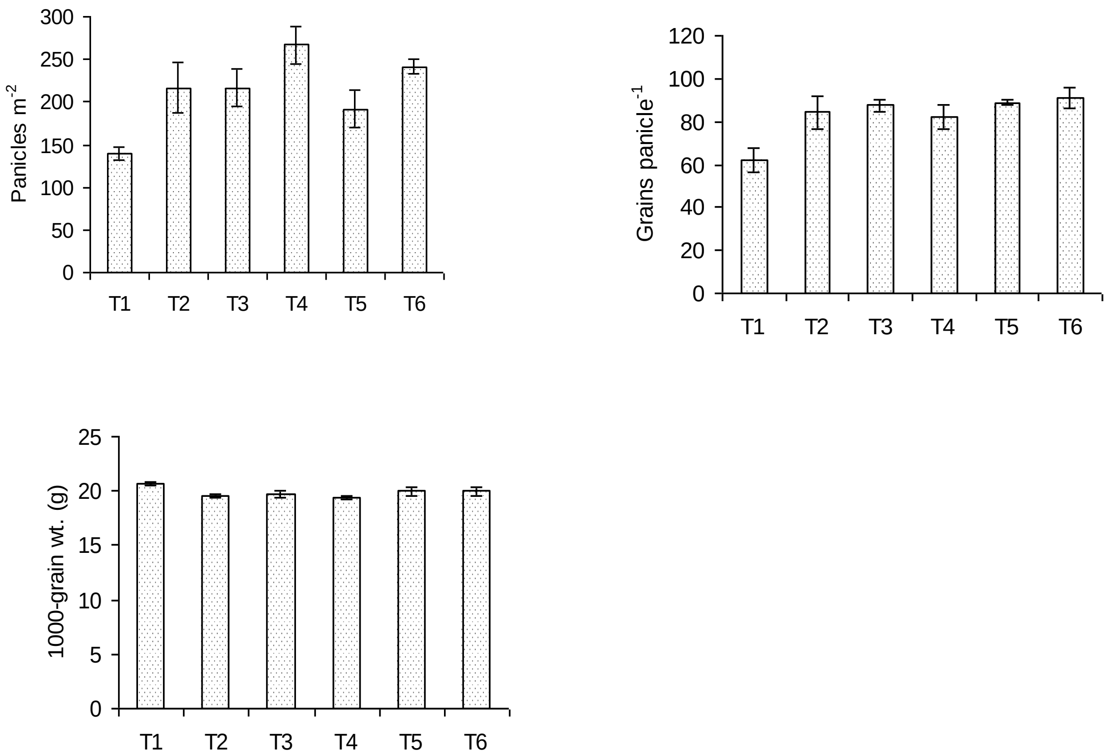

Fig. 3. Effect of different water stress on yield component of rice. The vertical bars represent the standard error. T1 = No fertilizer + continuous standing water, T2 = Water stress before first urea top dress, T3 = Water stress before second top dress, T4 = Water stress before third urea top dress, T5 = Water stress before first, second and third urea top dress, T6 = all fertilizer + continuous standing water

3.2.2. Yield and nitrogen use efficiency

Water stress exerted significant effects of grain yield (Figure 4). Statistically the highest grain yield was recorded from water stress before third urea top dress (T4) which was similar with all fertilizer + continuous standing water (T6). Statistically identical grain yield was obtained from water stress before first urea top dress (T2), water stress before second top dress (T3) and water stress before first, second and third urea top dress (T5).

The lowest grain yield was obtained from control (T1). Nitrogen use efficiency was 17 in T4 which was statistically similar with T6 (15). Water stress before first urea top dress (T2) and water stress before second top dress (T3) gave identical nitrogen use efficiency. The lowest nitrogen use efficiency was obtained from water stress before first, second and third urea top dress (T5).

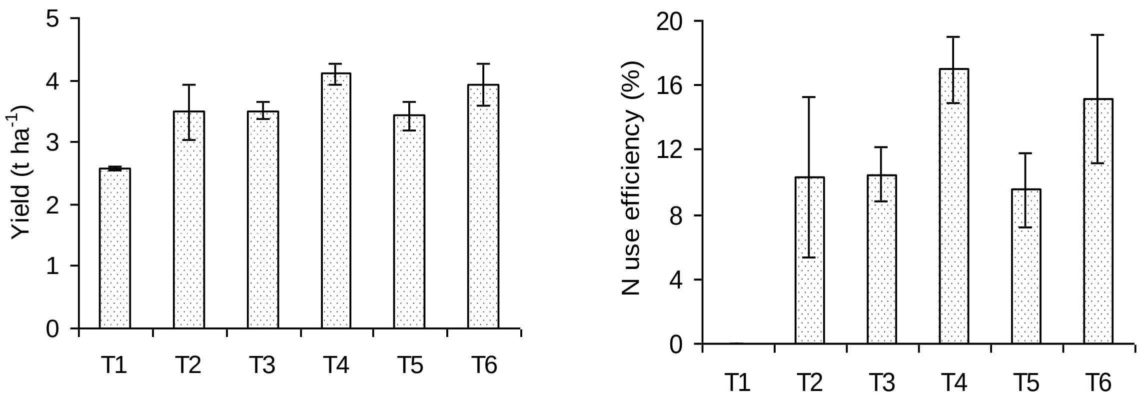

Fig. 4. Effect of different water stress on yield and nitrogen use efficiency. The vertical bars represent the standard error. T1 = No fertilizer + continuous standing water, T2 = Water stress before first urea top dress, T3 = Water stress before second top dress, T4 = Water stress before third urea top dress, T5 = Water stress before first, second and third urea top dress, T6 = all fertilizer + continuous standing water

5. Conclusion

Urea super granule produced higher grain yield and better use of nitrogen than prilled urea. Urea super granule at 75 kg N ha^{-1} was enough for rice production in aman season but when prilled urea was used farmers required 100 kg N ha^{-1}. During application of prilled urea water stress before third top dress gave higher yield and nitrogen use efficiency than continuous standing water.

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