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# Influences of Planting Geometry and Time of Nitrogen Application on the Performance of Boro Rice cv. BRRI dhan45

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## Abstract

Rice productivity influences by different agronomic factors among which planting geometry and nitrogen fertilization are important for obtaining higher yield by proper utilizing the growth elements and enhancing soil aeration to create congenial field condition. Therefore, this study was designed to define suitable planting geometry and nitrogen management for getting higher yield in *Boro* rice. The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, during the period from December 2017 to May 2018 to study the effect of planting geometry and time of nitrogen application on the yield of *Boro* rice cv. BRRI dhan45. The experimental treatments comprised four spacings viz. 20 cm × 10 cm, 20 cm × 15 cm, 20 cm × 20 cm and 25 cm × 15 cm and four times of nitrogen (138kg N ha$^{-1}$) application namely, nitrogen applied in two equal splits at (i) 15 and 45 days after transplanting (DAT) (ii) 20 and 40 DAT, and in three equal splits at (iii) 0, 20 and 40 DAT and (iv) 20, 40 and 60 DAT. The experiment was conducted in a split plot design with three replications assigning time of nitrogen application in the main plot and spacing in the sub-plot. Spacing showed significant effect on all the yield contributing characters except weight of 1000 grains and yield. The results revealed that the highest grain yield (5.46 t ha$^{-1}$) was obtained from 20 cm × 15 cm spacing, while the lowest one (4.66 t ha$^{-1}$) was obtained from 20 cm × 10 cm spacing. All the yield contributing characters were significantly influenced by time of nitrogen application except weight of 1000 grains. The highest grain yield (5.48 t ha$^{-1}$) was obtained from application of nitrogen in three equal splits at 20, 40 and 60 DAT, while the lowest one (4.60 t ha$^{-1}$) was obtained from nitrogen application in two equal splits at 20 and 40 DAT. Interaction between spacing and time of nitrogen application significantly influenced all the parameters except panicle length, weight of 1000 grains and biological yield. The highest grain yield (5.85 t ha$^{-1}$) was obtained from 20 cm × 15 cm spacing with application of nitrogen in three equal splits at 20, 40 and 60 DAT. Therefore, BRRI dhan45 can be transplanted at 20 cm × 15 cm spacing along with application of nitrogen in three equal splits at 20, 40 and 60 DAT for higher grain yield.



## Introduction

Rice (*Oryza sativa*) is a unique crop of great antiquity and akin to progress in human civilization. Its rich genetic diversity encompasses an enormous range of geographic-ecologic adaptation. Rice is the world's most important food grain crop since nearly half of the population of the world use rice as their main food. In Bangladesh more than 170 kg of rice (on average) per capita per annum is consumed while the world average is 57 kg (Mottaleb and Mishra, 2016). In Bangladesh, rice is the most extensively cultivated cereal crop and the staple food which provides about 70 % of the average per capita total calorie intake and 58% of protein intake (Mottaleb and Mishra, 2016). The soil and climate of Bangladesh are favorable for rice cultivation throughout the year. Among the rice growing countries, Bangladesh occupies fourth position in rice area and production (FAO, 2017). The average yield of rice in Bangladesh in 2018 is quite low (4.74 t ha$^{-1}$) compared to that in other leading rice growing countries such as China (7.03 t ha$^{-1}$), Korea (7.04 t ha$^{-1}$), Indonesia (5.19 t ha$^{-1}$), Vietnam (5.82 t ha$^{-1}$), Japan (6.62 t ha$^{-1}$) and USA (8.62 t ha$^{-1}$) (FAOSTAT, 2020 and WORLD ATLAS, 2020). The production of milled rice in Bangladesh in 2018/2019 is lower (34.91 million metric tons) compared to that in other leading rice growing countries such as China, India, Indonesia 148.5, 116.42, 36.7, million metric tons, respectively (STATISTA, 2020). About 75% of the total cultivable land of

