



Floodwater Nitrogen, Rice Yield and N Use Efficiency as Influenced by Deep Placement of Nitrogenous Fertilizers

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Abstract: An experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during the Aus season of 2012 to investigate the effects of deep placement of nitrogen (N) fertilizers on floodwater $\text{NH}_4\text{-N}$ concentration, rice yield and N use efficiency under alternate wetting and drying (AWD) condition. The experiment was laid out in a randomized complete block design with three replications. There were eight treatment combinations viz. T₁ (Control), T₂ [52 kg N from Urea super granule (USG)], T₃ (104 kg N from USG), T₄ [78 kg N from prilled urea (PU)], T₅ (120 kg N from PU), T₆ (51 kg N from NPK briquette), T₇ (78 kg N from USG) and T₈ (78 kg N from NPK briquette). The results regarding the floodwater $\text{NH}_4\text{-N}$ concentration revealed that, the highest value of ($\text{NH}_4\text{-N}$) was observed at the second day of PU application followed by gradual decrease with time. USG and NPK briquette treated plots showed negligible amounts of $\text{NH}_4\text{-N}$ in flood water during the sampling periods. The highest grain yield (5265 kg ha^{-1}) and straw yield (6434 kg ha^{-1}) was recorded from 104 kg N from USG (treatment T₃) and the lowest values were obtained from control. Apparent nitrogen recovery by rice plants was much higher when 78 kg N was applied as USG. Nitrogen use efficiency decreased with the increase in N rate either as PU, USG and NPK briquette and treatment T₇ (78 kg N as USG) showed the highest value. These results clearly indicate that the deep placement of N in the form of USG and NPK briquette minimizes the loss of N that results in higher N use efficiency and increased grain yield of rice as compared to broadcast application of N in the form of PU.

Key Words: Deep placement of N, Flood water Ammonium, Rice yield, Nitrogen Use Efficiency

Introduction: Rice (*Oryza sativa* L) dominates the Bangladesh agriculture sector covering 80% of the total cropped area of the country (AIS, 2008). For boosting the yield of rice, farmers are using different chemical fertilizers especially nitrogen, phosphorus and potassium. Nitrogen (N) is the most important nutrient element for crop production. Farmers of Bangladesh use mainly urea in rice field as the most available source of nitrogen. Annual requirement of urea of the country is about 24 lakh ton of which 50% is met by the domestic production. The rest amount of urea needs to be imported by spending a large amount of foreign currency (BBS, 2010). In rice cultivation system generally, N fertilizers are applied in the soil surface as conventional broadcast method. The lion part of those applied fertilizers is getting lost through a number of processes including volatilization, denitrification, run-off, leaching and fixation. These result in low crop yield and reduced efficiency of applied N. The efficiency of applied N from urea fertilizer is very low (30-35 %) in rice cultivation under continuous flooding condition (IFDC, 2007). On the contrary, alternate wetting and drying cultivation of rice can save 30% water and minimizes N losses to a significant extent. Loss of fertilizer-derived N_2 from continuous flooded soils has been found to be rather low (<10%, Nicolaisen *et al.*, 2004). In this situation, the deep placement of N

fertilizers (USG and NPK briquette) into the anaerobic soil zone is an effective method to reduce volatilization loss (Mikkelsen *et al.*, 1978). Deep placement of USG at 8-10 cm depth of soil can save 30% N compared to PU, increases absorption rate, improves soil health and ultimately increases rice yield (Savant *et al.*, 1991).

