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NITROGEN USE EFFICIENCY AND YIELD OF BRRI DHAN49 AS INFLUENCED BY DIFFERENT FORMS OF N FERTILIZERS UNDER AWD CONDITION

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A B S T R A C T

An experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during Aman season of 2016 to evaluate the effects of deep placement of N fertilizers in the form of urea super granule (USG) and NPK briquettes in comparison with prilled urea (PU) on nitrogen use efficiency and yield of BRRI dhan49. The soil was silt loam in texture having pH 6.27, organic matter content 1.95% and total N 0.136%. The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments and three replications. The treatments include T_1 (Control), T_2 (PU, 104 kg N ha^{-1}), T_3 (USG, 104 kg N ha^{-1}), T_4 (USG 78 kg N ha^{-1}), T_5 (USG, 52 kg N ha^{-1}), T_6 (NPK briquettes, 104 kg N ha^{-1}), T_7 (NPK briquettes, 78 kg N ha^{-1}) and T_8 (NPK briquettes, 52 kg N ha^{-1}). All the treatments except T_6, T_7 and T_8 received 16 kg P and 42 kg K ha^{-1} from TSP and MoP, respectively. In T_6, T_7 and T_8 treatments, P and K were supplied from NPK briquettes. The PU was applied in three equal splits. The USG and NPK briquettes were deep placed 10 DAT and the briquettes were placed at 8-10 cm depth between four hills at alternate rows. Application of PU, USG and NPK briquette under alternate wetting and drying (AWD) condition exerted significant influence on yield attributes as well as grain and straw yields of BRRI dhan49. The maximum grain yield of 6311 kg ha^{-1} (100% increases over control) and straw yield of 6956 kg ha^{-1} was recorded in T_3 (USG, 104 kg N ha^{-1}). The second highest grain yield of 5865 kg ha^{-1} produced by T_2 (PU, 104 kg N ha^{-1}) was statistically similar with T_4 (USG 78 kg N ha^{-1}) and T_6 (NPK briquettes, 104 kg N ha^{-1}). The lowest grain yield (3155 kg ha^{-1}) and straw yield (3908 kg ha^{-1}) were recorded in T_1 (Control). The deep placement of USG and NPK briquettes enhanced both the recovery of applied N and N use efficiency in comparison with broadcast application of prilled urea. The T_5 (USG, 52 kg N ha^{-1}) showed maximum apparent N recovery, and N use efficiency. Next to T_5, the T_4 depicted the position in respect of N recovery and N use efficiency. So the application of 78 kg N ha^{-1} in the form of USG can be recommended for the production of BRRI dhan49.

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INTRODUCTION

Rice (*Oryza sativa* L.) is considered as the major crop in Bangladesh as it constitutes 91.8% of the total food grain (rice, wheat & maize) production of 37.50 million metric tons (BBS 2012). Among other ecosystems, rainfed condition (T. Aman) is the most suitable for growing rice in this country. Area under T. Aman is about 49.63% of total rice land and contributes 40.57% of the total rice production (BBS, 2012). For cultivation of rice, farmers of Bangladesh mainly depend on urea fertilizer and 50% of the total demand is fulfilled by import which costs a huge amount of foreign currency. Moreover, water table is declining day by day and Aman rice is already an irrigation dependent crop in Bangladesh. 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). This applied fertilizer is getting lost to the environment through a number of processes including immobilization, denitrification, volatilization, leaching and fixation resulting low crop yield and reduced efficiency of applied nutrients. The volatilization loss of prilled urea (PU) is very high and farmers lose a huge amount of money for N fertilizer. Water saving is the main issue in maintaining the sustainability of rice production when water resources are becoming scarce (Arif et al. 2012). In the face of this troubling reality, the International Rice Research Institute (IRRI) has developed several water-saving technologies to help farmers cope better with water scarcity in their paddy fields. Intermittent irrigation or alternate wetting and drying (AWD) is one of those recently introduced in Bangladesh. In rice-growing areas, drainage water from paddy fields contaminated with N and P is thought to be the main cause of agricultural non-point-source pollution. AWD significantly reduces the amount of surface and deep (beyond the root zone) drainage from paddy fields. This in turn may reduce pollution from N and P in the drainage water and improve fertilizer-use efficiency (Belder et al. 2012).