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Bangladesh was used for growing rice. The area and production of rice in the country are 11.39/11.01 million hectares and 35.05/36.27 million metric tons, respectively (BBS, 2018 and AIS, 2019). In the year 2017-2018, the total area and production of *Boro* rice in Bangladesh is about 48, 59,367 hectares of land and 1,95,75,819 metric tons, respectively with average yield of 4.028 metric tons husked rice per hectare (BBS, 2018). Plant spacing needs to be considered during transplanting to get maximum benefit of rice yield in field condition. Both closer and wider spacing influenced the growth, development and yield of rice by hampering intercultural operations, increases competition among the plants for nutrients and growth elements , seedlings, labour and reduces plant stand, which may ultimately decrease yield per unit area. The optimum plant growth utilizing more solar radiation and nutrients ensures by proper plant spacing (Miah *et al*., 1990). The vegetative growth and yield of transplant rice is also significantly affected by variety, number of seedling per hill and fertilizer application (Mamun *et al*., 2010a, Mamun *et al*., 2010b and Rashid *et al*., 2015 and Shel *et al.,* 2019). Zhao *et al*. (1998) observed that grain yield with the medium density (23.3 cm × 13.3 cm) was significantly higher than the two higher densities or the lowest density.

Nitrogen is a primary nutrient element which plays a vital role in vegetative growth, development and yield of rice. BRRI (1990) reported that nitrogen has a positive influence on yield and yield components of rice. Though the nitrogen content of Bangladesh soil is low but farmers usually do not apply sufficient amount of nitrogen in their fields timely due to high cost. Naznin *et al*., (2013) estimated that only about 25 % of the added nitrogen is recovered by the crops and rest 75 % is lost due to leaching, surface runoff, $NH_3$-volatilization, decreased nitrification and other processes.

The efficiency of nitrogen use is dependent upon proper timing and frequency of its application. Effective fertilizer management gives higher yield of crops and reduces fertilizer cost. Rice yield was higher with N applied in three split dressings (25% at basal + 25% at tillering + 50% at panicle initiation) than when it was applied in two split dressings or in a single dressing (Raju and Reddy, 1989). Kamruzzaman *et al*. (2013) obtained highest rice grain yield from nitrogen application in three equal splits (viz., ⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at 45 DAT or one-third each at 15,30 and 45 DAT) than when it was applied in two splits, which was in agreement with the findings of Kaushal *et al*. (2010) who found highest grain yield from three splits of nitrogen(viz., ½ basal, ¼ at tillering, and ¼ at panicle initiation or 50%, 25% and 25% at basal, tillering and panicle initiation, respectively) application. This variation in results of the same number of nitrogen splits application caused might be due to region and climatic differences. Kumar *et al.* (2017) also obtained higher yields (grain, straw and biological) with the nitrogen application of 1/4 N as basal+1/4 at tillering+1/4 at panicle initiation and 1/4 at milking stage or 25% each at basal, tillering, panicle initiation and milking stage, respectively. Thind *et al.* (2018) observed highest grain yield at 120 kg N $ha^{-1}$ with three equal splits at 14, 35 and 63 days after sowing (DAS) in Dry direct-seeded aerobic rice (DSR). Hence, time of nitrogen application is an important aspect of overall nitrogen management in the rice field from the view point of efficient utilization. Proper timing of nitrogen application reduces the loss of nitrogen in the rice field and gives higher yield. The average yield of Bangladesh Rice Research Institute (BRRI) released variety BRRI dhan45 was found to be 6.5 t $ha^{-1}$ (BRRI, 2006). But sultana *et al.,* 2012 reported the highest grain yield (5.69 t $ha^{-1}$) of BRRI dhan45 achieved from 25 cm ×15 cm spacing during *Boro* season under aerobic system of cultivation while Islam (2015) reported grain yield ( 4.28 t $ha^{-1}$) in a raised transplant condition. Hosain *et al.* (2018) found grain yield (5.19 t $ha^{-1}$) from BRRI dhan45 in traditional cultivation method. So there is an ample scope to increase yield of BRRI dhan45 by means of agronomic management. *Boro* rice plays an important role in rice production leading to obtain lion share of self-sufficiency due to its high yield in the *Boro* season in Bangladesh. Thus, it is important to know the proper time of nitrogen application on the growth, development and yield of *Boro* rice cv. BRRI dhan45. An increase in the yield of *Boro* rice can be expected if appropriate combination of planting geometry and time of nitrogen application is used. The present study was, therefore, undertaken with the objectives to find out the effect of planting geometry, time of nitrogen application and their interaction on the yield of *Boro* rice cv. BRRI dhan45.

