J. Bangladesh Agril. Univ. 12(1): 37– 43, 2014 ISSN 1810-3030

Nitrogen use efficiency and rice yield as influenced by the application of prilled urea and urea super granule with or without organic manure

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Abstract

An experiment was conducted to examine the effect of prilled urea (PU), and urea super granule (USG) alone or in combination with poultry manure or cowdung on NH_4-N content of rice field with nitrogen use efficiency (NUE) and the yield of rice (cv. BRRI dhan50). The experiment was carried out at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during Boro season of 2012 and laid out in a randomized complete block design with three replications. There were six treatments viz. T_1 (Control), T_2 (78 kg N ha^{-1} from USG), T_3 (136 kg N ha^{-1} from PU), T_4 (58 kg N ha^{-1} from USG), T_5 (58 kg N ha^{-1} from USG + 3 t ha^{-1} poultry manure) and T_6 (58 kg N ha^{-1} from USG + 5 t ha^{-1} cowdung). All plots received recommended doses of P, K, S and Zn fertilizers. The NH_4-N in rice field water increased rapidly when N was applied as PU. In contrast, NH4-N release was very slow when applied as USG over the crop growth period. Application of PU, USG alone or in combination with poultry manure or cowdung significantly influenced grain and straw yield, all the yield components except 1000-grain weight of BRRI dhan50. Urea super granule with poultry manure (treatment T_5) produced the highest grain and straw yield and the lowest values were recorded from control. Nitrogen content and uptake, apparent N recovery and NUE were also influenced significantly by the application of PU, and USG alone or in combination with organic manure. Among the treatments, T_5 demonstrated the highest N recovery and NUE. The overall results suggest that application of USG in combination with poultry manure could be considered more effective for increasing the yield and NUE of BRRI dhan50.

Keywords: Prilled urea, USG, Organic manure, NUE, BRRI dhan50

Introduction

Nitrogen (N) is the most limiting factor in crop production. Hence, application of N fertilizer results in higher biomass yields and protein content in plant tissue (Blumenthal *et al.*, 2008).In most cases, surface broadcasting of PU is practiced by farmers to meet up the N demand for rice crop. Broadcasting of urea to agricultural soils can result in considerable losses by NH_3 volatilization (Rochette *et al*., 2009). Ammonia (NH_3) volatilization is an important pathway for fertilizer N loss from soil and is also a major source of air and environmental pollution (Wang *et al*., 2004). Bhuiyan *et al.* (1988) reported that deep point placement of USG produced significantly higher grain yield of rice than split application of PU. Further, increases in grain yield, better N use efficiency (kg grain per kg N) and higher apparent N recovery occurred when the whole was closed after USG application. Similarly, Mohanty *et al.* (1999) reported that USG deep placement resulted in additional grain yield of 1080, 510 and 350 kg/ha over prilled urea in alternate wetting and drying, shallow low land and intermediate low land, respectively. Broadcast application of N as urea resulted in an average 10 times higher amounts of ammonium N in flood water compared to deep placement of urea briquette and NPK briquette (Kapoor et al. (2008).

There is increased emphasis on the impact on environmental quality due to continuous use of chemical fertilizers. The integrated nutrient management system is an alternative and is characterized by reduced input of chemical fertilizers and combined use of chemical fertilizers with organic materials such as animal manures, crop residues, green manure and composts. Based on the evaluation of soil quality indicators, Dutta *et al.* (2003) reported that the use of organic fertilizers together with chemical fertilizers, compared to the addition of organic fertilizers alone, had a higher positive effect on microbial biomass and soil health. Application of organic manure in combination with chemical fertilizer has been reported to increase absorption of N, P and K in sugarcane leaf tissue in the plant and ratoon crop, compared to chemical fertilizer alone (Bokhtiar & Sakurai, 2005). In the recent years poultry farms of different sizes have been established all over the country. As poultry excreta are rich in nutrients, these can be a good source of manure of field crops. Poultry manure is widely used as an alternative source of N, P, and K for crops and forages and is often applied at excessive rates of both N and P (Mitchell & Tu, 2006).

