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Effect on nitrogen use efficiency and yield of rice variety (BRRI dhan50) under different nitrogen fertilizer rates

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ABSTRACT

Food security is a major global issue because of the growing population and decreasing land area. Rice (*Oryza sativa* L.) is the most important staple cereal crop in the world. Application of nitrogen (N) fertilizer has improved crop yield in the world during the past five decades but with considerable negative impacts on the environment. It is urgently needed to simultaneously increase yields while maintaining or preferably decreasing applied N to maximize the nitrogen use efficiency (NUE) of crops. The experiment was conducted at Bangladesh Agricultural University, Mymensingh, Bangladesh during boro season of 2018 to assess growth, yield and nitrogen use efficiency of a rice variety "BRRI dhan50". The rice variety was treated with five levels of nitrogenous fertilizers in a randomized complete block design with three replicates. The nitrogen levels 0, 40, 80, 100 and 120 kg N ha^{-1}. The maximum grain yield (6.7 t ha^{-1}) was found when the variety was fertilized with 120 kg N -1. Application of 120 kg N ha^{-1} also showed the highest nitrogen use efficiency (35 kg grain yield increased per kg N applied) of the rice variety. We concluded that application of the intermediate level of nitrogen was economical and environment-friendly for the cultivation of BRRI dhan50.

INTRODUCTION

The global population is predicted to reach 9 billion, and food supplies are projected to increase by 70–100% by 2050 (Godfray et al., 2010 and Tilman et al., 2011). Given the limited capacity for arable land expansion, it requires sustaining yield improvement in existing land to meet the increasing food demand (Cassman KG, 1999). Rice is one of the staple food crops for approximately half of the global population. Therefore, rice production must be increased significantly to satisfy the requirements of the growing world population. However, we are facing challenges in increasing rice production under the pressures of decreased arable land area, global climate change, intensified natural disasters, and frequent occurrence of diseases and pests (Wu et al., 2016).

Nitrogen (N) is one of the essential macro elements required for plant growth and development. Soil N availability usually limits plant yields in most agricultural cropping systems (Robertson and Vitousek, 2009). Thus, application of N fertilizer has become an important, cost-effective strategy to increase crop yields in intensive agricultural systems worldwide (Andrews et al., 2013). However, traditionally adding N fertilizer to improve crop yields may have reached a plateau. Excessive application of nitrogen fertilizer may not result in yield improvements but will lead to serious environmental problems (Vitousek et al., 2009, Good and Beatty, 2011). From 1960 to 2012, the global N fertilizer consumption increased by 800%, and the annual N consumption in China increased from 8 to 35% of the world's N consumption (Wu LL et al., 2016). Although the rate of cereal grain yield increased by 65%

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between 1980 and 2010, the consumption of chemical fertilizers increased by 512% (Zhang et al., 2011). High N fertilizer input leads to low nitrogen use efficiency (NUE) due to the rapid N losses from ammonia volatilization, denitrification, surface runoff, and leaching in the soil-flood water system. As a consequence, significant environmental problems (i.e., soil acidification, air pollution, water eutrophication) occurred (Smil, 1999, Diaz and Rosenberg, 2008 and Guoet al., 2010). To achieve further high crop productivity and high NUE under well-fertilized conditions, new solutions are urgently needed to increase yields while maintaining or preferably decreasing applied N (Han, 2015).

Importantly, the efficient use of nitrogen is recognized as a production factor for rice, but it has always been a problem to improve the N utilization rate of the rice plant and to increase efficiency of absorbed nitrogen for grain production. Further, nitrogen fertilizer is costly, thus it is important to minimize the losses of nitrogen fertilizers and maximize the economic utility. Nitrogen use efficiency (NUE) of different rice cultivars such as BRRI dhan1 (Haque and Haque, 2016), BRRI dhan28, BRRI dhan36 (Alim, 2012), BRRI dhan29 (Hasan et al., 2016; Alam et al., 2010) has been studied.

MATERIAL AND METHODS

Experimental site, weather, soil and variety

The experiment was carried out at Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh. The experimental field belongs to Sonatala soil series, Aeric Haplaquept (USDA taxonomy) under Old Brahmaputra Floodplain, (AEZ-9) (FAO-UNDP, 1988). 24.75ºN latitude and 90.5ºE longitude, elevation 18m above the sea level. The average temperature, rainfall and relative humidity were respectively 26.4ºC, 190.2 mm and 84.5%. The soil was a typical rice growing silt loam soil. BRRI dhan50, a high yielding variety of rice was used as the test crop in this experiment.