Ammonia volatilization losses in the flooded soils range from negligible to almost 60% of the applied N (De Datta, 1985; Xing and Zhu, 2000). Deep placement of N fertilizers into the anaerobic soil zone is an effective method to reduce volatilization loss (Mikkelsen et al. 1978). Alternate wetting and drying (AWD) irrigation causing alternating oxic and anoxic conditions in top soil may lead to increased N losses from coupled nitrification-denitrification (Nicolaisen et al. 2004). Denitrification loss could be enhanced under AWD irrigation system but ammonia (NH_3) volatilization is the major N loss pathway from irrigated rice field (Eriksen et al. 1985; De Datta et al., 1991). Moreover, groundwater irrigation also makes the soils polluted with arsenic (Williams et al., 2006). Therefore, water saving rice culture is expected to be as a water saving practice in many countries such as China (Cabangon *et al*. 2004), the Philippines (Belder et al. 2004) and Japan (Chapagain and Yamaji, 2010). Hence, deep placement of N fertilizer under AWD system introduces a new dimension in the N fertilization regime. Therefore, the present study was designed and carried out to evaluate the effects of form and placement of nitrogen fertilizers on yield attributes; yield and N use efficiency of BRRI dhan49.

MATERIALS AND METHODS

The experiment was carried out in the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during the Aman season of 2016. The study was performed to evaluate the effects of form and placement of nitrogen fertilizers on yield attributes; yield and N use efficiency of BRRI dhan49. 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 6.27, organic matter content 1.95% and total N 0.136%. The treatments were T_1 (Control), T_2 (PU, 104 kg N ha^{-1}), T_3 (USG, 104 kg N ha^{-1}), T_4 (USG 78 kg N ha^{-1}), T_5 (USG, 52 kg N ha^{-1}), T_6 (NPK briquettes, 104 kg N ha^{-1}), T_7 (NPK briquettes, 78 kg N ha^{-1}) and T_8 (NPK briquettes, 52 kg N ha^{-1}). All the treatments except T_6, T_7 and T_8 received 16 kg P and 42 kg K ha^{-1} from TSP and MoP, respectively. In T_6, T_7 and T_8 treatments, P and K were supplied from NPK briquettes. BRRI dhan49, a high yielding variety of rice was used as a test crop. Forty day-old seedlings were transplanted in the plots maintaining a spacing of 20 cm x 20 cm. The experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments and three replications. All the fertilizers except urea i.e. TSP, MoP, gypsum and zinc sulphate were applied as basal doses in all the plots at final land preparation. Prilled urea was applied in three equal splits.

The USG and NPK briquettes were deep placed at 10 DAT and the briquettes were placed at 8-10 cm depth between four hills at alternate rows. The first dose of PU was applied at 10 days after transplanting (DAT); the second dose was added as top dressing at 35 DAT (active tillering stage) and the third dose was top-dressed at 55 DAT (panicle initiation stage). Intercultural operations such as irrigation, weeding, pest control, etc. were done as and when required. The crop was harvested at maturity. The grain yield was assessed with 14% moisture basis while the straw yield was recorded on sun dry basis. Five hills were selected randomly from each plot and data on plant height, tillers hill^{-1}, panicle length, grains panicle^{-1} and 1000-grain weight were recorded. The N content in rice grain and straw was determined by Semi-micro Kjeldahl method (Bremner and Mulvaney, 1982). Nitrogen uptakes, apparent nitrogen recovery and nitrogen use efficiency were calculated from N content and yield data. The collected data were analyzed statistically by F-test to examine the treatment effects and mean differences were examined by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