Therefore, use of poultry manure (PM) and cowdung (CD) in combination with USG may optimize the need for N requirement of rice. Therefore, the present study was undertaken to examine the effect of PU and USG alone or in combination with poultry manure or cowdung on water NH_4-N content, apparent N recovery, NUE and the yield of BRRI dhan50.

Materials and Methods

Experimental site and period

The field experiment was carried out at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh from January to May, 2012.

Soil

Experimental fields belong to the Non-calcareous Dark Grey Floodplain Soils under the Old Brahmaputra Floodplain agro-ecological region (FAO-UNDP, 1988). The soil was silt loam in texture having pH 6.09, organic matter content 2.02%, total N 0.117%, available P 3.19 ppm, exchangeable K 0.092 me%, available S 9.52 ppm and EC 233 µS cm^{-1}.

Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. There were six treatments viz. T_1 (Control), T_2 (78 kg N ha^{-1} from USG), T_3 (136 kg N ha^{-1} from PU), T_4 (58 kg N ha^{-1} from USG), T_5 (58 kg N ha^{-1} from USG + 3 t ha^{-1} poultry manure) and T_6 (58 kg N ha^{-1} from USG + 5 t ha^{-1} cowdung). The nutrient content of cowdung and poultry manure has been depicted below:

Table 1. Nutrient content of cowdung and poultry manure

Manure	Nutrient content (%)			
	N	P	K	S
Poultry manure	1.18	1.13	0.81	0.35
Cowdung	0.57	0.47	0.69	0.17

Cultural Operations

Thirty-five-day old rice seedlings were transplanted at a spacing of 20 cm × 10 cm. Intercultural operations such as irrigation and drainage, weeding and pest control were done when required. The first dose of PU and USG was applied 8 days after transplanting (DAT); the second dose of PU was added as top dressing 38 DAT (active tillering stage); the third dose of PU was added as top dressing 68 DAT (panicle initiation stage).

Data Collection

The plant height was measured from the ground level to the top of the panicle. Total numbers of effective tillers $hill^{-1}$ and filled grains $panicle^{-1}$ were also measured. Panicle length was measured from basal node of the rachis to apex of each panicle. The 1000-grain weight was recorded by an electrical balance after sun drying. Grain and straw yields were recorded from 1 m^2 area of each plot and expressed in kg/ha.

Analyses of Soil Samples

The initial soil samples were analyzed for soil texture, pH, and organic matter, total N, available P, exchangeable K and EC. Particle size analysis of soil was done by hydrometer method ((Black, 1965) and the textural class was determined from Marshall's Triangular Coordinate. Soil pH was measured with the help of a glass electrode pH meter (Michael, 1965). Organic matter was determined by wet oxidation method ((Walkley and Black, 1934). Total N was determined by Semi-micro Kjeldahl method (Bremner and Mulvaney, 1982) and available P was determined colorimetrically by stannous chloride ($SnCl_2$) method (Olsen *et al.*, 1954). Exchangeable K and available S were determined by flame photometer (Knudsen *et al.*, 1982) and a spectrophotometer method (Williams and Steinbergs, 1959), respectively. The EC of soil was determined by conductivity meter.

Water sampling

The surface water in the rice field was collected twice, at first top dressing of PU and deep placement of USG and at second top dressing of PU. Both the time water sampling was done before irrigation and two hours after irrigation followed by next seven days sampling maintaining a specific time of the day to analyze flood water NH_4-N.

Determination of NH_4-N

Ammonium nitrogen of water samples was determined by titrimetric method as outlined by APHA (1998).

Measurement of nitrogen

Nitrogen contents in the plant samples were determined by Kjeldahl method. Nitrogen uptake was calculated multiplying the N content (%) by the corresponding yield divided by 100.

Apparent N Recovery (ANR) was measured by the following formula:

$$ANR\ (kgha^{-1}) = \frac{NU_F - NU_C}{FN}$$

Where, NU_F = Total N uptake in fertilized plot, NU_C = Total N uptake in control plot and FN = Fertilizer N applied (kg ha^{-1}).

Nitrogen Use Efficiency (NUE) was measured by the following formula:

$$NUE = \frac{Y_F - Y_C}{FN}$$

Where, Y_F = Yield of fertilized plot, Y_C = Yield of control plot and FN = Fertilizer N applied (kg ha^{-1}).