Again, the deep placement of USG and NPK briquette minimizes the concentration of $\text{NH}_4\text{-N}$ in floodwater compared to broadcast application of PU. Kapoor *et al.* (2008) reported that broadcast application of N as urea resulted on an average 10 times higher amounts of ammonium N in flood water compared to deep placement of urea briquette and NPK briquette. Islam *et al.* (2011) reported that application of NPK briquette (2.4 g x 2) produced the highest rice grain yield of 7.47 t ha^{-1} and demonstrated higher agronomic efficiency than PU and USG. They also observed that NPK briquette can save 33 kg N ha^{-1} compared to recommend PU. The results indicate that a great reduction in $\text{NH}_4\text{-N}$ concentration in floodwater occurs with urea deep placement (UDP). Based upon the reduced level of applied N required with UDP, it is apparent that there will also be a reduction in N losses to the atmosphere. Moreover, deep placement method of fertilizer application is environment-friendly and will not decrease the

normal fertility of land (BRRI, 2010). However, information on deep placement of N in rice cultivation especially under AWD condition is scarce in Bangladesh. Therefore, the present study was undertaken to evaluate the effect of deep placement of N fertilizers (USG and NPK briquette) on rice yield, N use efficiency and floodwater $\text{NH}_4\text{-N}$ in BRRI dhan27 cultivation.

Materials and Methods

The study was carried out at the Soil Science Field laboratory of Bangladesh Agricultural University, Mymensingh during the Aus season of 2012. The soil of the experimental site belongs to the Sonatala series under the AEZ of Old Brahmaputra Floodplain. The soil was silt loam in texture having pH 6.07, organic matter content 1.10%, total N 0.145%, available P 3.8 ppm, exchangeable K 0.12 me% and available S 14.56 ppm. There were eight treatments with three replications. The treatments were T_1 (Control), T_2 (52 kg N from USG), T_3 (104 kg N from USG), T_4 (78 kg N from PU), T_5 (120 kg N from PU), T_6 (51 kg N from NPK briquette), T_7 (78 kg N from USG), T_8 (78 kg N from NPK briquette). The experiment was laid out in a randomized block design. BRRI dhan27 was used as the test crop. Thirty-day old seedlings of BRRI dhan27 were transplanted in the experimental plots maintaining a spacing of 20 cm x 20 cm. Three seedlings were transplanted in each hill. Intercultural operations such as irrigation, weeding etc. were done as and when required. For maintaining AWD condition a PVC pipe was used and irrigations were applied when water level goes below 15 cm from the soil surface.

The fertilizers were applied as per treatments. All the treatments except T_6 and T_7 received 16 kg P and 42 kg K ha^{-1} from TSP and MoP, respectively. Prilled urea was applied in three equal splits. The first split was applied after 7 days of transplanting. The second and third splits of PU were applied after 30 and 45 days of transplanting. Before application of N fertilizers, the water in the rice plots was drained out. PU was applied to the fields and mixed with the soils. The USG and NPK briquettes were placed at 8-10 cm depth between four hills at alternate rows after 7 days of transplanting.

Water samples were collected for three different times from BRRI dhan27 rice field. First sampling was done immediately after the application of USG, NPK briquettes and PU. The second and third samplings were done after each split application of PU. For every sampling, water samples were collected for seven consecutive days. The collected water samples

were brought to the laboratory for determining $\text{NH}_4\text{-N}$ concentration. The concentration of $\text{NH}_4\text{-N}$ was determined by Phenol-hypochlorite method (Solorzano, 1969).

The crop was harvested at full maturity and the grain and straw yields were recorded. The grain yield was expressed on 14% moisture basis and the straw yield on sun dry basis. The grain and straw samples were analyzed for N content following semi-micro Kjeldahl method (Bremner and Mulvaney, 1982). The N uptake by grain and straw was determined from N content and yield data. The N use efficiency ($\text{kg grain yield increase kg}^{-1}$ N applied) and apparent N recovery were determined by the following formulae: $\text{NUE} = (\text{Gy}_{+\text{N}} - \text{Gy}_{\text{ON}}) / \text{FN}$, where $\text{Gy}_{+\text{N}}$ = grain yield in treatment with N application; Gy_{ON} = grain yield in treatment without N application and FN = amount of fertilizer N applied (kg ha^{-1}) and $\text{ANR} (\text{kg ha}^{-1}) = (\text{UN}_{+\text{N}} - \text{UN}_{\text{ON}}) / \text{FN}$. Where, $\text{UN}_{+\text{N}}$ is total N uptake (kg ha^{-1}) with grain and straw; UN_{ON} is the N uptake (kg ha^{-1}) in control; FN is amount of fertilizer N applied (kg ha^{-1}). All the data were statistically analyzed by F-test and the mean differences were ranked by DMRT at 5% level (Gomez and Gomez, 1984).

