SAARC Journal of Agriculture
Journal Homage: https://www.banglajol.info/index.php/SJA

Research Article

Nitrogen Application Alters Growth and Yield of BRRI dhan28

M. Biswas, K. G. Quddus and M. S. Jahan*
Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh

Abstract

Nitrogen is not only a major nutrient but the most limiting nutrient element for rice production. The present study was conducted to examine the effect of different doses of nitrogen on growth and yield of BRRI dhan28. The experiment was conducted in a Randomized Complete Block Design (RCBD) with four replications. The treatments include six doses of nitrogen, 0 - 175 kg N ha^{-1} with an interval of 35 kg N ha^{-1} as urea. Data on growth and yield contributing characters of rice were collected and analyzed statistically. The optimum dose for BRRI dhan28 was estimated 140 kg N ha^{-1}. Results showed that plant height (cm), tillers m^{-2} and dry matter (kg ha^{-1}) yield increased significantly with increasing levels of N. However, at 60 DAT, plant height (cm), tillers m^{-2} and dry matter (kg ha^{-1}) production with 140 kg N ha^{-1} were statistically similar to that displayed by other nitrogen doses. The yield contributing parameters especially the panicle m^{-2} and test weight (g) were found superior with the treatment of 140 kg N ha^{-1}. Application of 140 kg N ha^{-1} showed AE and PFP for N as 14.5 kg kg^{-1} and 23.31, respectively. Application of N fertilizer @ 140 kg ha^{-1} increased grain yield by about 62% compared to N-control treatment in BRRI Dhan 28.

Keywords: Boro rice, BRRI dhan28, Growth, Nitrogen, Yield

Introduction

Rice is the most dominant cereal food in Bangladesh and provides two-third of total calorie requirement and about one-half of the total protein consumption of an average person in the country (BRRI, 2023). In Bangladesh rice is cultivated in three seasons namely Aus (March-September), Aman (July-December) and Boro (November-May) (Shelley *et al*., 2016, Al Mamun *et al*., 2021). Boro is the principal rice crop here regarding amount of production. But, the national mean yield of boro rice is lesser

* Corresponding author: mjahan70@at.ku.ac.bd

Received: 30. 07. 2024 *Accepted: 30. 11. 2024*

(4.193 t ha^{-1}) than that of other rice-producing nations (BRRI, 2022). It is mentionable that for rice production application of fertilizer and water are two important management practices. Though nitrogen fertilizer plays a major role in rice production, all fertilizers should be applied judiciously for increasing crop productivity (Islam *et al*., 2018).

Nitrogen (N) is one of the supreme yield-controlling nutrient elements in rice cultivation worldwide, especially in tropical Asia (Saleque *et al*., 2004). It is an essential constituent of chlorophyll and increases leaf photosynthesis which promotes growth of the crop. Rice plants need N during vegetative stage to stimulate growth and tillering, which ultimately governs the number of panicles. Nitrogen contributes to spikelet production and sink size formation throughout the panicle formation stage. It also helps in grain filling, taming the photosynthetic capacity, and stimulating carbohydrate buildup in culms and leaf sheaths (Mae, 1997). Bufogle *et al.,* (1997) reported that nitrogen absorbed by rice during the vegetative growth stages contributed in growth during reproduction and grain-filling through translocation. This could support minimize pressures posed by break down of structural protein in stem and leaves, thus prolonging the life-period of green leaves by preserving high photosynthetic rate (Juan *et al.,* 2006). Plant growth is seriously hampered when lower dose of nitrogen is applied, which drastically reduces the yield. It is a concern that inadequate usage of nitrogen, instead of providing yield benefit, may decrease the same (Adhikari *et al.,* 2018). A number of studies have indicated that an optimum dose of nitrogen is essential for good rice yield. Jahan *et al*., (2014) demonstrated that grain yield of three local aromatic rice varieties increased progressively up to 60 kg ha^{-1} and then declined with higher doses. Khatun *et al*., (2014) indicated that the highest yield of rice varieties, BRRI dhan28 and BRRI dhan29 was obtained with 150 kg N ha^{-1}. However, both excess and insufficient supply of N may decrease grain yield of rice to a great extent (Awan *et al*., 2011). An adequate N supply can increase as much as 60% rice production over control (Mikkelsen *et al.,* 1995).