Statistical Analysis

The analysis of variance of different parameters of the treatments was made and then mean differences were judged by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Irrigation water NH_4-N

Fig. 1 shows the effect USG and PU on NH_4-N concentration of water in BRRI dhan50 field. The amount of NH_4-N in the BRRI dhan50 field water was determined consecutively for 7 days after the application of PU and USG to monitor the release and availability of NH_4-N from nitrogenous fertilizers. The measurement was done three times. First measurement was done after application of first split of PU as well as deep placement of USG. Second one was done after application of second split of PU and the third one was done after the application of third split of PU. In first sampling, the amount of available NH_4-N in rice field water started to increase after 2 hours of application, continued up to 2 days and then decreased gradually (Fig. 1). Similar results were obtained for the 2nd and 3rd sampling (data not shown). In comparison with PU, the USG application generated available NH_4^+-N slowly rather spontaneously over the time indicating a beneficial role of USG.

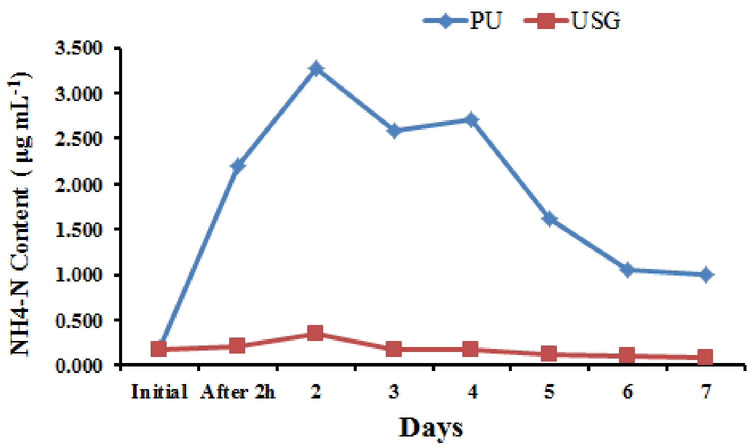

Fig. 1. Effect of PU and USG on the NH_4-N content of irrigation water

Yield contributing characters of BRRI dhan50: The effect of nitrogen supplied from PU, USG and manures on the yield components of BRRI dhan50 has been shown in Table 2. Plant height was increased due to application of USG alone or in combination with poultry manure. The tallest plant of 88.9 cm was found in T_5 which was statistically similar with T_2, T_3, T_4 and T_6 and the smallest plant of 76.3 cm was noted in control. The maximum number of effective tillers hill^{-1} was found in T_5 and the minimum value was observed in T_1. The largest panicle length was also found in T_5. Filled grains panicle^{-1} of BRRI dhan50 was influenced profoundly due to application of USG alone or in combination with poultry manure. The 1000-grain weight was not influenced significantly due to different treatments. The results are in agreement with Jahan *et al.* (2014) who obtained similar findings from a trial with USG and PU on rice.

Table 2. Effect of PU and USG with or without organic manures on the yield components of BRRI dhan50

Treatment	Plant height (cm)	Effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	1000-grain weight (g)
T_1	76.3b	10.33d	18.98b	96.0b	19.25
T_2	87.7a	13.67ab	22.69a	123.0a	19.80
T_3	82.1ab	11.67c	20.74ab	113.0a	19.57
T_4	84.7a	12.33c	22.08a	118.7a	19.75
T_5	88.9a	14.33a	22.82a	125.3a	19.93
T_6	86.9a	12.67bc	22.45a	119.7a	19.05
SE(±)	1.91	0.58	0.61	4.34	NS
CV%	5.06	5.49	5.06	6.69	6.25

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, NS= Non Significant

Grain and straw yields of BRRI dhan50: Application of PU and USG alone or in combination with poultry manure and cowdung showed a positive effect on the grain yield of BRRI dhan50 (Table 3). It was found that the grain yield ranged from 2431 kg ha^{-1} to 4700 kg ha^{-1}. The highest grain yield was recorded in T_5 and the lowest value was recorded in T_1. The treatment T_3, T_4 and T_6 produced the identical grain yield. USG in association with poultry manure treated plot gave better grain yield than other treatments. This might be due to optimum release of N from deep placed USG for prolonged period and adequate release of N and other nutrients from poultry manure. Gupta *et al*. (1995) observed that PM and FYM produced yields of 4.1 and 3.9 t ha^{-1} of rice grain respectively. Rajput *et al*. (1992) reported that application of PM, FYM and cowdung with chemical fertilizers was found to produce higher grain yield than from chemical fertilizers alone.

