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EFFECT OF SPLIT APPLICATION OF NITROGEN FERTILIZER ON YIELD AND YIELD ATTRIBUTES OF TRANSPLANTED AMAN RICE (*Oryza sativa* L.)

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Abstract

Improper doses and splits of nitrogenous fertilizer are two major constraints achieving higher yield of transplanted aman rice in Bangladesh. A field experiment was carried out to study the effect of different levels and split application of nitrogen (N) fertilizer on yield and yield attributes of transplanted aman rice (var. BRRI dhan30). The experiment was laid out in a split-plot design with four split levels of N : T_1 [⅓ N at basal + ⅓ N at 25 days after transplanting (DAT) + ⅓ N at 50 DAT], T_2 [½ N at 25 DAT + ½ N at 50 DAT], T_3 [⅓ N at 15 DAT + ⅓ N at 30 DAT + ⅓ N at 45 DAT], T_4 [¼ at N 15 DAT + ½ N at 30 DAT + ¼ N at 45 DAT] in the main plot and four levels of N in the sub-plot: control (0 kg N/ha), N_1 (40 kg N/ha), N_2 (80 kg N/ha), and N_3 (120 kg N/ha). Data collected were total tillers/hill, effective tillers/hill, number of grains/panicle, grain yield (t/ha), biological yield (t/ha) as well as some other morphological characters. Among the N splits, treatment T_3 produced highest total tillers/hill (16.45), effective tillers/hill (12.73), panicle length (24.97 cm), grains/panicle (127.92), grain yield (5.53 t/ha), biological yield (12.87 t/ha), and harvest index (42.79%). Among the N levels, treatment N_3 produced highest total tillers/hill (16.50), effective tillers/hill (12.69), grains/panicle (130.36), grain yield (5.40 t/ha), and biological yield (12.66 t/ha). Conversely, the treatment combination of N_3 and T_3 produced the highest value for most of the traits evaluated, namely total tillers/hill (18.03), effective tillers/hill (14.97), grains/panicle (137.48), grain yield (5.77 t/ha), biological yield (13.08 t/ha), and harvest index (44.10%). Hence, the treatment combination of N_3 and T_3 is suggested to bring higher economic benefit from transplanted aman rice in the study area.

Keywords: Transplanted aman rice, levels of nitrogen, split application, yield attributes.

Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop in the world with more than half of the world's population depending on rice as a staple food, especially

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in developing countries. It is expected that by 2025, the world will need about 760 million tons of rice in order to meet the demand for the growing population; most arable lands are exploited in Asia, where 90 % of the world's rice is produced and consumed. More than 90% of the world's rice is grown and consumed in Asia as it is considered as the most important staple food for the people in Asia, and where 60% of the world's population lives. Rice provides about 35-60% of the caloric intake of three billion Asians (Guyer *et al*., 1998). In Bangladesh, only rice contributes 13.05% to gross domestic product (BBS, 2012). In turns, the national mean yield (2.60 t/ha) of rice in Bangladesh is lower than the potential national yield (5.40 t/ha) and world average rice yield (3.70 t/ha) (Pingali *et al*., 1997). Two plausible explanations for this disparity are improper fertilizer management and the use of traditional varieties even though the use of high-yielding varieties and judicious application of fertilizer are two of the most effective means for maximizing rice yield. In Bangladesh, during 2009 and 2010, rice covered about 11.34 million ha with an average production of 31.96 million tons among which transplanted aman rice covered 5.66 million ha with a yield of 2.16 t/ha which is also lower than the national average (2.60 t/ha). The lower yield of transplanted aman rice has been attributed to several reasons, one of them being poor nitrogen (N) fertilizer management, which is vital as N fertilizer can increase rice yield by 70-90% (Win, 2012) proving that rice plants require more N-based nutrients for higher yield. In addition, N positively influences the production of effective tillers/plant, yield and yield attributes (Islam *et al.,* 2008). Although N is the major input for rice production, heavy fertilization does not always result in higher yield; moreover, it decreases nitrogen use efficiency (Hasan *et al.,* unpublished data). Selection of the appropriate level of N fertilizer is a major concern for achieving economic benefit of the crop by decreasing the quantity and increasing nitrogen use efficiency (NUE) while maintaining a sound environment. A rice crop fertilized by 120 kg/ha N showed highest NUE (Baba *et al.,* 2010). Thus, the timely and split application of N allows for more efficient use of N by rice throughout the growing season as this practice provides specific amounts of nutrients to the crop during peak periods of growth and reduces N losses. Two splits of N before plantation and tillering are commonly practiced at the farmer's level for transplanted aman rice production in Bangladesh. However, the application of N into three splits at planting, tillering, and panicle initiation stages is most beneficial for achieving higher grain yield of modern rice varieties at medium to high land elevation (Kaushal *et al.,* 2010). Indeed, excessive N causes vigorous vegetative growth resulting in lodging of plants, increased susceptibility to insects, pests and diseases that ultimately reduces yield. Hence, the present study was conducted to assess the proper dose and split of N fertilizer application for efficient utilization of N to achieve higher yield of transplanted aman rice.