A number of studies have been conducted in Bangladesh to examine the effect of nitrogen levels on rice yield on the yield of BRRI dhan28 (Diba *et al*., 2005, Khatun *et al*., 2014, Hoque *et al*., 2021, Mollik, 2022). Determination of the optimum dose nitrogen for rice in coastal soils received scanty attention. Islam *et al*., (2015) reported 145 kg N ha^{-1} in one year and 200 kg ha^{-1} in the following year in BRRI dhan29 in a coastal non-saline soil. Although BRRI dhan28 is a salt-sensitive rice variety, many coastal farmers prefer to grow BRRI dhan28 in low to moderately saline soils with non-saline irrigation water. Under these situations, the present study was undertaken to determine the optimum dose of N on growth and yield of BRRI dhan28 in a coastal saline soil of Bangladesh.

Material and Methods

Experimental Site

The experiment was accomplished during Boro season (January to May) at the Professor Dr. Purnendu Gain Field Laboratory, Agrotechnology Discipline, Khulna University, Khulna. The experimental site is under the agro-ecological zone Gangas Tidal Flood Plain (AEZ-13, Bajoa silty clay loam). The climate of the experimental site enjoys low temperature and humidity during the *Rabi* season and relatively high temperature, humidity, and heavy rainfall during the *Kharif* season. The experimental field soil (0-15 cm) had pH 7.90, organic matter 3.66%, total N 0.17%, available P 12 (µg/g soil), exchangeable K 0.47 (cmol/kg) and available Zn 0.76 (µg/g soil). The field soil was rich in sulphur 96 (µg/g soil) and B 0.63 (µg/g soil). The experimental field soil was moderately saline (EC 5.04 dS m^{-1}).

Treatments and Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with 4 replications and 6 treatments 0, 35, 70, 105, 140 and 175 kg N ha^{-1}.

Seed Collection and Raising of Seedlings

BRRI dhan28, a high yielding rice variety was used as a test crop in this experiment. Seeds were immersed in water in a bucket for 24 hrs. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs. The nursery bed was prepared by puddling with repeated plowing followed by laddering. The sprouted seeds were sown in the seed bed uniformly as possible on December 12.

Preparation of Main Field

The experimental land was ploughed on with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings followed by laddering to have a good puddled field. All kinds of weeds and crop residues were removed from the field. Individual plots were cleaned and finally leveled with the help of a wooden plank.

Crop Management

The experimental field was fertilized with 60 kg TSP, 90 kg MOP, 6 kg zinc sulfate and 52 kg gypsum ha^{-1}, respectively as suggested by BRRI. Full doses of fertilizers except urea were applied during final land preparation and thoroughly incorporated into the soil. Urea was top dressed in three equal installments at 20, 35, and 50 days after transplanting (DAT). Forty-day-old seedlings were uprooted carefully and were transplanted as per experimental treatment on January 21. Three seedlings were given in each hill, and spacing between plant to plant and row to row of (20 x 20) cm was maintained properly. Two hand weeding were done to check weed infestation in the crop at 30 and 50 DAT. In the field 2-4 cm of standing water was maintained throughout the growing period until the grain filling stage. Furadan 5G was applied at 21 DAT to control ufra and malathion @ 1.00 l ha^{-1} was applied to control insects.

The crop was harvested at full maturity when 80% of the grain turns golden yellow. Before harvesting five hills were uprooted randomly from each plot for taking yield components data. Grain and straw yields were adjusted at 14% moisture and recorded as a whole plot (10 m^2) basis.