Table 3. Effect of PU and USG with or without organic manures on grain and straw yield of BRRI dhan50

Treatment	Grain yield (kg ha^{-1})	Increase over control (%)	Straw yield (kg ha^{-1})	Increase over control (%)
T_1	2431c	-	2930c	-
T_2	4541a	86.77	5714a	94.98
T_3	3526b	45.00	4671b	59.38
T_4	3800b	56.27	4790b	63.47
T_5	4700a	89.28	5888a	95.92
T_6	3925b	61.41	4918b	67.82
SE(±)	332.69	-	429.86	-
CV%	6.77	-	7.61	-

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.

The straw yield of BRRI dhan50 was also influenced significantly due to the application of PU, USG, poultry manure and cowdung as shown in (Table 3). The highest straw yield of 5888 kg ha^{-1} was obtained in T_5 and the lowest value of 2930 kg ha^{-1} was noted in T_1. The treatments may be ranked in the order of $T_5>T_2>T_6>T_4>T_3>T_1$ in terms of straw yield as depicted in (Table 3). Regarding the percent increase of straw yield, maximum increase (95.92%) was noted in T_5 and the minimum increase (59.38%) was found in T_3 as demonstrated. These results support the findings of Ahmed and Rahman (1991) who reported that the application of organic matter and chemical fertilizer increased straw and grain yields of rice. Rahman *et. al.* (2009) reported that the application of urea-N in combination with cowdung and poultry manure increased the straw yields of rice.

Nitrogen content

Table 4 shows the effects of PU, USG, CD and PM on the nitrogen content of BRRI dhan50. The grain N content varied from 1.03% to 1.32%. The highest N content of 1.32% was observed in T_5 and the lowest N content of 1.03% was noted in T_1. Application of USG in combination with poultry manure increased the N content in rice grain markedly in T_5 which was statistically different from other treatments. In case of straw, The N content of BRRI dhan50 also varied significantly due to different treatments (Table 4). The N content in straw ranged from 0.46% in T_1 to 0.75% in T_5. The effect of poultry manure in combination with USG was more pronounced in increasing the N content both in grain and straw of BRRI dhan50 compared to other treatments. The cowdung combined with USG also increased the N content in both grain and straw but not like poultry manure. The results reveal that the N content in rice grain was higher than that of straw. Bhaskaram and Krisna, (2009) also reported a significant increase in N content in rice grain and straw due to manures and fertilizers application.

Table 4. Effect of PU and USG with or without organic manures on the N content and uptake by BRRI dhan50

Treatments	N content (%)		N uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1 (Control)	1.03c	0.46c	24.85d	13.55e	38.40e
T_2 (78 kg N ha^{-1} from USG)	1.30ab	0.64b	59.09a	36.30b	95.39b
T_3 (136 kg N ha^{-1} from PU)	1.10c	0.50bc	38.73c	23.40d	62.13d
T_4 (58 kg N ha^{-1} from USG)	1.16bc	0.54bc	43.96bc	25.76cd	69.72c
T_5 (58 kg N ha^{-1} from USG + 3 ton ha^{-1} PM)	1.32a	0.75a	60.19a	41.67a	101.86a
T_6 (58 kg N from USG + 5 t ha^{-1}CD)	1.17abc	0.56bc	45.88b	27.54c	73.42c
SE	0.05	0.05	5.68	4.78	10.37
CV%	7.06	11.95	6.37	4.89	3.96

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.