Treatments

Rice varieties (BRRI dhan50) with five levels of N fertilizer rates were used as treatments of this experiment.

Table 1: List of treatments with different N fertilizers rates

Treatments	Name of N Fertilizers	Amount of fertilizers (kg ha-1)
T1	Control	-
T2	Urea	40
T3	Urea	80
T4	Urea	100
T5	Urea	120

Fertilizer application

Thirty days old seedlings of rice variety (BRRI dhan50) was transplanted with maintaining distance of 20 cm × 15 cm. The crop was treated with five levels of nitrogen fertilizer viz. 0, 40, 80, 100 and 120 kg N ha^{-1}. The crop was fertilized with 25-70-10-1 kg PKSZn ha^{-1} at the time of final land preparation. All other fertilizer was applied in control plots except N fertilizer. Nitrogen was applied in the form of urea in three equal installments as top dressing. Top dressing of nitrogen was done at 6, 25 and 50 days after the transplanting (DAT). Irrigation, weeding and other agronomic practices were done whenever necessary.

Data collection

Data collected on different growth parameters e.g. plant height, effective tillers per hill, panicle length, grains panicle^{-1} and 1000grain weight, grain and straw yield of BRRI dhan50 were recorded. For determination of yield attributes five hills were selected and number of tillers per hill, number of filled and unfilled grains per panicle and thousand grain weight was measured. The above ground plant parts were segmented into different components as leaf, stem, leaf sheath and panicle. The above ground plant parts were then dried in an oven at 70˚C for 72 hours and weighed. The harvested yield was converted into t·ha^{-1} at 14% moisture content. Total N content in soil was determined by micro-Kjeldhal method. Digestion was made with H_2O_2, conc. H_2SO_4 and a catalyst mixture (K_2SO_4:$CuSO_45H_2O$: Se =100:10:1).

Nitrogen in the digest was estimated by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01N H_2SO_4 (Page et al., 1982).

The NUE (kg grain yield increase kg^{-1} N applied) was determined by the following formula: NUE = (GY+N– GY0N) / FN; Where, GY+N = grain yield in treatment with N application, GY0N = grain yield in treatment without N application and FN = amount of fertilizer N applied (kg ha^{-1}). The apparent N recovery was calculated by the following formula: ANR (kg ha^{-1}) = (UN+N - UN0N) /FN; where, UN+N is total N uptake (kg ha^{-1}) with grain and straw; UN0N is the N uptake (kg ha^{-1}) in control; FN is amount of fertilizer N applied (kg ha^{-1}) according to Fageria et al. (2010). All the data were statistically analyzed by F-test and the mean differences were ranked by DMRT at 5% level (Gomez and Gomez, 1984). All collected data were subjected to MSTAT-C software package to perform analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Plant height, panicle length, tillers per hill, grains per panicle responded significantly due to application of different N fertilization rates (Table 2). Plant height varied from 91.29-124.84 cm. The highest plant height of 124.84 cm was observed for treatment T_4 where the lowest plant height of 91.29 cm in treatment T_1 (control). The maximum panicle (26.05 cm) was observed for T_3 while the minimum panicle (19.73 cm) was recorded in T_1 (control). The highest number of tillers $hill^{-1}$for treatment T_5 (15.24) and the lowest number of tillers $hill^{-1}$in treatment T_1 (10.48). The highest grain $panicle^{-1}$was found in for treatment T_4(121.15) where the lowest grain $panicle^{-1}$ in treatment T_1 (79.79). 1000-grain weight varied from 15.92 to 23.86 g. The highest grain weight 23.86 g was observed for treatment T_5 where the lowest grain weight 15.92 g in treatment T_1 (control) for BRRI dhan50.

Table 2: Effect of yield contributing parameters e.g. plant height, panicle length, tillers per hill, grains per panicle responded significantly due to application of N fertilizer in comparison with control for BRRI dhan50.

Treatment	Plant height (cm)	Panicle Length (cm)	Tillers $hill^{-1}$ (no.)	Grains $panicle^{-1}$ (no.)	1000- grain weight (g)	Grain yield (t ha-1)	Straw Yield (t ha-1)
T_1	91.29d	19.73c	10.48b	79.79d	15.92c	3.04b	5.93b
T_2	106.53c	21.46bc	11.89ab	107.2c	19.82b	4.27c	7.56a
T_3	118.78b	26.05a	14.85a	113.09b	21.31b	6.24ab	8.47a
T_4	124.84a	24.19ab	13.41ab	121.15a	20.81b	6.15b	8.28a
T_5	120.15b	22.87bc	15.24a	117.45ab	23.86a	6.7a	8.63a
*CV%	2.06	7.71	13.99	2.6	7.88	4.84	6.9
LSD	4.35	3.26	0.57	5.27	3.05	0.48	1.09