RESULTS

Yield attributes of BRRI dhan49

Plant height of BRRI dhan49 responded significantly to the deep placement of N fertilizers in the form of USG and NPK briquette (Table 1). The tallest plant of 96.33 cm was recorded in T_3 [USG, 104 kg N/ha] and the shortest plant of 67.33 cm was recorded in T_1 (Control). A significant variation in the number of effective tillers/hill of BRRIdhan49 was observed in response to PU, USG and NPK briquettes as shown in Table 1. The maximum number of tillers/hill of 16.00 was found in T_3 [USG, 104 kg N/ha] and the minimum number of tillers/hill (10.33) was observed in T_1 (control). Table 1 reveals that the application of PU, USG and NPK briquette showed a positive effect on panicle length of BRRI dhan49 over control. The highest panicle length of 9.40 cm was recorded in T_3 [USG, 104 kg N/ha] which was statistically similar with T_2, T_4 and T_6. The effect of PU, USG and NPK briquette on grains/panicle of BRRI dhan49 was significant over control (Table 1). The highest grains/panicle (156.67) was recorded in T_3 [USG, 104 kg N/ha] which was statistically similar with T_2, T_3, T_5, T_6 and T_8. The lowest grains/panicle (116.67) was observed in T_7 (NPK briquette, 78 kg ha^{-1}). The 1000-grain weight of BRRI dhan49 varied significantly due to application of PU, USG and NPK briquettes (Table 1). The numerical difference in 1000-grain weight found in various treatments was quite low. The highest 1000-grain weight was observed in T_6 (NPK briquette, 104 kg N ha^{-1}) and the lowest value was noted in T_2 (PU 104 kg ha^{-1}).

Grain yield of BRRI dhan49

Significant response of the grain yield of BRRI dhan49 was found due to the deep placement of N fertilizers in the form of USG and NPK briquette (Table 2). The grain yield ranged from 3155 to 6311 kg/ha where the highest grain yield was recorded in T_3 [USG, 104 kg N/ha] and the lowest value was observed in T_1 (control). There were numerical variations in grain yield among the treatments. The maximum grain yield increase over control (100%) was found in T_3 [USG, 104 kg N/ha] and the minimum increase (60.57%) was noted in T_8 [NPK briquette, 52 kg N/ha] (Figure 1) 2). Based on grain yield, the treatments may be ranked in the order of T_3> T_2> T_4> T_6> T_5>T_7>T_8>T_1. USG performed better in increasing grain yield of rice as compared to PU and NPK briquette.

Straw yield of BRRI dhan49

Straw yield of BRRI dhan49 also responded significantly to different treatments under study. The highest straw yield (6956 kg/ha) was found in T_3 [USG, 104 kg N/ha]. The straw yield produced by the treatments T_2, T_4 and T_6 with the value of 6351, 6346 and 6133 kg/ha was statistically similar. The lowest straw yield of 3908 kg/ha was observed in T_1 (control). The maximum straw yield increase over control (78%) was noted in T_3 and the minimum value (33%) was found in T_8 (Figure 1). Based on straw yield the treatments may be ranked in the order of T_3>T_2>T_4> T_6> T_5> T_7>T_8>T_1. USG (104Kg N/ha) performed better than other treatments in increasing straw yield under AWD condition.

Table 1. Effect of deep placement of N fertilizers in the form of USG and NPK briquettes as compared to PU on the yield components of BRRI dhan49

Treatments	Plant height (cm)	Tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicles^{-1} (no.)	1000-grain weight (g)
T_1 (Control)	67.33f	10.33e	6.72e	130.33bc	36.24bc
T_2 (PU, 104 kg N ha^{-1})	89.67b	14.33b	8.61abc	154.67a	35.75c
T_3 (USG, 104 kg N ha^{-1})	96.33a	16.00a	9.40a	147.33ab	37.35abc
T_4 (USG, 78 kg N ha^{-1})	82.33c	14.00b	9.03ab	156.67a	37.75ab
T_5 (USG, 52 kg N ha^{-1})	76.67de	12.67d	7.84cd	143.00ab	36.19bc
T_6 (NPK briquette, 104 kg N ha^{-1})	85.00c	13.67bc	8.46abc	141.33ab	38.36a
T_7 (NPK briquettes, 78 kg N ha^{-1})	77.67d	12.67cd	8.17bcd	116.67c	37.48abc
T_8 (NPK briquettes, 52 kg N ha^{-1})	73.33e	12.00d	7.27de	141.67ab	37.97ab
CV%	2.52	4.17	6.70	8.18	2.67
SE(±)	1.1785	0.3181	0.3164	6.6844	0.5725

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

Table 2. Yield of BRRI dhan49 as influenced by the form and placement of N fertilizers