Results and Discussion

$\text{NH}_4\text{-N}$ concentration in rice field water

The results on the $\text{NH}_4\text{-N}$ concentration in floodwater as influenced by different treatments have been reported in Figure 1. In all three samplings, the amount of available $\text{NH}_4\text{-N}$ in rice field water released from PU (T_4 and T_5) started to increase after application of PU, continued up to 2-3 days and then decreased gradually up to 7 days (Figure 1). In USG and NPK briquette plots, the $\text{NH}_4\text{-N}$ in surface water did not show any significant variation among the treatments including T_2 , T_3 , T_6 , T_7 and T_8 although the values of $\text{NH}_4\text{-N}$ in first sampling were a bit higher than that in second and third samplings as USG and NPK briquette were not applied in the preceding samplings. However, a continuous release of $\text{NH}_4\text{-N}$ in the rice field water was observed during the sampling period in case of deep placement of USG and NPK briquette. In first sampling, the treatment with 120 kg N from PU (T_5) showed higher $\text{NH}_4\text{-N}$ concentration than those with 78 kg N from urea (T_4). In both the treatments (T_4 and T_5), the highest concentration of $\text{NH}_4\text{-N}$ was observed at day 2 and then decreased with time. By day 6 the concentration of $\text{NH}_4\text{-N}$ in all treatments became almost similar. The USG treated plots (T_2 , T_3 and T_7) and NPK briquette treated plots (T_6 and T_8) had much lower concentration of $\text{NH}_4\text{-N}$ in floodwater indicating that deep placement of urea fertilizer can reduce N loss

by NH_3 volatilization. Deep placement of N reduces $\text{NH}_4\text{-N}$ in water. This not only improves fertilizer N use efficiency of rice but also minimizes N loss resulting from ammonia volatilization and denitrification (Savent and Stangel, 1990; Mohanty *et al.* 1999). Xiang *et al.* (2013) also found lower $\text{NH}_4\text{-N}$

in floodwater in deep placed fertilizer treated plots compared to traditional broadcast application of PU. In case of second and third sampling, the amount of available $\text{NH}_4\text{-N}$ in flood water of BRRi dhan27 rice field followed the similar trend as that of first sampling.

