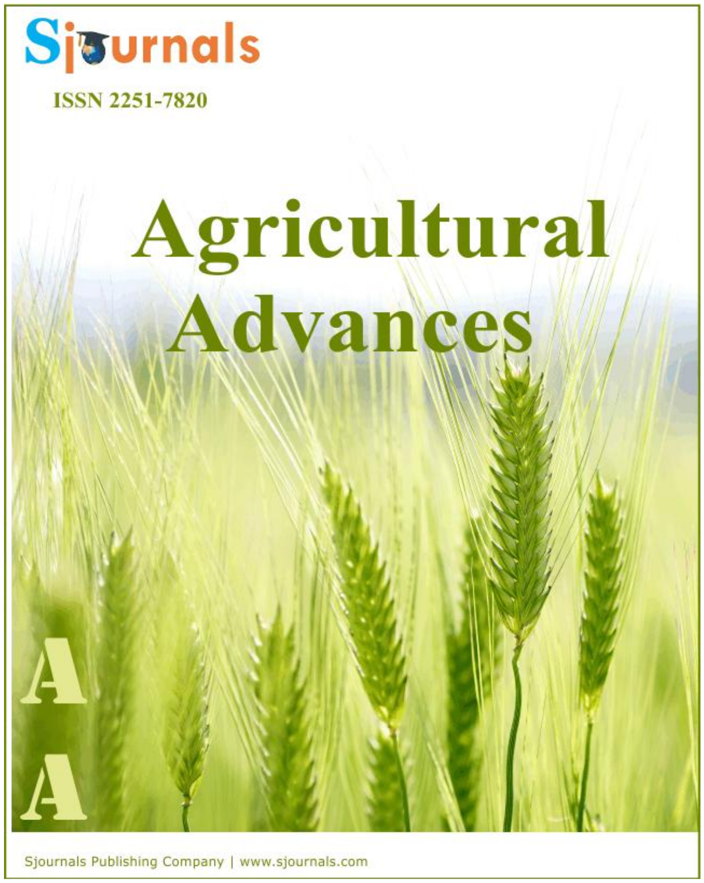
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Original article

Effect of split application of nitrogen fertilizer on yield traits and yield of high yielding aromatic rice varieties in Bangladesh

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A B S T R A C T

A field experiment was conducted at Bangladesh Agricultural University, Mymensingh, Bangladesh during *Aman* season in 2013 to evaluate the effect of proper time of nitrogen application on yield and yield parameters of high yielding rice varieties. Two transplanted aromatic aman rice varieties (BRRI dhan37 and BRRI dhan38) and four timing of nitrogen fertilizer application (N_1= ½ during final land preparation + ½ at 30 DAT, N_2= $^1/_3$ at 15 DAT + $^1/_3$ at 30 DAT + $^1/_3$ at 45 DAT, N_3= $^1/_4$ at 15 DAT + ½ at 30 DAT + $^1/_4$ at 45 DAT and N_4= $^2/_3$ at 15 DAT + $^1/_3$ at 45 DAT) were used in this experiment. The experiment was arranged in a randomized complete block design with three replications as factorial arrangement. All agronomic practices were applied as recommended for each cultivar. Yield and yield traits (plant height, total tillers, effective panicle, panicle length, grains per panicle, 1000-grain weight, grain yield, straw yield, harvest index) was measured. Results showed that the effect of nitrogen split application on plant height, total tillers, effective panicle, panicle length, grains per panicle, 1000-grain weight, grain yield and straw yield was significant. The results revealed that three equal splits of nitrogen (N_2) application ($^1/_3$ at 15 DAT + $^1/_3$ at 30 DAT + $^1/_3$ at 45 DAT) produced the highest grain yield (3.29 t ha^{-1}) which was statistical differed from all N splits application treatments and the lowest grain yield (2.41 tha^{-1}) was obtained from N_1 treatment which was statistically similar to N_4 treatment. The variety effect was significant on all traits except plant height, number of grains $panicle^{-1}$, number sterile spikelets $panicle^{-1}$ and stubble yield. The variety BRRI dhan38 produced more grain yield than BRRI dhan37. The effect of nitrogen split application and variety (N×V) on total traits was significant and $N_2 \times V_2$ combination produced the highest grain yield among all the combinations.