## Materials and Methods

### *Experimental site*

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh during the period from December 2017 to May 2018. Geographically the experimental site is located at 24.75° N latitude and 90.50° E longitude at an elevation of 18 m above the sea level under the Agro-ecological Zone of the Old Brahmaputra Floodplain (AEZ-9) (UNDP and FAO, 1988). The research field was medium high land with moderate drainage facility and silt loam texture soil of non-calcareous dark grey flood plain belongs to Sonatala soil series. The experimental soil contained pH 6.20, organic matter content 1.67%, total nitrogen 0.10%, available P 26.0 ppm, exchangeable K me 0.14% and available S 13.90 ppm. The experimental site is under the subtropical climate where the *Rabi* season (October to March) starts with low temperature and plenty of sunshine. The average air temperature ranges from 18- 27 $^{0}$C, total rainfall from 18-453 mm and average relative humidity from 3-82% with monthly total sunshine from 138-200 hours during the experimental period.

### *Treatments and design*

Two factors included in the experiment were as follows: viz A**.** Spacing (cm): 4-i) 20 × 10, ii)20 × 15, iii**)** 20 × 20 and iv) 25 × 15 and B. Time of nitrogen application: 4**-** i) Nitrogen applied in 2 equal splits at 15 and 45 days after transplanting (DAT)**,** ii) Nitrogen applied in 2 equal splits at 20 and 40 DAT**,** iii**)** Nitrogen applied in 3 equal splits at 0, 20 and 40 DAT and iv**)** Nitrogen applied in 3 equal splits at 20, 40 and 60 DAT**.** The experiment was laid out in a split-plot design with three replications. Each replication was divided into 16 unit plots where the nitrogen application in the main plot and spacing in the sub-plot were allocated. There were 48 unit plots in the experiment. Spaces between main plots were 1.0 m and those of sub-plots were 0.75 m. The size of each unit plot was 4.0 m × 2.5 m.

### *Crop husbandry*

The variety used in this experiment was BRRI dhan45. It was developed by the Bangladesh Rice Research Institute (BRRI) and released in 2005 as transplant *Boro* rice. Seeds of BRRI dhan45 were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. Seedling nursery was prepared by puddling the soil. Sprouted seeds were sown in broadcast method in the wet nursery bed. Proper care was taken to raise good seedlings in the seedbed. Weeds were removed and irrigation was given in the seed bed as and when necessary.

The experimental land was prepared by ploughing and cross ploughing with power tiller followed by laddering. Weeds and stubble were removed from the field. The individual plots of each block were prepared and leveled just before the specified date of transplanting. The field was fertilized with urea (46% N), triple super phosphate (21.12% P), muriate of potash (49.80% K), gypsum(18% S) and zinc sulphate(36% Zn) @ 300, 80, 125, 45 and 6 kg ha$^{-1}$, respectively (FRG, 2012). Except urea, the whole amount of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at final land preparation. Urea was applied in splits following treatments specification. Thirty five days old seedlings were transplanted in the plots at the rate of 2-3 seedlings hill$^{-1}$ maintaining spacing as per experimental treatments. Intensive care was taken during the growing period for proper growth and development of the crop. Weeding (at 15, 30 and 45 DAT), gap filling (within 7 DAT), irrigation were done as and when needed. Excess water was drained out of the plots before 15 days of harvest to enhance maturity of the crop. Sumithion 50EC @ 1.5 litres ha$^{-1}$ was sprayed twice at 30 and 50 DAT to control leaf hopper (*Nephotettix verescens***)** and stem borer (*Scirpophaga incertulas*) infestation. The crop was harvested at full maturity when 90 % of the grains became golden yellow in colour. Five hills (excluding border hills) were selected randomly from each unit plot and uprooted before harvesting for recording data. The grains were cleaned and dried to a moisture content of 14 %. Final grain and straw yields plot$^{-1}$ were recorded and converted to t ha$^{-1}$.