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1 (Control)	3155e	3908f
T_2 (PU, 104 kg N ha^{-1})	5865b	6391b
T_3 (USG, 104 kg N ha^{-1})	6311a	6956a
T_4 (USG, 78 kg N ha^{-1})	5800b	6346b
T_5 (USG, 52 kg N ha^{-1})	5474c	5900cd
T_6 (NPK briquette, 104 kg N ha^{-1})	5780b	6133bc
T_7 (NPK briquettes, 78 kg N ha^{-1})	5400c	5633d
T_8 (NPK briquettes, 52 kg N ha^{-1})	5066d	5200e
CV%	2.77	2.74
SE(±)	85.63	91.96

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

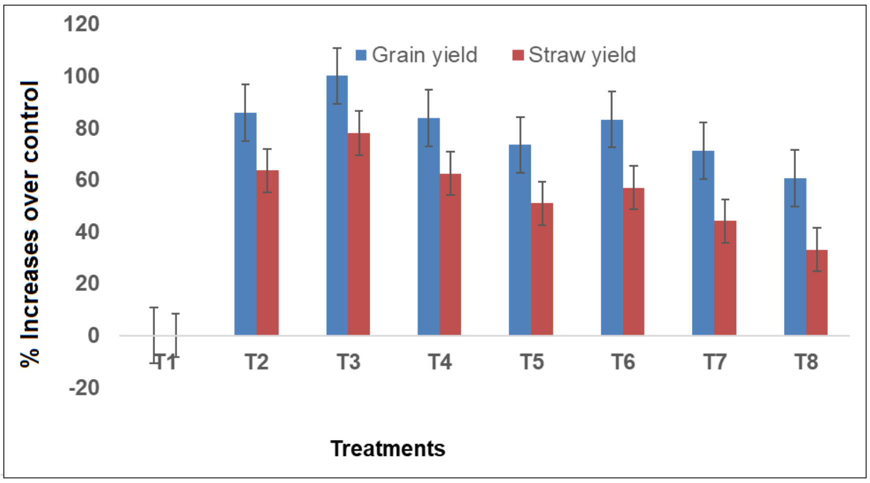

Figure 1. Bar diagram showing %yield increase over control of BRRI dhan49 as influenced by the application of PU, USG and NPK briquettes

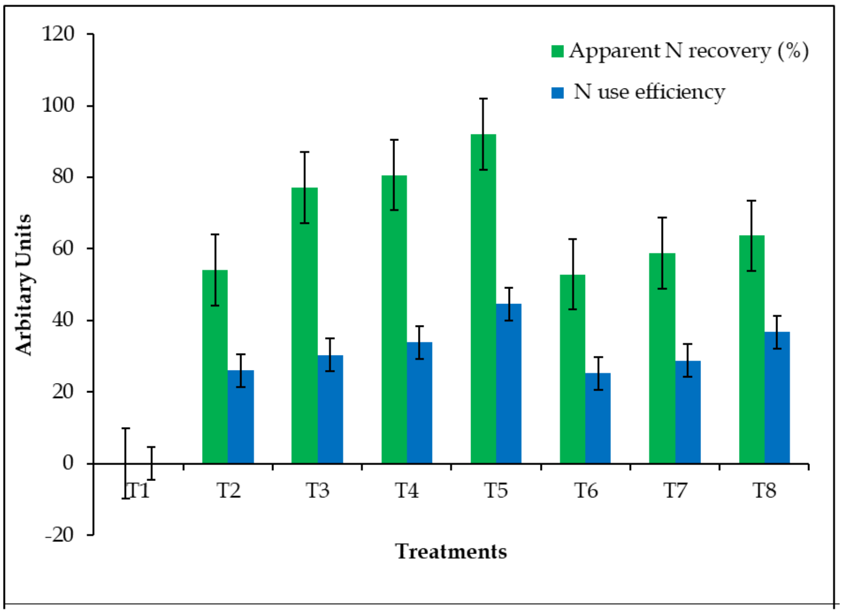

Figure 2. Bar diagram on the effect of PU, USG and NPK briquettes on apparent N recovery (%) and N use efficiency (NUE) of BRRI dhan49

Apparent N recovery (ANR)

The apparent N recovery (ANR) indicates the absorption efficiency of applied N. The ANR by BRRI dhan49 has been presented in Figure 2. Mean apparent recovery of N by BRRI dhan49 ranged from 52.91 to 92.06% in different treatments (Figure 2). The maximum value of ANR was obtained with the application of USG in T_5 [USG, 52 kg N ha^{-1}] followed by T_4 [USG,78kg ha^{-1}], T_3 [USG, 104 kg N ha^{-1}], T_8 [NPK briquette, 52 kg N ha^{-1}], T_7 [NPK briquette, 78 kg N ha^{-1}], T_2 [PU, 104 kg N ha^{-1}] and the minimum value was found in T_6 [NPK briquette, 104 kg N ha^{-1}].The data clearly indicate that the deep placement of USG and NPK briquettes enhanced the recovery of applied N compared to broadcast application of NPK fertilizers under AWD condition.