Data Collection and Analysis

Data were recorded for different growth parameters (plant height, tillers $hill^{-1}$and dry matter $hill^{-1}$) starting from 45 DAT and continue till maturity. Data on yield and yield attributes (effective tiller m^{-2}, grains $panicle^{-1}$, 1000-grains weight, grain yield, biological yield and harvest index) were gathered after harvest. Before harvesting five hills were uprooted randomly from the center rows of each plot for obtaining effective tiller m^{-2}, grains $panicle^{-1}$and 1000-grain weight data. Grain and straw yields were adjusted at 14% moisture and recorded as a whole plot (10 m^2) basis, and then converted to per hectare basis. Biological yield was calculated with the following formula:

Biological yield (t/ha) = Grain yield (t/ha) + Straw yield (t/ha)

The harvest index (%) was estimated by the formula given by Donald and Humblin (1976):

Harvest Index (%) = (Grain yield/Biological yield) x 100

The recorded data were analyzed following the analysis of variance (ANOVA) technique by using a computer package Statistical Tools for Agricultural Research (STAR). Regression analysis (linear and polynomial) was used to examine the relationships between various nitrogen levels and growth parameters as well as between different nitrogen levels and yield parameters and yield. Student's'*t*' statistic was employed to test the significance level of various constants (a, b and c) and '*F*' test for the coefficient of determination (R^2).

Optimum Dose of N

Functional relationship between grain yield and nitrogen doses was established using regression analysis. Optimum nitrogen dose was determined by differentiating the quadratic N response equation (Colwell, 1994). The form of the quadratic equation was given by,

$$\bar{Y} = a + bN + cN^2$$

Where is estimated output (e. g. yield), N is applied rate of nitrogen application, a is intercept, b and c are regression coefficients.

Differentiating the above equation we get,

$$d\bar{Y}/dN = b + 2cN$$

The optimum rate of N at the point, where,

$$d\bar{Y}/dN = 0$$

$$0 = b + 2cN$$

$$N = -b/2c$$

The economic optimum dose of N was

$$N = (E_n\text{-}b)/2c$$

Where,

$$E_n = Pf/Py$$

Where, P_f is Price of fertilizer and P_y is price of product.

Nutrient Use Efficiency

Agronomic use efficiency and partial factor productivity of applied nitrogen was calculated by the following equation (Khatun, 2013):

Agronomic use efficiency (kg kg^{-1}) was expressed as the difference in grain yield between N fertilized and N-control plot divided by the quantity of N applied, as

$$AE = (Y_f - Y_0)/N_a$$

Where, AE is agronomic use efficiency ((kg kg^{-1}), Y_f is the grain yield (kg ha^{-1}) with N, Y_0 is the yield (kg ha^{-1}) in N-control plot and N_a is the amount of applied N (kg).

Partial factor productivity (PFP) is the grain yield per quantity of nitrogen applied. PFP is unit less and can be calculated as

$$PFP = Y_f/N_a$$

Results and Discussion

Crop Growth Characters

Plant Height, Tiller m^{-2} and Dry Matter Yield at Panicle Initiation Stage (60 DAT)

Nitrogen (N) is the key element in the production of rice and gives by far the largest response in plant height which promotes entire growth and development of plant. Different N levels showed significant effects on plant height for all growth stages (data not shown). Regardless of treatment differences, plant height increased progressively up to maturity (data not shown). In all growth stages the highest plant height was observed with N_5 (175 kg N ha^{-1}) and the lowest plant height was recorded from control treatment, N_0. Plant height at the panicle initiation (PI) stage ranged from 71 cm in the N-control plot to 85 cm in the plot receiving the highest dose of N (Table 1).