Data on yield contributing characters were recorded from five randomly selected sample plants from each plot. The biological yield was calculated with the following formula:
Biological yield = Grain yield + straw yield.
Harvest index was calculated on the basis of grain and straw weights using the following formula (Gardner *et al*., 1985).

HI (%) = (Grain yield/Biological yield) x 100

### *Statistical analysis*

All the collected data were analyzed following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using a computer operated programme named MSTAT.

## Results and Discussion

### *Effect of spacing*

The highest plant height (87.69 cm), number of effective tillers hill$^{-1}$ (12.69), panicle length (23.34cm), number of grains panicle$^{-1}$ (161.93), grain yield (5.46 t ha$^{-1}$), biological yield (11.99 t ha$^{-1}$), harvest index (45.56 %) from by 20 cm × 15 cm spacing, number of non-effective tillers hill$^{-1}$ (3.30), straw yield (7.18 t ha$^{-1}$) from 20 cm × 10 cm spacing, and number of sterile spikelets panicle$^{-1}$ (18.68) from 20 cm × 20 cm spacing were obtained. The lowest plant height (83.09 cm), number of effective tillers hill$^{-1}$ (9.40), panicle length (19.52cm), number of grains panicle$^{-1}$ (139.98), grain yield (4.66 t ha$^{-1}$), harvest index (39.35 %) from by 20 cm × 10 cm spacing, number of non-effective tillers hill$^{-1}$ (2.47), number of sterile spikeletspanicle$^{-1}$ (11.73), straw yield (6.53 t ha$^{-1}$) from 20 cm × 15 cm spacing and biological yield (11.33 t ha$^{-1}$) were obtained. Weight of 1000 grains varied between 25.42 g to 27.89 g depending on the plant spacing used (Fig. 1 and Table 1). Bozorgi *et al*. (2011) found the highest grain yield (3.415 t ha$^{-1}$), biological yield (8.033t ha$^{-1}$) and harvest index (42.43%) from 20 cm × 20 cm spacing, plant height (133.2cm), straw yield (4.69) from 15 cm × 15 cm spacing, panicle length (26.99), number of grains panicle$^{-1}$(87) from 25 cm × 25 cm spacing in rice. Shel *et al.* (2019) obtained the highest plant (107.70 cm), number of effective tillers hill$^{-1}$ (9.23) at 35cm × 15cm, number of grains panicle$^{-1}$ (119.52), 1000-grain weight (24.87 g), grain yield (3.80 t ha$^{-1}$) and harvest index (40.29) were obtained at 25cm × 15cm row spacing in rice. However, spacing had no significant effect on weight of 1000 grains. Khan (2004) stated that 20 cm × 15 cm spacing produced the highest number of effective tillers hill$^{-1}$. Mahato and Adhikari (2017) also found the maximum number of tillers m$^{-2}$ from 20 cm × 15 cm planting geometry in rice in all growth stages. The highest grain yield in 20 cm × 15 cm spacing was possible due to the combined of higher number of total tillers hill$^{-1}$, more effective tillers hill$^{-1}$, bigger panicle length, higher number of grains panicle$^{-1}$ and reasonably having individual grains. Similar results were found by Rahman (2005) and Kipgen, (2018). It might be due to the fact that widely spaced plants accomplish more light, air, nutrients and moisture which enhanced plant growth. The result revealed that 20 cm × 15 cm spacing had the greatest opportunity to produce more number of effective tillers hill$^{-1}$ due to availability of more nutrient, air and light in wider spacing which ultimately resulted in the production of more grain yield.