Nitrogen 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 NUE varied from 25.24 to 44.60 kg grain increase per kg N applied among the treatments (Figure 2). The highest value of NUE (44.60 kg grain increase per kg N applied) was obtained in T_5 [USG, 52 kg N ha^{-1}] followed by T_8 (36.76 kg), T_4 (33.91 kg), T_3 (30.34.76 kg), T_7 (28.78 kg) and T_2 (26.06 kg grain increase per kg N applied). The lowest NUE (25.24 kg grain increase per kg N applied) was found in T_6 [NPK briquette, 104 kg N ha^{-1}]. The data clearly indicate that the deep placement of USG and NPK briquettes enhanced the recovery of applied N as compared to broadcast application of NPK fertilizers.

DISCUSSION

In Bangladesh, farmers generally apply N fertilizers using conventional broadcast method in the soil surface especially in rice cultivation system. The nitrogen use efficiency especially of urea fertilizer is very low (30-35%) in rice cultivation due to loss of applied nitrogen through a number of processes including volatilization, denitrification, surface run-off, leaching, etc. (IFDC, 2007). Many strategies have been developed to increase the efficiency of applied fertilizers through proper timing, deep placement, modified forms of fertilizers, irrigation control etc. Among them deep placement of fertilizers is one of the most effective methods in reducing loss of N. On the other hand, use of slow release fertilizer under alternate wetting and drying (AWD) system introduces a new dimension in the N fertilization regime. But, AWD practice has been found to have negative, similar or positive effect on yield of rice which is still a researchable topic. The present study was conducted to evaluate the effects of deep placement of N fertilizers especially of USG and NPK briquettes in comparison with broadcast application of PU on N use efficiency and yield of BRRI dhan49 under AWD condition. The results revealed that the deep placement of USG and NPK briquettes was more effective than broadcast application of PU. The treatments receiving USG and NPK briquettes increased the yield and N use efficiency as compared to PU. This not only improves N use efficiency in AWD rice cultivation system but also minimizes N loss resulting from ammonia volatilization and denitrification (Savant and Stangel, 1990; Mohanty et al. 1999). It also reduces the chance of fertilizer-related environmental pollution by minimizing N runoff and volatilization losses.

The grain yield of BRRI dhan49 has been significantly increased due to the application of N fertilizers under AWD condition. The highest grain yield was recorded in T_3 [USG, 104 kg N ha^{-1}] which was statistically similar to T_2 [PU, 104 kg N ha^{-1}], T_4 [USG. 78 kg ha^{-1}] and T_6 [NPK briquette, 104 kg N ha^{-1}]. These results indicate positive effects of deep placement of N fertilizers on rice yield. The increase in rice yield as observed in the present study is due to the spontaneous supply of nitrogen from USG throughout the growing period of rice and due to minimum loss of nitrogen as because of deep placement. These findings are well corroborated with Kapoor et al. (2008) and Islam et al. (2011) who observed increased rice yield due to application of USG and NPK briquettes.

Due to deep placement of N fertilizer under AWD condition, the N uptake by rice was increased to a significant extent. However, the uptake held with the application of USG (104 kg N ha^{-1}) was higher than the application of PU and NPK briquette). Accordingly, the maximum N recovery of applied N and N use efficiency were also obtained from the application of USG.

CONCLUSION

The deep placement of N fertilizers has numerous benefits over broadcast application of PU and NPK briquettes. From the results of the present study it was observed that the deep placement of USG had better performances on grain and straw yields, nitrogen recovery and nitrogen use efficiency as compared to the broadcast application of PU and NPK briquettes. Based on grain yield, N recovery and N use efficiency it can be concluded that application of N @ 78 kg ha^{-1} (75% of recommended N) as USG can be used for the production of BRRI dhan49.

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