A linear regression equation explained the relationship between plant height and the applied N (Table 1). Intercept, regression coefficient and R^2 were significant for the linear relationship (p value the parameters were 0.00, 0.01 and 0.01, respectively). Shorter plant at 140 kg N ha^{-1} compared to both 105 and 175 kg N ha^{-1}, was an observation in the plant height data. Taller plant usually bears more leaves, produces more photosynthesis and eventually contributes to yield of rice. However, excessive plant height may contribute to plant lodging and tolls yield.

Table 1. Response of plant height, tiller m^{-2} and dry matter yield m^{-2} at the panicle initiation stage (60 DAT) to the applied nitrogen in BRRI dhan28

Applied N (kg ha^{-1})	Plant height (cm)	Tiller m^{-2}	Dry matter (kg ha^{-1})
0	71	266	9905
35	76	345	10970
70	80	429	12437
105	83	452	12650
140	80	519	13827
175	85	521	13900
a	73 ± 2 (p = 0.00)	292 ± 20 (p = 0.00)	10227 ± 307 (p = 0.00)
b	0.07 ± 0.02 (p = 0.01)	1.48 ± 0.19 (p = 0.01)	23.48 ± 2.90 (p = 0.01)
R^2	0.81 (p = 0.01)	0.93 (p = 0.01)	0.94 (p = 0.01)

Previous report showed the highest plant height of 86 cm with 200 kg N ha^{-1} application in BRRI dhan28 (Chameley *et al.* (2015). Paramanik *et al.* (2015) and Sarker *et al.* (2018) also found that the plant height considerably increases with the higher doses of nitrogen.

Number of Tillers m^{-2}

Tiller number m^{-2} was significantly influenced by the nitrogen levels at all growth stages (data not shown). Irrespective of nitrogen rates, tiller production increased progressively up to 75 DAT and declined slightly at maturity (data not shown). Earlier studies also showed reduction in tillers m^{-2} in boro rice after 50% flowering that continued to harvest (Ahmed *et al*., 2018). The results indicates that the number of tillers per unit area was the highest at the 75 DAT and after that began to decline owing to the mortality of tertiary tillers under plant competition for growth resources (Bhuyan *et al*., 2014, Haque and Haque, 2016). Except 45 DAT, in other growth stages the maximum number of tillers was obtained with N_5 (175 kg N ha^{-1}) and the minimum number was found in control treatment, N_0. Tillers number at the PI stage varied from 266 in the N-control plot to 521 in the plot getting 175 kg N (Table 1). A linear regression equation clarified the association between tillers number and the N dose (Table 1). Intercept, regression coefficient and R^2 were significant for the linear relationship (p value the parameters were 0.00, 0.01 and 0.01, respectively). Our findings corroborate with findings of Adhikari *et al.* (2018) who reported that tillers m^{-2} increase with the increased dose of nitrogen. Chamely *et al.* (2015) also recorded the higher number of tillers per unit area with the application of 200 kg N ha^{-1}.

Dry Matter (kg ha^{-1})

Total dry matter (TDM) production denotes the production potential of a crop and high TDM production is the prerequisite for high yield. TDM of rice plants were measured at 45, 60, and 75 DAT and at harvest (data not shown). Accumulation of dry matter was very slow at early stage (45 to 60 DAT) and increased progressively over time attaining the highest at harvest (data not shown). Dry matter m^{-2} was significantly influenced by the nitrogen levels at all growth stages except 45 DAT (data not shown). A linear regression equation described the correlation between dry matter m^{-2} and the N rates (Table 1). Intercept, regression coefficient and R^2 were significant for the linear relationship (p value the parameters were 0.00, 0.01 and 0.01, respectively). At 60 DAT (PI stage) the highest dry matter (13,900 kg ha^{-1}) was obtained with the treatment N_5 (175 kg ha^{-1}) and the lowest (9905 kg ha^{-1}) was obtained from N_0, the control treatment. Application of nitrogen causes significant difference in the pattern of partitioning of dry matter of rice at all the growth stages where low nitrogen levels triggers allocation of lowest dry matter to all plant parts (Haque and Haque*,* 2016).