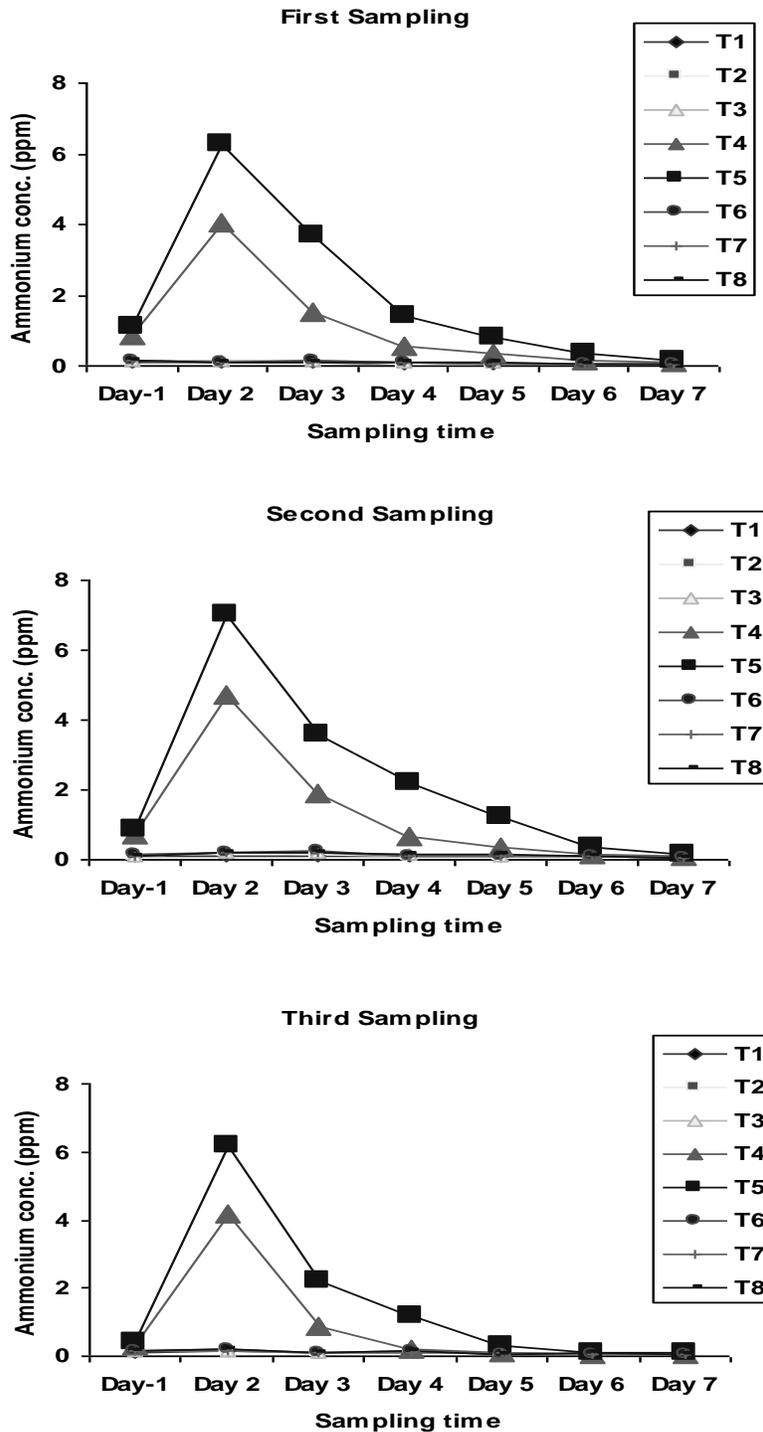


Fig 1: Ammonium concentration in floodwater after application of N fertilizers

Grain yield

The grain yield of BRRI dhan27 ranged from 3133 kg ha⁻¹ to 5265 kg ha⁻¹ due to different treatments (Table 1). The highest grain yield of 5265 kg ha⁻¹ was obtained in T₃ treatment (104 kg N from USG) followed by T₇ (78 kg N from USG) and T₈ (78 kg N from NPK briquette). The grain yields obtained in treatments with 52 kg N from USG and 120 kg N from PU were statistically similar. Again, in treatments with 78 kg N from PU and 51 kg N from NPK briquette produced statistically similar grain yield. The lowest grain yield of 3133 kg ha⁻¹ was observed in T₁ (control). The increase in grain yield over control ranged from 32.60 to 68.04% where the highest increase was obtained in T₃ and the lowest one was obtained with T₄ (Table 1). USG followed by NPK briquettes performed better in increasing grain yield of rice compared to PU. The increase in rice yield as observed in the present study is due to the spontaneous supply of nitrogen from USG and NPK briquettes throughout the growing period of rice and due to minimum loss of nitrogen as because of deep

placement. These findings are well supported with Kapoor *et al.* (2008); Islam *et al.* (2011) and Naznin *et al.* (2013) who observed increased rice yield due to application of USG and NPK briquettes.

Straw yield

Straw yield of BRRI dhan27 also responded significantly to different treatments under study. The yields of straw ranged from 3944 to 6434 kg ha⁻¹ (Table 1). The highest straw yield of 6434 kg ha⁻¹ was obtained in T₃ (104 kg N from USG) which was identical with that of treatment T₇ (78 kg N from USG). The straw yield produced by treatments with 52 kg N from USG, 78 kg N from PU and 51 kg N from NPK briquette were statistically similar. Regarding the percent increase of straw yield, maximum increase (63.14%) was noted in T₃ and the minimum one (20.98%) was found in T₆ as shown in Table 1.