Materials and Method

The experiment was carried out at the agricultural research farm of Bangladesh Agricultural University, Mymensingh, Bangladesh (24° 21' N lat., 88° 95' E long.) during July to November 2010. The experimental site belongs to the old Brahmaputra flood plain (AEZ-9) consisting primarily of non-calcarious Dark Grey Flood Plain Soil (UNDP and FAO, 1988). The land was sandy loam in texture, flat, well drained, above the flood level and with a pH of 5.9-6.5. Four levels of N [control (0 kg N/ha), N_1 (40 kg N/ha), N_2 (80 kg N/ha) and N_3 (120 kg N/ha)] and four split applications of N [T_1 (⅓ N at basal + ⅓ N at 25 DAT + ⅓ N at 50 DAT), T_2 (½ N at 25 DAT + ½ N at 50 DAT), T_3 (⅓ N at 15 DAT + ⅓ N at 30 DAT + ⅓ N at 45 DAT) and T_4 (¼ at N 15 DAT + ½ N at 30 DAT + ¼ N at 45 DAT)] were considered as treatments. The trial followed a split-plot design with three replications in which the split application of N was imposed in the main plot and the level of N fertilizer made up the sub-plot. A total of 48 unit plots with a unit plot size of $4 \times 2.5 = 10$ m^2 were employed and the distance between each main plot was 1.0 m and that of subplots was 0.5 m. Land preparation involved ploughing, harrowing, and leveling the field to make it suitable for crop establishment by a 4-wheel tractor. Soil was flooded and soaked once with sufficient water to bring the topsoil to saturation and create an overlying water layer. The water depth was 5 cm but approximately 10 cm was maintained for about one week after transplanting. Through tillering, a maximum depth of about 3 cm was maintained. From 30 days before head formation and flowering to the start of maturity, soil was frequently covered with water to a depth of 8 or 10 cm. A continual flow of water was maintained. The field was drained completely 30 to 45 days before harvest to ensure that the field would be dry enough for harvest. The source of nitrogen was commercially produced urea. Triple super phosphate, muriate of potash, gypsum, and zinc sulphate was applied at 100, 70, 60, and 10 kg/ha, respectively, during final land preparation. Thirty days old seedlings were transplanted from a nursery bed to the main field maintaining 3 seedlings hill^{-1} with a spacing of 20×15 cm. Necessary intercultural operations, such as weeding, irrigation, pest management, etc. were performed accordingly and whenever needed to ensure the growth of a successful crop. Ten hills/plot were randomly uprooted before harvesting in order to collect the following data: total number of tillers/hill, number of effective tillers/hill, panicle length, number of grains/panicle, number of sterile spikelets/panicle, grain yield, biological yield, harvest index (HI). Final data were recorded by averaging 10 values. Data on grain and straw yield/plot were recorded on a plot basis after drying in the sun maintaining 12% moisture, threshing, winnowing and finally converted into ha. The biological yield (grain + straw) was measured and HI was calculated using the following formula (Gardner *et al.,* 1985).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield (grain + straw)}} \times 100$$

All data was statistically analyzed with the help of MSTAT (Gomez and Gomez, 1984). Analysis of variance (ANOVA) was measured and significant differences between means were calculated by Duncan's multiple range test (DMRT) at $P \leq 0.01$ and 0.05.