Yield Contributing Characters

Number of Panicle m^{-2}, Field Grain per Panicle and 1000-Grain Weight

The variation of panicle m^{-2} due to nitrogen rates is shown in Table 2. It was observed that in BRRI dhan28 the number of panicles increased with the increasing level of nitrogen. In plots getting the control treatment, BRRI dhan28 produced 315 panicles m^{-2}. Receiving 35 kg N ha^{-1}, panicles m^{-2} in BRRI dhan28 reached 320. At 70 kg N ha^{-1}, BRRI dhan28 produced 358 panicles m^{-2} which increased to 392 with 105 kg N application. Application of 140 kg N ha^{-1} increased panicles m^{-2} sharply to 417 in BRRI dhan28. However, there was slight reduction in panicles m^{-2} in plots receiving 175 kg N ha^{-1}. Previous studies also reported more number of panicles m^{-2} in BRRI dhan28 with higher rates of N (Khatun *et al*., 2014). According to their findings, application of 250 kg N ha^{-1} (314) produced 109 more panicle m^{-2} compared to N-control treatment (205). The polynomial function ($Y = 305 + 0.930N - 0.0016N^2$, $R^2 = 0.93^*$) elucidated the relationship between applied N and panicles m^{-2} (Table 2). Adequacy of nitrogen probably favored the cellular activity during tiller formation and development, which led to increased number of panicles. This finding commensurate with the statement made by Pramanik *et al.* (2015) that number of panicles m^{-2} increases with the increment of nitrogen level up to 75 kg N ha^{-1} and thereafter decreases in 100 kg N ha^{-1}. Miah *et al.* (2012) found that panicles m^{-2} was affected by the doses of nitrogen as USG 240 kg N ha^{-1}.

Table 2. Effect of various nitrogen doses on yield and yield attributes of BRRI dhan28 rice

Nitrogen dose (kg ha^{-1})	Panicles m^{-2}	Filled grains panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
0	315	76	21.03	1.22	3.24	37.59
35	320	84	21.36	2.46	5.11	47.85
70	358	98	22.08	3.11	6.26	49.66
105	392	99	21.92	3.92	7.29	53.76
140	417	105	22.17	3.25	6.17	52.73
175	411	108	22.07	3.8	6.98	53.61
a	304.96^{**}	76^{*}	20.99^{*}	1.29^{*}	3.35^{*}	38.67^{**}
b	0.9301^{ns}	0.328^{*}	0.0163^{*}	0.0353^{*}	0.055^{*}	0.229^{*}
c	-0.0016^{ns}	-0.00083^{ns}	-0.000058^{ns}	0.00013^{ns}	0.00021^{**}	-0.00085^{*}
R^2	0.93^{*}	0.97^{**}	0.91^{*}	0.92^{*}	0.91^{*}	0.95^{*}
Optimum N (kg ha^{-1})	290	197	139	140	132	135

Filled Grains Panicle^{-1}

The application of nitrogen increased filled grains panicle^{-1} (Table 2). The lowest filled grains panicle^{-1} (76) was observed from the control plot, which increased to 84 with 35 kg N ha^{-1}. Increasing the N rates increased grain per panicle progressively up to 108 with 175 kg N ha^{-1}. A quadratic equation ($Y = 76 + 0.328^{*}N - 0.00083^{ns}N^2$, $R^2 = 0.97^{**}$) explained the relationship between applied N and filled grain per panicle (Table 2). This result agrees to the observation made by Ahmed *et al.* (2005) that N fertilizer management significantly affects the number of grains panicle^{-1}. Khatun *et al.*, (2014) obtained the higher number of grains panicle^{-1}with 50 kg N ha^{-1}, while the inferior number from plots receiving no nitrogen in BRRI dhan28 during boro season. Their study further disclosed that in BRRI dhan28 the growth in number of grains per panicle was 31% at 50 kg N ha^{-1} (114) compared to control-N treatment (87).