### *Effect of time of nitrogen application*

The tallest plant (87.96 cm), highest number of effective tillers hill$^{-1}$ (12.52), panicle length (23.49 cm) number of grains panicle$^{-1}$ (157.40), grain yield (5.48 t ha$^{-1}$), biological yield (12.25 t ha$^{-1}$) and harvest index (44.73 %) were recorded when nitrogen was applied in three equal splits at 20, 40 and 60 DAT. The highest number of non-effective tillers hill$^{-1}$ (3.28) from two equal splits at 15 and 45 DAT, sterile spikelets panicle$^{-1}$ (20.06) and straw yield (6.88 t ha$^{-1}$) were obtained when nitrogen was applied in two equal splits at 20 and 40 DAT. On the other hand, the shortest plant height (82.36 cm), number of effective tillers hill$^{-1}$ (9.42), panicle length (20.61 cm) from nitrogen application in two equal splits at 15 and 45 DAT, number of grains panicle$^{-1}$ (138.50), grain yield (4.60 t ha$^{-1}$), biological yield (11.48 t ha$^{-1}$), harvest index (40.07 %) from nitrogen application in two equal splits at 20 and 40 DAT, number of non-effective tillers hill$^{-1}$ (2.68),number of sterile spikeletspanicle$^{-1}$ (12.87) from nitrogen application in three equal splits at 20, 40 and 60 DAT and straw yield (6.68 t ha$^{-1}$) nitrogen application in three equal splits at 0, 20, 40 DAT (Fig. 1 and Table 2) were obtained. Ye *et al*. (2019) reported that the application of nitrogen significantly promoted the growth of rice. Alam *et al*. (2002) reported highest number of grains panicle$^{-1}$(118.50), grain yield (4.79 t ha$^{-1}$), straw yield (6.60 t ha$^{-1}$), biological yield (11.40 t ha$^{-1}$) and harvest index (41.24%) from three equal splits (as basal, early tillering and panicle initiation stages) of application of nitrogen. Djaman *et al*. (2018) found rice grain yield ranges from 4.10 to 11.58 t ha$^{-1}$along with most of the yield parameters due to split application of nitrogen. Results showed that like plant spacing, the weight of 1000-grains was not significantly affected by time of nitrogen application. Alam *et al*. (2002) also observed statistically non-significant weight of 1000-grains of rice. Nitrogen enhances vegetative growth of the plants leading to increase number of tillers hill$^{-1}$and the cellular activity during panicle initiation and development stage with the positive physiological effects. Higher doses and splitting application of nitrogen increase grain yield of *Boro* rice with the improvement of growth and yield characters like dry matter production, number of effective tillers hill$^{-1}$ and number of grains panicle$^{-1}$ at different DATs (Sathiya and Ramesh 2009 and Tadesse *et al*., 2017). As a result, though the grain yield differed significantly but the weight of 1000- grain weight found statistically non-significant.

### *Interaction effect of spacing and time of nitrogen application*

Effect of interaction between spacing and time of nitrogen application had significant influence on the most of the studied yield contributing characters except panicle length, 1000-grains weight and biological yield. The highest plant height (91.21 cm), number of effective tillers hill$^{-1}$ (14.73), number of grains panicle$^{-1}$ (166.50), grain yield (5.85 t ha$^{-1}$), harvest index (46.06 % ) from interaction of 20 cm × 15 cm spacing and nitrogen in three equal splits at 20, 40 and 60 DAT, number of non-effective tillers hill$^{-1}$ (3.80) from interaction of 20 cm × 10 cm spacing and nitrogen in three equal splits at 20, 40 and 60 DAT, number of sterile spikeletspanicle$^{-1}$ (22.40) from the interaction of 20 cm × 20 cm spacing and nitrogen in two equal splits at 20, 40 DAT and straw yield (7.55 t ha$^{-1}$) from the interaction of 20 cm × 10 cm spacing and nitrogen in two equal splits at 20, 40 DAT were obtained. On the other hand, the shortest plant height (80.40 cm), the lowest number of effective tillers hill$^{-1}$ (8.47) from the interaction of 20 cm × 10 cm spacing and nitrogen in two equal splits at 15, 45 DAT, grain yield (4.20 t ha$^{-1}$), harvest index (35.74 %) from the interaction of 20 cm × 10 cm spacing and nitrogen in two equal splits at 20, 40 DAT, number of non-effective tillers hill$^{-1}$ (2.00), number of sterile spikeletspanicle$^{-1}$ (9.20) from the interaction of 20 cm × 15 cm spacing and nitrogen in two three splits at 20, 40 and 60 DAT, number of grains panicle$^{-1}$ (130.10) from the interaction of 20 cm × 20 cm spacing and nitrogen in two equal splits at 20, 40 DAT, and straw yield (6.25 t ha$^{-1}$) from the interaction of 20 cm × 20 cm spacing and nitrogen in two equal splits at 15, 45 DAT were produced (Fig.1 and Table 3). The Results are in agreement with Shel *et al*. (2019).