Grain yield

Grain yield was increased with increasing the fertilizer rates. Grain yield varied from 3.04 to 6.7 t ha^{-1}. The highest grain yield was observed 6.7 t ha^{-1} for treatment $T_5$when rice plants were fertilized with120 kg N ha^{-1} which was statistically similar to T_3 and T_4 and the lowest grain yield 3.04 t ha^{-1} in treatment T_1 (control). Figure 1 shows the percent increase of grain yield over control for all treatments. The grain yield increased over control varied from 29% to 55%. The highest grain yield was observed 55% for treatment T_5 (N_{120}) and the lowest was recorded 29% in treatment T_2 (N_{40}). Similar results were found for some other varieties of rice (Huda et al., 2016), (Kapoor et al., 2008). For instance, in case of BRRI dhan28 up to 97% increase over control was reported with the application of USG (Islam et al., 2014). Based on grain yield, the treatments may be ranked in the order of $T_5>T_3>T_4>T_2>T_1$. The rate of 120 kg ha^{-1} and at the rate 80 kg ha^{-1}

performed better in increasing grain yield of rice compared to 100 kg ha^{-1} and 40 kg ha^{-1} applied nitrogen in BRRI dhan50. Thus, 120 kg ha^{-1} of N fertilizers demonstrated the most positive effect on grain yield in BRRI dhan50.

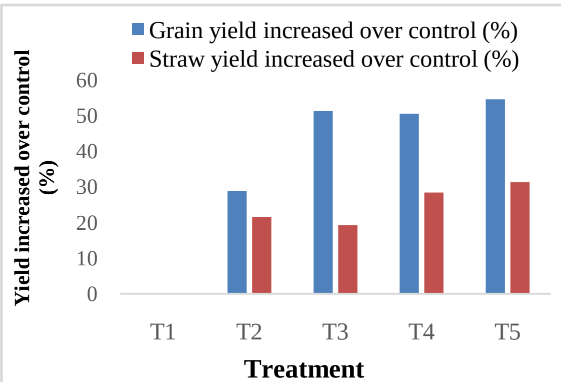

Figure 1: Grain and straw yield increased over control due to N fertilization for BRRI dhan50 during boro season.

Straw yield

Straw yield was increased with increasing the fertilizer rates. Grain yield varied from 5.93 to 8.63 t ha^{-1}. The highest straw yield was observed 8.63 t ha^{-1} for treatment $T_5$when rice plants were fertilized with 120 kg N ha^{-1} which was statistically similar to T_3 and T_4 and the lowest straw yield 5.93 t ha^{-1} in treatment T_1 (control). Figure 1 shows the percent increase of straw yield over control for all treatments. The straw yield increased over control varied from 19% to 32%. The highest straw yield was observed 32% for treatment T_5 (N_{120}) and the lowest was recorded 19% in treatment T_2 (N_{40}). Based on straw yield, the treatments may be ranked in the order of $T_5>T_3>T_4>T_2>T_1$. The rate of 120 kg ha^{-1} and the rate 80 kg ha^{-1} performed better in increasing straw yield of rice compared to 100 kg ha^{-1} and 40 kg ha^{-1} applied nitrogen in BRRI dhan50. Thus, 120 kg ha^{-1} of N fertilizers demonstrated the most positive effect on straw yield in BRRI dhan50.

N Uptake

Figure 2 presented the N uptake and N uptake increased over control for BRRI dhan50 during boro season. N uptake ranged from 55 to 132 kg ha^{-1}. The highest N uptake was observed 132kg ha^{-1} for treatment $T_5$when rice plants were fertilized with 120 kg N ha^{-1} which was statistically similar to T_4 and T_3 and the lowest 55 kg ha^{-1} in treatment T1(control). N uptake increased over control varied from 24 to 58%. The highest was found 58% for treatment $T_5$when rice plants were fertilized with 120 kg N ha^{-1} which was statistically similar to T_4 and T_3 and the lowest 24% in treatment T2 when rice plants were fertilized with 40 kg N ha^{-1}.The trend of N uptake conforms with the published work (Jahan et al. 2014). The total N uptake by BRRI dhan46 due to different treatments may be ranked in the order of $T_5> T_4> T_3>T_2> T_1$. The result revealed that the rate of N fertilizers (N_{120}) increases the total N uptake by rice plant.