1000-Grain Weight (g)

Weight of 1000 grains is one of the most important parameters among the yield contributing characters. The application of N changed in the 1000-grain weight by about 5.42%, the lowest (21.03 g) in the control plots and the highest (22.17 g) with

140 N kg ha^{-1} applications (Table 2). The quadratic equation Y = 21 + 0.016N – 0.000058N^2, R^2 = 0.91*, explained the relationship between applied N and the1000-grain weight of BRRI dhan28 in the coastal soil. The estimated optimum level of N for the 1000-grain weight of BRRI dhan28 was 139.5 kg ha^{-1}. Mohaddesi *et al.* (2011) reported that the 1000-grain weight was significantly influenced by increasing nitrogen levels in the rice line 843 in Iran. They recorded an increase in 1000-grain weight of 5.2% at 250 kg N ha^{-1} application compared to 300 kg N ha^{-1} application in the year 2006. However, the 1000-grain weight of rice usually varies with variety. Management practices poorly influence 1000-grain weight of a given variety. Under most conditions, the 1000-grain weight for a given variety varies only slightly (Yoshida, 1981).

Grain Yield (t ha^{-1})

The lowest grain yield (1.22 t ha^{-1}) was obtained with the native N, which increased to 2.46 t ha^{-1} with the application of 35 kg N ha^{-1}. Increasing the level of N application, increased grain yield progressively up to 105 kg N ha^{-1}, and then there was noticeable decrease with 140 kg N ha^{-1}. Increasing the rate of N application to the highest level (175 kg N ha^{-1}) increased grain yield but that was lower than the yield obtained with 140 kg N ha^{-1}. Increased doses of nitrogen helps increase panicle length, effective tillers per hill, and filled grains panicle^{-1} which ultimately enhances the grain yield (Miah *et al.* 2012). This results consonance with the findings of Haque and Haque (2016) who found the highest grain yield (5.36 t ha^{-1}) in BUDhan 1 during aman season when the crop was fertilized with 60 kg N ha^{-1} followed by 80 kg N ha^{-1} (4.99 t ha^{-1}).

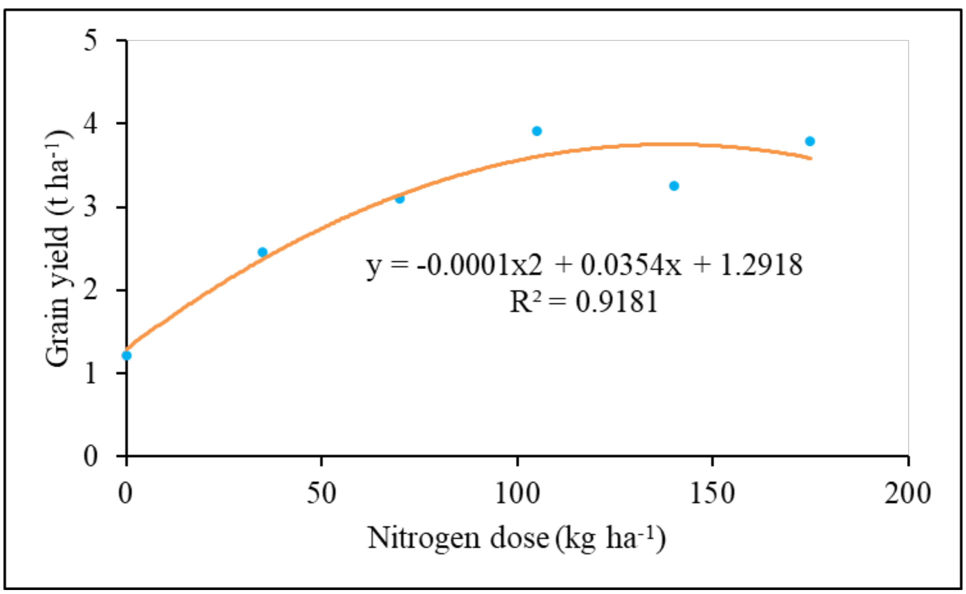

Fig. 1. Functional relationship between grain yield and different doses of nitrogen