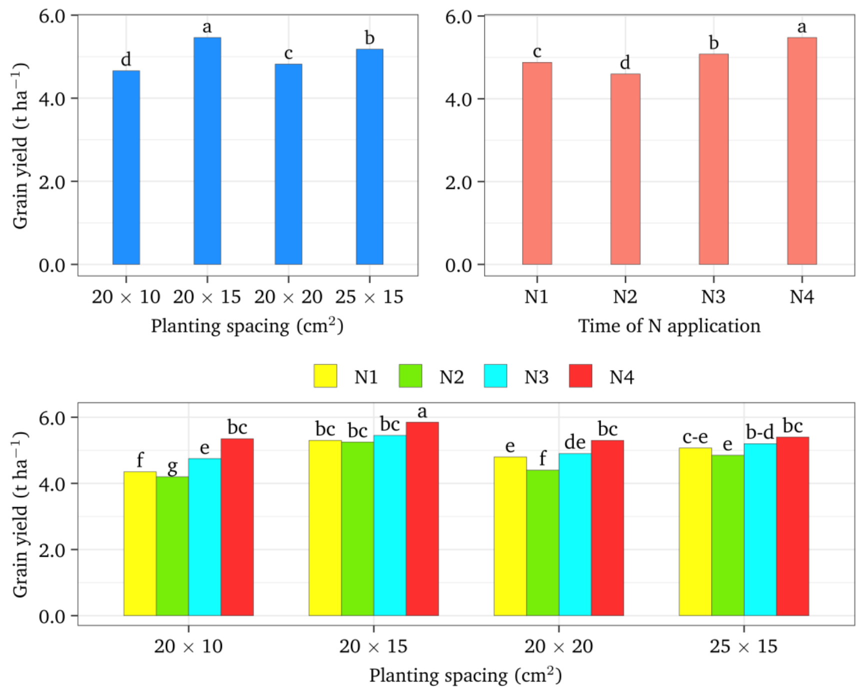


Figure 1. Effect of Planting spacing, time of nitrogen application and their interaction on yield of

Table 1. Effect of spacing on the yield components and yield of *Boro* rice cv. BRRI dhan45

| Spacing (S) (cm²) | Plant height (cm) | No. of effective tillers hill-1 | No. of non-effective tillers hill-1 | Panicle length (cm) | No. of grains panicle-1 | No. of Sterile spikelets panicle-1 | WTS (g) | Straw yield (t ha-1) | Biological yield (t ha-1) | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 × 10 | 83.09c | 9.40c | 3.30a | 19.52c | 139.98c | 15.88c | 25.42 | 7.18a | 11.84a | 39.35c |
| 20 × 15 | 87.69a | 12.69a | 2.47c | 23.34a | 161.93a | 11.73d | 27.89 | 6.53c | 11.99a | 45.56a |
| 20 × 20 | 83.96c | 10.10c | 2.90ab | 22.00b | 142.13bc | 18.68a | 26.12 | 6.53c | 11.33b | 42.80b |
| 25 × 15 | 85.74b | 11.17b | 2.75b | 21.90b | 147.27b | 16.57b | 26.93 | 6.80b | 11.94a | 43.04b |
| Sig. level | ** | ** | ** | ** | ** | ** | NS | ** | * | ** |
| Stand. error | 0.29 | 0.23 | 0.14 | 0.21 | 1.51 | 0.08 | 0.58 | 0.06 | 0.11 | 0.41 |
| CV% | 5.21 | 7.80 | 10.30 | 5.95 | 6.22 | 3.87 | 5.05 | 4.18 | 4.90 | 5.56 |

In a column, the means having same letter(s) or without letters do not differ significantly as per DMRT.* Significance at 5% level of probability, ** Significance at1% level of probability.