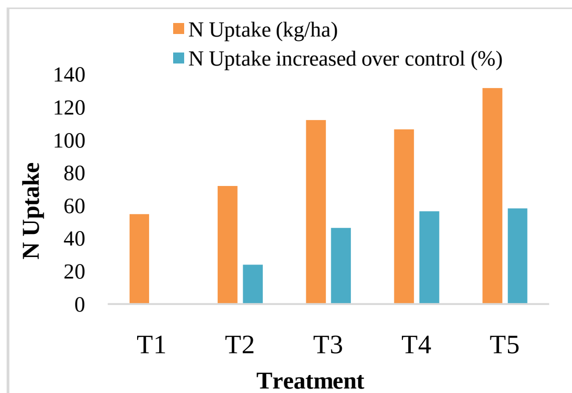

Figure 2: Effects of N uptake and N uptake over control due to application of N fertilizer in comparison with control of BRRI dhan50.

Apparent N recovery (ANR)

Apparent N recovery efficiency (ANR) is one of the more complex forms of NUE expressions and is most commonly defined as the difference in nutrient uptake in above-ground parts of the plant between the fertilized and unfertilized crop relative to the quantity of nutrient applied. Figure 3 presented the apparent N recovery (ANR) and Nitrogen use efficiency (NUE) for BRRI dhan50 during boro season. ANR ranged from 43 to 64 %. The highest ANR was observed 64% for treatment $T_5$when rice plants were fertilized with 120 kg N ha^{-1} which was statistically similar to T_3 and T_4 and the lowest ANR 43% in treatment $T_2$when rice plants were fertilized with 40 kg N ha^{-1}.

Nitrogen use efficiency (NUE)

Nitrogen use efficiency (NUE) is defined as the ratio of the crop nitrogen uptake, to the total input of nitrogen fertilizer. It can also be defined more broadly as the ratio, of crop nitrogen uptake, to available soil N which would include applied fertilizer N plus residual mineral N in the soil. NUE varied from 25 to 35 kg grain yield increase per kg N applied). The maximum NUE was found 35kg grain yield increase per kg N applied for treatment $T_5$when rice plants were fertilized with 120 kg N ha^{-1} which was statistically similar to T_4 and T_2 and the lowest NUE was recorded 25 kg grain yield increase per kg N applied in treatment $T_3$when rice plants were fertilized with 80 kg N ha^{-1}. The estimation of NUE in crop plants is crucially needed to assess the fate of applied nitrogen and their role in improving maximum economic yield through efficient absorbed or utilization by the plant. The diminishing trend of NUE at higher N rates pointed out that rice plants are unable to absorb or utilize N at higher rates or the rate of N uptake by plant cannot keep pace with the loss of N (Fageria and Baligar, 2005).

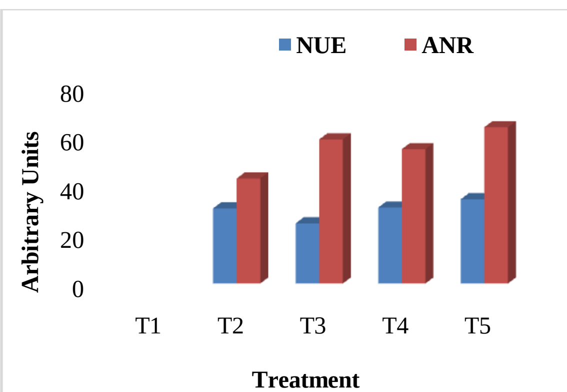

Figure 3: Apparent N recovery (%) and N use efficiency due to application of N fertilization for BRRI dhan50

Nitrogen usually loss by means of ammonia volatilization, denitrification, surface runoff and leaching in the soil floodwater system (Vlek, 1986, De Dattaand and Buresh, 1989)causing enormous problems for instance environmental pollution, increased production cost, grain yield reduction and could even lead to global warming (Peng, 2008 and Li et al., 2012). Nonetheless, the magnitude and nature of N losses vary depending on the timing, rate and method of N application, source of N fertilizer, soil chemical and physical properties, climatic conditions and crop status (Zhu, 1997). Decreases in N uptake efficiency at higher N rates have also been reported by Eagle et al., 2001,Timsina et al., 2001and Mae et al., 2006.

CONCLUSION

From the results it may be concluded that growth, yield and nitrogen use efficiency of the new rice variety were significantly influenced by different levels of nitrogen fertilizer. This study was conducted using a highly cultivated rice variety of Bangladesh to maximize nitrogen use efficiency (NUE) with compromising the yield of five different N fertilizers rates. The overall result showed that N fertilizer of 120 kg lead to the best grain yield, NUE and apparent N recovery of BRRI dhan50.

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