1. Introduction

Rice (*Oryza sativa* L.) is an important food in the diet of the world population (FAO, 2004) because of its nutritional features (Juliano, 1993) and low price. On a global basis, it ranks second only to wheat in terms of area harvested, but in terms of its importance as a food crop, rice provides more calories per ha than any other cereal food. Rice is the staple food of about 160 million people of Bangladesh. It provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intakes of an average person in the country. Rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh (BBS, 2015). Almost all of the 13 million farm families of the country grow rice. Thus, rice plays a vital role in the livelihood of the people of Bangladesh. Total rice production in Bangladesh was about 10.59 million tons in the year 1971 when the country's population was only about 70.88 millions. However, the country is now producing about 34.4 million tons to feed her 160 million people (BBS, 2015). This increased rice production has been possible largely due to the adoption of modern rice varieties on around 66% of the rice land which contributes to about 73% of the country's total rice production.

Rice grain is characterized into course, medium and fine with different colours based on physical properties. Some of them have special appeal for their aroma. In Bangladesh, a number of fine rice cultivars are grown by the farmers. Fine rice is mainly used by the people in the preparation of palatable dishes and sold at a higher price in the market. Cultivation of aromatic rice is becoming popular due to its higher prices and huge export potentiality (Gangaik and Prasad, 1999). Aromatic rice varieties are preferred by some consumers despite of their higher price and lower yield (Ratho, 1984). Rice yield depends on several factors: climate, physical conditions of the soil, soil fertility, water management, sowing date, cultivar, seed rate, weed control, and fertilization (Jing et al., 2008). For fertilization, N is the main nutrient associated with yield (Sahrawat, 2006; Bouman et al., 2007; De-Xi et al., 2007; Jing et al., 2008). Its availability promotes crop growth and tillering, finally determining the number of panicles and spikelets during the early panicle formation stage. This nutrient also provides sink during the late panicle formation stage (Artacho et al., 2009).

Moreover, the dominant form of nitrogen is nitrate and relatively little ammonia volatilization is expected after fertilizer nitrogen application. The alternate moist and dry soil conditions may stimulate nitrification-denitrification processes in dry sown rice, resulting in a loss of nitrogen through N_2 and N_2O (Prasad, 2011). The differences in soil N dynamics and pathways of nitrogen losses in dry sown rice system may result in different fertilizer nitrogen recoveries. With even high nitrogen applications in rice, grain filling may be limited by a low contribution of post-anthesis assimilates (Zhang et al., 2009). In order to reduce N losses from the soil, different timing of fertilizers application have been developed which would provide a continuous and regular supply of nitrogen during the life cycle. The N application in different splits increased crop yield and also increased of N use efficiency (Beşer, 2001; Jing, 2007). Therefore, the present research was undertaken to know the effects of N splitting method in different times on the rice growth and yield.

2. Materials and methods

2.1. Site of the experiment

The experiment was conducted at Bangladesh Agricultural University, Mymensingh, Bangladesh, during *Aman* season. Geographically, the experimental area is situated at a latitude 24°75N and longitude of 90°50 E having sub-tropical climate at the elevation of above 18.0 m the sea level. The topography of the soil is medium low, loamy in texture and moderately fertile. The physical and chemical properties of the soil of the experimental field have been presented in Table 1.

Table 1
Physio-chemical properties of the soil of the experimental field.

Traits	Value
Total nitrogen (%)	0.87
Organic matter (%)	1.028
Available phosphorus (ppm)	18.00
Available sulphur (ppm)	16.00
Exchangeable potassium (me/100 g soil)	0.23
pH	6.90

2.2. Treatments of the experiment

The aim of the experiment was to study the effects of four timing/levels of nitrogen split application on two rice varieties (BRRI dhan37 and BRRI dhan38). The varieties were released by Bangladesh Rice Research Institute in 1998 as transplant aman rice, modern aromatic rice varieties of Bangladesh. The four timing of nitrogen treatments were N_1 (at two equal splits, ½ during final land preparation + ½ at 30 DAT), N_2 (at three equal splits, $^1/_3$ 15 DAT + $^1/_3$ at 30 DAT + $^1/_3$ at 45 DAT), N_3 (at three splits, $^1/_4$ at 15 DAT + $^1/_2$ at 30 DAT + $^1/_4$ at 45 DAT) and N_4 (at two splits, $^2/_3$ at 15 DAT + $^1/_3$ at 45 DAT). Fertilizers in each plot were applied as urea, triple super phosphate (TSP), muriate of potash (MP) and gypsum @ 150, 100 and 70, 60 kg ha^{-1}, respectively. All fertilizers except urea were applied at final land preparation and urea was applied as per treatments specification. The experiment was carried out in a Randomized Complete Block Design (RCBD) with three replications as factorial arrangement. The size of the each experimental pot was 4 m × 2.5 m. Layout of the experiment was done with inter-plot spacing 0.75 m and inter-block spacing 1.0 m. Pre-germinated seeds were sown in wet nursery bed and proper care was taken to raise the seedlings in seedbed. Thirty (30) days old seedlings were uprooted carefully and transplanted three healthy seedlings in each hill maintaining spacing of 20 cm × 15 cm. Intercultural operations were done properly. About 6-8 cm water layer was maintained in the plot up to maximum tillering stage (MTS), 9-12 cm from MTS to flowering stage, and then drained out water until the crop attained maturity.