Table 2. Effect of time of nitrogen application on the yield components and yieldof *Boro* rice cv. BRRI dhan45

| Time of N application (N) | Plant height (cm) | No. of effective tillers hill-1 | No. of non-effective tillers hill-1 | Panicle length (cm) | No. of grains panicle-1 | No. of Sterile spikelets panicle-1 | WTS (g) | Straw yield (t ha-1) | Biological yield (t ha-1) | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| N1 | 82.36d | 9.42d | 3.28a | 20.61c | 146.00b | 14.32c | 26.28 | 6.70b | 11.58b | 42.14c |
| N2 | 84.04c | 10.20c | 2.95ab | 21.15b | 138.50c | 20.06a | 26. 07 | 6.88a | 11.48b | 40.07d |
| N3 | 86.12b | 11.63b | 3.00ab | 21.51b | 149.40b | 15.61b | 26.54 | 6.68b | 11.75b | 43.23b |
| N4 | 87.96a | 12.52a | 2.68b | 23.49a | 157.40a | 12.87d | 27.48 | 6.78ab | 12.25a | 44.73a |
| Sig. level | ** | ** | * | ** | ** | ** | NS | * | ** | ** |
| Stand. error | 0.29 | 0.23 | 0.18 | 0.18 | 1.37 | 0.18 | 0.58 | 0.04 | 0.10 | 0.31 |
| CV% | 5.21 | 7.80 | 10.30 | 5.95 | 6.22 | 3.87 | 5.05 | 4.18 | 4.90 | 5.56 |

In a column, the means having same letter(s) or without letters do not differ significantly as per DMRT.* Significance at 5% level of probability, ** Significance at1% level of probability, NS = Not significant, $N_1$= Nitrogen applied in 2 equal splits at 15 and 45 DAT, $N_2$= Nitrogen applied in 2 equal splits at 20 and 40 DAT, $N_3$= Nitrogen applied in 3equal splits at 0, 20 and 40 DAT and $N_4$= Nitrogen applied in3 equal splits at 20, 40 and 60 DAT.

Table 3. Effect of time of nitrogen application on the yield components and yieldof *Boro* rice cv. BRRI dhan45