Nitrogen uptake

The N uptake both by grain and straw of BRRI dhan50 increased significantly due to application of PU, USG, poultry manure and cowdung (Table 4). The N uptake by grain ranged from 24.85 kg ha^{-1} to 60.19 kg ha^{-1} and that by straw from 13.55 kg ha^{-1} to 41.67 kg ha^{-1}. The highest N uptake by grain (60.19 kg ha^{-1}) and straw (41.67 kg ha^{-1}) was obtained in T_5 and the lowest N uptake by grain (24.85 kg ha^{-1}) and straw (13.55 kg ha^{-1}) was found in T_1. The total N uptake by rice was also influenced significantly by different treatments (Table 4). The highest total N uptake (101.86 ha^{-1}) was observed in T_5 and the lowest value (38.40kg ha^{-1}) was found in T_1. The treatments may be ranked in the order of $T_5 > T_2 > T_6 > T_4 > T_3 > T_1$ in terms of N uptake. Jahan *et al.* (2014) reported that the N uptake by rice grain and straw was increased significantly with the application USG alone or in combination with poultry manure. Rahman*et al.* (2009) and Akter*et al*. (2012) also reported similar results.

Apparent N Recovery (ANR)

The apparent N recovery by BRRI dhan50 has been presented in (Fig. 2A). Mean apparent recovery of N by rice ranged from 17.45% to 95.21%. The data clearly indicate that the maximum values of apparent N recovery were obtained with the application of USG in combination with poultry manure. The reasons for high recovery of applied N could be the deep placement of USG in rice field that resulted in continuous supply of available N throughout the growth period of rice plant.

N Use Efficiency (NUE)

Agronomic nitrogen use efficiency (NUE) is a term used to indicate the relative balance between the amount of fertilizer N taken up and used by the crop versus the amount of fertilizer N lost. Nitrogen use efficiency represents the response of rice plant in terms of grain yield to N fertilizer. The highest value of NUE was obtained in T_5 and the lowest value was found in T_3. The range of NUE varied from 8.05 to 29.85 (Fig. 2B). This result indicates that application of USG in combination with poultry manure in rice field decreases the losses of N or the rate of N, leading to efficient uptake and utilization of applied N. Akter *et al.* (2012) and Jahan *et al.* (2014) also reported similar results.

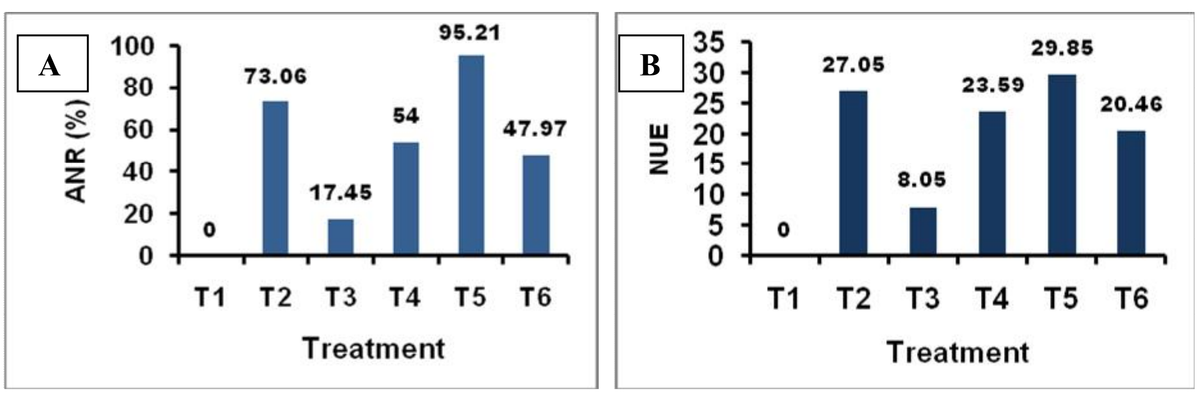

Fig. 2. Apparent N recovery (A) and NUE (B) of BRRI dhan50 as influenced by different treatments

Conclusion

The results of the present study indicate that treatments T_2 (78 kg N ha^{-1} from USG) and T_5 (58 kg N from USG + 3 t ha^{-1} PM) were statistically at par with in producing grain and straw yields of BRRI dhan50, but the use of T_5 (58 kg N from USG + 3 t ha^{-1} PM) may be a better choice for rice cultivation considering the efficient use of nitrogen. However, application of 58 kg N from USG and 3 t ha^{-1} PM may be tested in different AEZs of Bangladesh before making final inference.

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