2.3. Measurements

At the end of growth season five sample plants were harvested from each plot and traits of yield quantity and yield were analyzed. Yield quantity traits include of yield and yield components (based on 14% moisture) such as plant height, total tiller number, effective tillers, panicle lengths, number of grains per panicle, number of non-filled grains per panicle, 1000-grain weight, grain yield stubble yield and harvest index.

Data analysis

Data were analysed statistically using 'analysis of variance' technique and differences among treatments were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

3. Results and discussion

Application of nitrogen in different splits significantly increased the plants height of BRRI dhan37 and BRRI dhan38 (Table 2). The tallest plant (138.87 cm) was observed at N_2 treatment which is statistically similar to N_3 treatment and the shortest plant height (129.88 cm) was recorded at N_1 treatment which statistically different to other treatments as well as 7.2 and 6.7% higher than N_2 and N_3. These results explicitly confirm of the results obtained by Islam et al. (2009); Hasanuzzaman et al. (2009). Availability of nitrogen at early growth stages caused for creasing of plant height (Manzoor *et al.*, 2006). Three splits of nitrogen application were better than two splits. The increase in plant height due to application of three split of nitrogen might be associated with the increasing nitrogen use efficiency of rice. There was no significant difference of plant height between the varieties of BRRI dhan37 and BRRI dhan38 (Table 3). Plant height also insignificant among the interaction effect of nitrogen split application and variety and the highest plant height (130.64 cm) was obtained from V_2N_2 treatment and the lowest (116.86 cm) was recorded at V_1N_1 treatment combinations (Table 4).

Number of total tillers of rice plant was also significantly affected by nitrogen split treatments (Table 2). Application of nitrogen with three equal splits produced the highest number of tillers hill^{-1} than three treatments. The highest number of tillers hill^{-1} (10.73) was found at N_2 which was statistically similar to N_3 and the lowest was recorded at N_4 treatment i.e. two splits- $^2/_3$ at early stage (15 DAT) and $^1/_3$ at 45 DAT. This result indicated that continuous supply of nitrogen from seedling establishment to maximum tillering stage is more important of the crop. These results were accordance with the findings of Singh and Singh (1998); Singh et al. (2006). BRRI dhan38 produced statistically higher total tillers hill^{-1} than BRRI dhan37 (Table 3). The number of total tillers hill^{-1} was significantly influenced by the interaction of split application of nitrogen and variety (Table 4). The result revealed that BRRI dhan37 gave the highest number of tillers hill^{-1} with three equal splits of nitrogen (V_1N_2) and the lowest was recorded at V_2N_4 treatment combinations (Table 4).

Number of effective tillers hill^{-1} was significantly influenced due to effect of nitrogen split application (Table 2). The highest number of effective tillers was found at N_2 followed by N_3 and the lowest was found at N_4 treatment which was statistically similar to N_4 treatment. The result indicated that three splits of nitrogen application were better than two splits. Rao et al. (1997) cited that three splits application of nitrogen showed better response than two splits. Rana et al. (1989) and Hasanuzzaman (2009) observed similar results. BRRI dhan38 produced significantly more tillers hill^{-1} than BRRI dhan37. BRRI dhan38 gave the highest number of effective tillers hill^{-1} with N_2 combination. Number of non-effective tillers hill^{-1} also significantly influenced by the action split application of nitrogen (Table 2). The highest number of non-effective tillers was found at N_4 and the lowest was found at N_1 treatment and the second highest was observed at N_2 which was statistically similar to N_3 treatment. The variety V_1 produced higher non-effective tillers than V_2 (Table 3). The remarkable interaction effect of variety and split application of nitrogen was observed on the non-effective tillers hill^{-1}, and the highest and the lowest values were recorded with the combination of V_1N_3 and V_2N_3, respectively (Table 4).