Table 1. Effect of deep placement of N fertilizers on the yield of BRRI dhan27

Treatments	Grain yield (kg ha ⁻¹)	% increase over control	Straw yield (kg ha ⁻¹)	% increase over control
T ₁ (Control)	3133f	-	3944e	-
T ₂ (52 kg N from USG)	4453d	42.14	5121d	29.83
T ₃ (104 kg N from USG)	5265a	68.04	6434a	63.14
T ₄ (78 kg N from PU)	4154 e	32.60	4906d	24.40
T ₅ (120 kg N from PU)	4431d	41.43	5574c	41.34
T ₆ (51 kg N from NPK briquette)	4228e	34.94	4771d	20.98
T ₇ (78 kg N from USG)	5154b	64.49	6284ab	59.33
T ₈ (78 kg N from NPK briquette)	4870c	55.44	5933bc	50.44
CV (%)	1.06	-	4.16	-
SE (±)	27.31	-	129	-

The figure(s) in a column do not differ significantly at 5% level of probability

CV= Co-efficient of variation and SE = Standard error of means

Nitrogen content

The N content in grain and straw of BRRI dhan27 was influenced significantly by the application of PU, USG and NPK briquettes (Table 2). The highest N content of 1.21% was observed in T₃ (104 kg N from USG) which was statistically similar with that of treatment T₇ (78 kg N from USG) and T₈ (78 kg N from NPK briquette) with the value of 1.19 and 1.15%. The lowest N content of 0.91% was noted in T₁ (Control). The N content in the straw ranged from 0.52% in T₁ to 0.71 in T₃. The results revealed that N content in rice grain was higher than that of straw.

Nitrogen uptake

The N uptake both by grain and straw of BRRI dhan27 varied significantly due to deep placement of USG and NPK briquettes. The N uptake by grain ranged from 28.47 to 63.83 kg ha⁻¹ and that by straw from 20.48 to 45.64 kg ha⁻¹. The highest N uptake by grain (63.83 kg ha⁻¹) and by straw (45.64 kg ha⁻¹) was recorded in T₃ (104 kg N from USG) which was identical with treatment T₇ (78 kg N from USG) and the lowest N uptake by grain (28.47 kg ha⁻¹) and by straw (20.48 kg ha⁻¹) was found in T₁ (Table 2). The highest total N uptake (109.5 Kg ha⁻¹) was observed in T₃ and the lowest value (48.95 Kg ha⁻¹) was found in T₁. Jahan *et al.* (2014) observed increased N uptake by the deep placement of USG.

Table 2. N content and uptake of BRR1 dhan27 as influenced by deep placement of N fertilizers

Treatments	N content (%)		N uptake (kg ha ⁻¹)		
	Grain	Straw	Grain	Straw	Total
T ₁ (Control)	0.91e	0.52h	28.47f	20.48e	48.95e
T ₂ (52 kg N from USG)	1.08cd	0.67c	48.04cd	34.43c	82.47c
T ₃ (104 kg N from USG)	1.21a	0.71a	63.83a	45.64a	109.5a
T ₄ (78 kg N from PU)	1.05cd	0.56g	43.58de	27.42d	71.0d
T ₅ (120 kg N from PU)	1.10bcd	0.614e	48.81c	34.25c	83.07c
T ₆ (51 kg N from NPK briquette)	1.008d	0.57f	42.61e	27.33d	69.95d
T ₇ (78 kg N from USG)	1.19ab	0.69b	61.36a	43.56a	105.0a
T ₈ (78 kg N from NPK briquette)	1.15abc	0.63d	56.01b	37.61b	93.61b
CV (%)	5.14	1.92	5.34	4.18	3.75
SE (%)	0.03	0.01	1.51	0.82	1.79