| Interaction (S x T) | Plant height (cm) | No. of effective tillers hill$^{-1}$ | No. of non-effective tillers hill$^{-1}$ | Panicle length (cm) | No. of grains panicle$^{-1}$ | No. of Sterile spikelets panicle$^{-1}$ | WTS (g) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| T1 (S1 × N1) | 80.40h | 8.47h | 3.00a-d | 18.44 | 139.30ef | 14.30hi | 24.95 | 7.30b | 11.65 | 37.34g |
| T2 (S1 × N2) | 81.87gh | 8.73gh | 3.00a-d | 19.40 | 132.10fg | 20.30c | 25.17 | 7.55a | 1 1.75 | 35.74g |
| T3 (S1 × N3) | 84.56def | 9.60e-h | 3.40abc | 19.80 | 135.13fg | 15.63fg | 25.30 | 7.15bc | 11.90 | 39.92f |
| T4 (S1 × N4) | 85.54cd | 10.80c-f | 3.80a | 20.44 | 153.40bcd | 13.30ij | 26.27 | 6.70e-h | 12.05 | 44.40a-d |
| T5 (S2 × N1) | 84.57def | 11.07cde | 3.00a-d | 22.40 | 160.20abc | 10.40k | 27.48 | 6.35ij | 11.65 | 45.49ab |
| T6 (S2 × N2) | 86.30cd | 11.87bcd | 2.80a-d | 22.80 | 158.60abc | 16.20efg | 27.38 | 6.40ij | 11.65 | 45.06ab |
| T7 (S2 × N3) | 88.67b | 13.07b | 2.07d | 23.24 | 162.40ab | 11.10k | 27.58 | 6.50g-j | 11.95 | 45.61ab |
| T8 (S2 × N4) | 91.21a | 14.73a | 2.00d | 24.90 | 166.50a | 9.20 l | 29.09 | 6.85def | 12.70 | 46.06a |
| T9 (S3 × N1) | 81.73gh | 8.73gh | 3.73ab | 20.80 | 137.10fg | 17.30e | 25.93 | 6.25j | 11.05 | 43.44bcd |
| T10 (S3 × N2) | 82.87efg | 9.80e-h | 3.00a-d | 21.20 | 130.10g | 22.40a | 25.72 | 6.52g-j | 10.92 | 40.29f |
| T11 (S3 × N3) | 84.67cde | 10.27d-g | 2.27cd | 21.60 | 147.00de | 18.40df | 26.11 | 6.60f-i | 11.50 | 42.61cde |
| T12 (S3 × N4) | 86.56c | 11.60bcd | 2.60bcd | 24.40 | 154.30bcd | 16.63ef | 26.77 | 6.75efg | 12.05 | 43.98a-d |
| T13 (S4 × N1) | 82.73fg | 9.40fgh | 3.40abc | 20.80 | 147.30de | 15.30gh | 26.53 | 6.90cde | 11.97 | 42.36de |
| T14 (S4 × N2) | 85.13cd | 10.40c-f | 3.00a-d | 21.20 | 133.30fg | 21.33b | 26.21 | 7.05bcd | 11.90 | 40.76ef |
| T15 (S4 × N3) | 86.57c | 11.93bc | 2.60bcd | 21.40 | 153.10cd | 17.30e | 27.17 | 6.45hij | 11.65 | 44.64abc |
| T16 (S4 × N4) | 88.53b | 12.93b | 2.33cd | 24.20 | 155.33bcd | 12.33j | 27.81 | 6.80def | 12.20 | 44.26a-d |
| Sig. level | * | * | * | NS | * | ** | NS | ** | NS | ** |
| Stand. error | 0.59 | 0.49 | 0.35 | 0.37 | 2.75 | 0.35 | 0.77 | 0.09 | 0.15 | 0.63 |
| CV% | 5.21 | 7.80 | 10.30 | 5.95 | 6.22 | 3.87 | 5.05 | 4.18 | 4.90 | 5.56 |

In a column, the means having same letter(s) or without letters do not differ significantly as per DMRT.* Significance at 5% level of probability, ** Significance at1% level of probability, NS = Not significant, $N_1$= Nitrogen applied in 2 equal splits at 15 and 45 DAT, $N_2$= Nitrogen applied in 2 equal splits at 20 and 40 DAT, $N_3$= Nitrogen applied in 3equal splits at 0, 20 and 40 DAT and $N_4$= Nitrogen applied in3 equal splits at 20, 40 and 60 DAT.

Liu *et al*. (2016) observed the highest tillers hill$^{-1}$(14.9), 1000-grain weight (28.6g) grain yield (12.6 t ha$^{-1}$), straw yield (10.3 t ha$^{-1}$) from split application (basal, tillering and jointing stages) of nitrogen and 25 cm × 18 cm spacing in rice. Tilahun, 2019 reported that optimum plant spacing ensures plants to grow properly both in their above and underground parts through different utilization of below and above ground resources like nitrogen which is integral part of structural and functional protein, chlorophyll and nucleic acid, and main nutrient to increase 25-30 per cent yield. Closer spacing hampers intercultural operations, arises competition among the plants for growth elements (Alen *et al.*, 2012) and wider spacing also allows more competition among crop plants and weeds. As a result plant growth slows down and their grain yields decreases (Martin *et al.,* 2010) due to insufficient utilization of the growth factors.

## Conclusion

From the above results it was observed that among the studied planting geometry 20 cm × 15 cm spacing and three times equal split nitrogen application were better in respect of yield and yield contributing characters of *Boro* rice cv. From the results of the present study, it may be concluded that 20 cm × 15 cm spacing combined with nitrogen application in three equal splits at 20, 40 and 60 DAT appears as the promising practice to get the higher grain yield of *Boro* rice cv. BRRI dhan45.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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