Table 2

Effects of split application of nitrogen on yield and yield contributing characteristics of fine rice.

Treatment	Plant height (cm)	Total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	No. of sterile spikelet panicle^{-1}	Weight of 1000-grains (g)	Yield tha^{-1}	Straw yield tha^{-1}
N_1	129.88b	9.17b	7.16b	2.81c	22.87b	75.61b	20.53	16.70ab	2.41c	5.70b
N_2	138.87a	10.64a	8.25a	3.13b	27.13a	78.98a	20.69	17.53a	3.29a	6.64a
N_3	138.14a	9.73ab	8.15a	2.90bc	26.53a	70.21bc	21.70	16.10b	2.89b	6.06b
N_4	134.47ab	8.62b	7.31b	4.40a	26.28a	67.57c	20.52	15.47bc	2.50c	6.01b
CV	4.23	10.54	10.74	7.69	5.44	10.04	12.58	11.07	13.11	7.67
Sx	1.652	0.292	0.231	0.073	0.404	2.119	NS	0.526	0.78	0.57

In a column figures having similar letter(s) do not differ significantly whereas figures having dissimilar letter(s) differ significantly as per DMRT, N_1 = ½ as basal + ½ at 30 DAT; N_2 = $^1/_3$ at 15 DAT +$^1/_3$ at 30 DAT + $^1/_3$ at 45 DAT; N_3 = $^1/_4$ at 15 DAT +½ at 30 DAT + $^1/_4$ at 45 DAT; N_4 = $^2/_3$ at 15 DAT + $^1/_3$ at 45 DAT; NS = Non significant.

The length of panicle was significantly increased by the splits application of nitrogen. The highest panicle length (27.13 cm) was found at N_2 treatment which was statistically similar to N_3 and N_4 treatments and the lowest value (22.87 cm) was obtained at N_1 treatment. Three splits produced significantly higher panicle length than two splits. BRRI dhan38 produced significantly longer panicle length tillers^{-1} as compare to BRRI dhan37. The interaction effect of nitrogen split application and variety was significant and the highest panicle length was observed at the combination of V_2N_2 which was statistically similar to V_2N_3 and V_2N_4 and the lowest value (20.33 cm) was recorded at V_1N_1 which was statistically similar (20.93 cm) to V_1N_4 combination (Table 4).

Significantly the highest number of grains panicle^{-1} (78.98) was observed with N_2 and the lowest value was found at N_4 treatment. On the other hand, BRRI dhan38 produced higher number of grains panicle^{-1} than BRRI dhan37 although there was no significant difference between the varieties. The number of filled grains is the important component of rice yield. The grains panicle^{-1} was insignificant due to interaction between split application and variety. The highest grains panicle^{-1} was recorded with the combination of V_2N_2 and the lowest value was at V_1N_1 combination. However, significant increase was noticed for panicle length and number of filled grain per panicle at N_2. The numbers of panicles are associated with the tiller production which is most important yield attributing character. There was no significant difference in the effects of split application of nitrogen, variety, and interaction between nitrogen split and variety on sterile grains panicle^{-1}. The 1000-grains weight was significant due to application of nitrogen. The highest 1000-grain weight was recorded with N_2 and the lowest was found at N_4 treatment. BRRI dhan38 produced significantly higher 1000-grains weight than BRRI dhan37. Shamsuddin et al. (1988) also found significant variation in 1000-grains weight due to variety. The reason is that 1000-grain weight is the stable character (Yoshida, 1981; Raza et al., 2003). The interaction between split application of nitrogen and variety was not significant in respect of 1000-grains weight. The highest and the lowest 1000-grains weight were recorded at V_2N_2 and V_1N_3 combination, respectively (Table 4).

Table 3

Effects of variety on yield and yield contributing characteristics of fine rice.

Treat ment	Plant height (cm)	Total tillers hill^{-1}	No. of effective tiller hill^{-1}	No. of non-effective tiller hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	No. of sterile spikelet panicle^{-1}	Weight of 1000-grains (g)	Yield tha^{-1}	Straw yield tha^{-1}
V_1	123.83	10.24b	7.01b	3.23a	22.52b	75.55	21.54	15.41b	2.66b	6.36
V_2	122.62	10.64a	7.74a	2.90b	29.11a	77.57	20.16	19.93a	3.18a	6.24
CV	4.23	10.54	10.74	7.69	5.44	10.04	12.58	11.07	6.89	14.1
Sx	NS	0.292	0.231	0.073	0.404	NS	NS	0.526	0.615	NS

In a column figures having similar letter(s) do not differ significantly whereas figures having dissimilar letter(s) differ significantly as per DMRT, V_1 = BRRI dhan37; V_2 = BRRI dhan38; NS = Non significant.