The figure(s) in a column do not differ significantly at 5% level of probability

CV= Co-efficient of variation and SE = Standard error of means

Nitrogen Use Efficiency (NUE)

Nitrogen use efficiency represents the response of rice plant in terms of grain yield to N fertilizer. The NUE of BRR1 dhan27 varied from 10.82 to 25.90 kg grain per kg N applied (Figure 2). The highest value of NUE (25.90 kg grain increase per kg N applied) was obtained in T₇ (78 kg N from USG) followed by T₂ (52 kg N from USG), T₈ (78 kg N from NPK briquette) with the value of 25.39 and 22.27 kg grain

increase per kg N applied. The lowest value (10.82 kg grain increase per kg N applied) was found in T₅ (120 kg N from PU). Deep placement of USG increased nitrogen use efficiency by keeping most of the urea nitrogen in the soil, close to plant roots and out of the irrigation water. Naznin *et al.* (2013) also observed increased N use efficiency due to deep placement of USG and NPK briquettes.

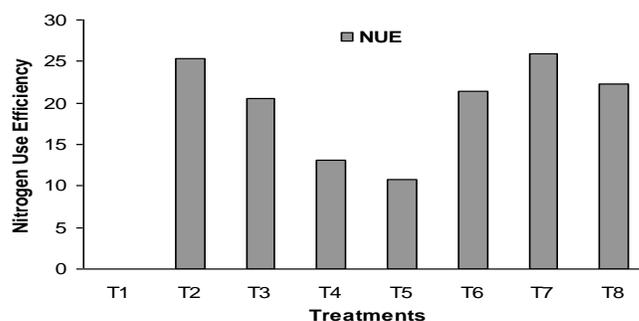


Fig 2: Nitrogen use efficiency as influenced by deep placement of N fertilizers

Apparent N Recovery (ANR)

The apparent N recovery by BRR1 dhan28 rice is presented in Figure 3. Mean apparent recovery of N by rice ranged from 28.27 to 71.76% in different treatments. The maximum value of apparent N recovery was obtained with the application of 78 kg N

from USG in treatment T₇ followed by T₂ (52 kg N from USG), T₃ (52 kg N from USG), T₈ (78 kg N from NPK briquette) and the minimum value was found in T₄ (78 kg N from PU). The data clearly indicate that the deep placement of USG and NPK briquettes enhanced the recovery of applied N

compared to broadcast application of PU. 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 nitrogen throughout the growth period of rice plant, which ultimately gave maximum N uptake.

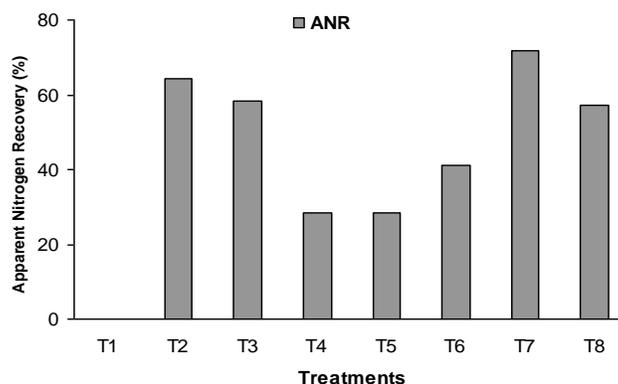


Fig 3: Influence of deep placement of N fertilizers on apparent N recovery

Conclusion

The overall results clearly indicate that the maximum values of grain and straw yields, total N uptake, apparent N recovery and N use efficiency were obtained with the deep placement of N fertilizers (USG and NPK briquette) compared to PU. The deep placement of USG and NPK briquettes enhanced the recovery of applied N and N use efficiency in comparison with broadcast application of PU. As a consequence, the grain yield of BRR1 dhan28 was increased to a significant extent. Based on overall results, it can be concluded that deep placement on N fertilizers under AWD condition can be practised for rice cultivation for getting increased yield, and N use efficiency and for reducing N losses.

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