Plotting grain yield (t ha^{-1}) against N doses produced a polynomial line (Figure 1). From Figure 1 it is clear that the responses of rice yield to nitrogen was usually rapid at low levels, slower at intermediate levels and could become negative at high levels. The relationship between the variables under consideration produced was explained by a polynomial regression equation $Y = 1.29 + 0.03531N – 0.00013N^2$. ($R^2$= 0.92*). The equation explained that about 92% the variation in yield was explained by various nitrogen applications. Differentiating the polynomial equation, the optimum level of N for rice was 140 kg N ha^{-1} in the experimental field. Khatun *et al*. (2016) also found a quadratic relationship between grain yield and nitrogen doses in BRRI dhan28. Singh *et al*., (1998) also demonstrated that increased grain yield of 20 lowland rice genotypes was gained at 150–200 kg N ha^{-1} at IRRI, Philippines. In fertilizer experiments, 90% of the maximum yield is frequently considered as an economical dose (Fageria *et al*., 2003). The 90% of the maximum grain yield was attained at 136 kg N ha^{-1} (Fageria *et al*., 2008). Likewise, Dobermann *et al*., (2000) received the highest mean grain yield during the dry season at IRRI, Philippines with 120 to 150 kg N ha^{-1}. Singh *et al*., (2007) detected 120 kg N ha^{-1} as an optimum rate for a yield level of 7.45 and 6.80 t ha^{-1} in Indo-Gangetic plain of Ludhiana, India.

It is worth to mention that the rice yield was lower than the expected in experimental field soil. The experimental field soil had 0.17% N, which is sufficient to produce 4.25 t grain ha^{-1} according to the equation derived from (IRRI, 1980),

Where, is estimated yield t ha^{-1}, N_f is N applied through fertilizer, S_N is total N content in soil. The soil had capacity to produce about 6.88 t ha^{-1} with the application of 105 kg N ha^{-1}, which is about 75% higher than the obtained yield of 3.92 t ha^{-1}.

The reason for the lower yield in the experimental field may be attributed to (i) delay transplanting, (ii) aged seedlings, (iii) salinity stress at panicle initiation stage, (iv) mild insect (stem borer) and disease (blast) infection in the ripening phase, and/or (v) tendency to lodge during maturity (Islam *et al*., 2015, Ahmed *et al*., 2022).

Biological Yield (t ha^{-1})

Table 2 shows the effects of different N treatments on biological yield. Biological yield was significantly influenced by different doses of nitrogen. The highest biological yield (7.29 t ha^{-1}) was obtained from N_3 which was statistically different from N_{35} (5.11 t ha^{-1}) and N_0 (3.24 t ha^{-1}). The lowest yield (3.24 t ha^{-1}) was recorded from the control. The quadratic equation $Y = 3.35 + 0.05539N – 0.00021N^2$, $R^2 = 0.91^*$ explained the relationship between N application and biological yield. The optimum N was estimated as 132 kg ha^{-1} for the biological yield. These results are in agreement with the findings of Singh and Lallu (2005) who reported that each increment doses of nitrogen significantly increased biological yield over its preceding dose.

Harvest Index (%)

Harvest index is the ratio of grain yield and biomass yield and is expressed in percentages (%). Results revealed that harvest index was significantly affected by different level of N application (Table 2). The highest harvest index (53.76%) was resulted from N_{175} that was statistically similar to harvest index noticed from N_{105} and N_{140}. The lowest harvest index (37.59%) was resulted from N_0. Polynomial equation $Y = 38.67 + 0.229N – 0.00085N^2$, $R^2 = 0.95^*$ explained the relationship between the rate of N application and HI of BRRI dhan28 (Table 2). However, Pramanik and Bera (2013) reported substantial influence of nitrogen on harvest index, maximum harvest index (47.07%) was detected when nitrogen was applied @ 150 kg ha^{-1} while minimum (42.60%) was achieved in control treatment.