Table 4

Yield and yield contributing characteristics of fine rice as affected by the interaction between variety split applications of nitrogen.

Treatment combination (V x N)	Plant height (cm)	Total tillers hill^{-1}	No. of effective tiller hill^{-1}	No. of noneffec tive tiller hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	No. of sterile spikelet panicle^{-1}	Weight of 1000 grains (g)	Yield tha^{-1}	Straw yield tha^{-1}
V_1N_1	116.86	9.53cd	6.03b	2.80c	20.33d	78.86	21.29	15.23	3.15b	6.37
V_1N_2	124.59	11.67a	9.20a	2.70c	26.22b	81.80	24.69	16.66	3.48a	6.80
V_1N_3	128.93	10.20bc	8.10ab	4.03a	22.61cd	78.18	25.50	14.28	3.42a	6.18
V_1N_4	124.91	8.67c	9.27a	3.50b	20.93d	71.37	14.69	15.30	3.00b	6.12
V_2N_1	116.88	9.47cd	6.40b	3.03b	23.94bc	71.18	19.61	19.25	3.15b	6.15
V_2N_2	130.64	10.37bc	9.29a	2.70c	30.50a	82.05	19.87	19.89	3.57a	6.50
V_2N_3	124.59	9.47cd	6.80b	2.47c	31.07a	71.71	23.80	19.82	3.23ab	6.20
V_2N_4	118.37	8.26c	6.70b	3.40b	30.94a	69.35	17.36	19.75	3.08b	6.11
CV (%)	4.23	10.54	10.74	7.69	5.44	10.04	12.58	11.07	5.92	16.01
Sx	NS	0.583	0.462	0.147	0.808	NS	NS	NS	0.089	NS

In a column figures having similar letter(s) do not differ significantly whereas figures having dissimilar letter(s) differ significantly as per DMRT. V_1 = BRRI dhan37 V_2 = BRRI dhan38 NS = Non significant N_1 = ½ as basal + ½ at 30 DAT N_2 = $^1/_3$ at 15 DAT + $^1/_3$ at 30 DAT + $^1/_3$ at 45 DAT N_3 = $^1/_4$ at 15 DAT +½ at 30 DAT + $^1/_4$ at 45 DAT N_4 = $^2/_3$ at 15 DAT + $^1/_3$ at 45 DAT.

Split application of nitrogen had significant effect on grain yield (Table 2). The highest grain yield was achieved from the three equal split application of nitrogen as 1/3 at 15 DAT + 1/3 at 30 DAT + 1/3 at 45 DAT (N_2) and the lowest grain yield was obtained from nitrogen application as ½ at basal + ½ at 30 DAT. The increased grain yield was contributed by higher number of effective tillers hill^{-1}, higher number of grains panicle^{-1} and maximum weight of 1000-grains. Splits application maintained continuous supply of nutrients which might have favored the crop for good growth, yield attributes and finally the yield of rice. Statistically higher grain yield was achieved from BRRI dhan38 than BRRI dhan37. However, the interaction effect clearly showed that the treatment combination V_2N_2 recorded the highest grain yield that has struck a balance between time of nitrogen application and varieties, because of the reason that continuous and optimum supply of nitrogen throughout the crop growth period might have increased the yield traits and yield. Straw yield was statistically significant due to different split application of nitrogen. The highest straw yield was achieved at N_2 treatment and the lowest value was found at N_4 treatment which was statistically identical at N_1 and N_3 treatments. Statistically equal straw yield was found between the two varieties and also among the treatment combinations. Raza et al. (2003) and Kenzo (2004) claimed that 1000-grain weight, grain yield and straw yield were highly significant where nitrogen was applied in three equal splits i.e. 1/3 at transplanting + 1/3 at tillering +1/3 at panicle initiation. Similar results were also observed by Moridani et al. (2013).

4. Conclusion

The results revealed that higher grain yield of fine rice could be obtained with BRRI dhan38 when 150 kg ha^{-1} urea into three splits either three equal as 1/3 at 30 DAT +1/3 at 30 DAT +1/3 at 30 DAT or $^1/_4$ at 15 DAT +½ at 30 DAT + $^1/_4$ at 45 DAT than two splits of different doses.

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