Nitrogen Use Efficiency

Agronomic use efficiency (AE) of N in BRRI dhan28 varied from 14.50 to 35.43 kg kg^{-1} (Table 3). The AE was the highest at 35 kg N ha^{-1} and then decreased progressively with the increase of N rates up to 140 kg N ha^{-1}. There was a little reduction in AE when application was 175 kg N ha^{-1}. The 140 kg N ha^{-1}, which was the desired level of N application for coastal soils, had AE of 14.50 kg kg^{-1} (Table 3). Prior studies disclosed AE of BRRI dhan29 ranging from 6.0 to 35.7 kg kg^{-1} in 2009 but from 12.36 to 24.40 kg kg^{-1} during 2010 in a tidal flooded non-saline soil of Barisal, Bangladesh (Islam *et al*., 2015). Khatun *et al*., (2015) obtained significant variation in AE in BRRI dhan28 for urea deep placement in two locations of Gazipur, Bangladesh. They documented an AE of 22.0 to 42.0 kg kg^{-1} in BRRI dhan28 at BRRI farm, Gazipur, while 18.0 to 31.0 at Dhirasshram village, Gazipur Sadar Upazila, Gazipur, Bangladesh. Fageria and Baligar (2001) reported that AE was 23 kg grain produced per kg of N applied across N rates. Yoshida (1981) reported AE in lowland rice in the tropics in the range of 15 to 25 kg grain produced per kg of applied N.

Table 3. Agronomic use efficiency and partial factor productivity of N by BRRI dhan28

Applied N (kg ha^{-1})	Agronomic Use Efficiency (AE) (kg kg^{-1})	Partial Factor Productivity (PFP)
0	-	-
35	35.43	70.28
70	27.00	44.43
105	25.71	37.33
140	14.50	23.31
175	14.74	21.71

Partial Factor Productivity (PFP) of N in BRRI dhan28 differed from 21.71 to 70.28 (Table 3). The PFP was the highest at 35 kg N ha^{-1} and then declined gradually with the increase of N rates. The 140 kg N ha^{-1}, which was the anticipated level of N application for coastal soils, had PFP of 23.31 (Table 3). Former studies reported that PFP of N ranged from 18 to 83 in BRRI dhan28 (Khatun, 2013). Khatun *et al*., (2015) described significant variation in PFP in BRRI dhan28 for urea deep placement in two locations of Gazipur, Bangladesh. They reported PFP of 57.20 to 81.87 in BRRI dhan28 at BRRI farm, Gazipur, while 59.90 to 84.73 at Dhirasshram village under Gazipur Sadar Upazila, Gazipur, Bangladesh.

Conclusion

Results revealed that grain yield, yield components and biological yield of rice grown in Bajoa silty clay loam soil were significantly influenced by N rates. Hence, proper nitrogen management is vital for improving N use efficiency and obtaining more rice yield. The optimum N dose for coastal soils in Boro season might be 140 kg ha^{-1} for rice. The application of 140 kg N ha^{-1} offered taller plants (80 cm), 519 tillers m^{-2} and a biomass of 13,827 kg ha^{-1}. Similarly, panicles m^{-2} as well as 1000-grain weight (g) was found maximum with 140 kg N ha^{-1}. The application of 140 kg N ha^{-1} exhibited AE and PFP for N as 14.5 kg kg^{-1}, and 23.31, respectively in BRRI dhan28. Application of N fertilizer increased grain yield by about 1.2-2.6 t ha^{-1} compared to control in BRRI dhan28. Thus, adequate N application is one of the approaches to increase straw yield and subsequently grain yield in coastal soil.

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