Results and Discussion

Effect of different levels of nitrogen on rice yield

The study showed that every morphological and yield-contributing character was positively affected by the increasing levels of N except panicle length and HI (Table 1). Total number of tillers/hill and effective number of tillers/hill increased as the rate of N increased. The highest number of total tillers/hill (16.50) and effective number of tillers/hill (12.69) was recorded when the highest N level (120 kg N/ha) was applied. The maximum number of effective tillers/hill in rice was found when the rate of N application was 100 kg/ha (Islam *et al.,* 2008). Moreover, the number of grains/panicle (130.36 when the crop was fertilized by 120 kg N/ha; Table 1) was significantly influenced by different levels of nitrogenous fertilizer though panicle length remains insignificant irrespective of the level of N application. Similar findings were obtained for number of grains/panicle, which increased with an increased rate of N application up to 120 kg N/ha (Mandal and Swamy, 2003) and 100 kg N/ha (Islam *et al.,* 2008). The maximum number of sterile spikelets/panicle (24.80) was recorded when no N was applied and fewest sterile spikelets/panicle (20.37) formed at 120 kg N/ha. Highest grain yield (5.40 t/ha) was obtained when the crop was fertilized by 120 kg N/ha and the lowest (4.68 t/ha) in the control (Table 1). These results are in partial agreement with Islam *et al.* (2008) who found maximum number (36) of sterile spikelets/panicle when no nitrogen was applied to the rice field and highest grain yield (2.40 t/ha) in aromatic rice, which was fertilized with a nitrogen of 100 kg/ha. Maximum biological yield (12.66 t/ha) was obtained when the crop was fertilized with 120 kg N/ha (Table 1). The application of N at 150 kg/ha resulted in the highest number of total tillers/hill (11.7) (Islam *et al.,* 2008), grains/panicle (109.79) (Salahuddin *et al.,* 2009), grain yield (4.91 t/ha) (Salahuddin *et al.,* 2009), highest biological yield (12.10 t/ha) (Rahman *et al.,* 2007); (6.23 t/ha) (Islam *et al*., 2008), and lowest number of sterile spikelets/panicle (31.4, Islam *et al.*, 2008). When the rice crop was fertilized with 120 kg N/ha, it produced highest grain yield (5.63 t/ha) (Russo, 2012; 4.8 t/ha) Kaushal *et al.*, 2010; 6.1, Baba *et al.*, 2010), while 100 kg N/ha produced highest grain yield (2.23 t/ha), number of total tillers/hill (16.31) as well as lowest number of sterile spikelets/panicle (31.4) (Islam *et al.*, 2008).

Table 1. Effect of nitrogen level on yield and yield characters of BRRI dhan30.

Level of nitrogen (kg N/ha)	Total tillers/ hill	Effective tillers/ hill	Panicle length (cm)	Grains/ panicle	Sterile spikelets/ panicle	Harvest index (%)
Control	12.63 c	8.85 b	22.86	96.24 d	24.80 a	40.99
N_1	14.13 b	10.00 b	23.64	113.34 c	22.41 b	41.93
N_2	15.63 a	11.81 a	24.04	125.54 b	21.66 bc	42.66
N_3	16.50 a	12.69 a	23.83	130.36 a	20.37 c	42.57
Sx	0.300	0.27	0.259	0.699	0.363	0.373
LS	**	**	NS	**	**	NS
CV(%)	5.07	7.51	3.78	1.72	5.37	3.14

In each column, mean with same or without letter do not differ significantly

LS = Level of significance; * = Significant at $P \leq 0.05$, ** = Significant at $P \leq 0.01$, NS = Non significant

Sx = Standard deviation, CV = Coefficient of variation

Table 2. Effect of split nitrogen application on yield and yield characters of BRRI dhan30.

Splits of application of nitrogen	Total tiller/ hill	Effective tillers/hill	Panicle length (cm)	Grains/ panicle	Sterile spikelets/ panicle	Harvest index (%)
T_1	15.44 b	11.32 b	23.66 b	118.39 b	21.72 b	42.22
T_2	12.23 c	8.83 c	22.21 c	103.06 c	25.06 a	41.29
T_3	16.45 a	12.73 a	24.97 a	127.92 a	20.65 b	42.79
T_4	14.76 b	10.46 b	23.54 b	116.10 b	21.81 b	41.85
Sx	0.215	0.235	0.257	0.577	0.346	0.381
LS	**	**	**	**	**	NS
CV(%)	5.07	7.51	3.78	1.72	5.37	3.14

In each column, mean with same or without letter do not differ significantly

LS = Level of significance; * = Significant at $P \leq 0.05$, ** = Significant at $P \leq 0.01$, NS = Non significant

Sx = Standard deviation, CV = Coefficient of variation

Table 3. Interaction effect of nitrogen level and split nitrogen application on yield and yield characters of BRRI dhan30.

Level of N × Split of N	Total tillers/ hill	Effective tillers/hill	Panicle length (cm)	Grains/ panicle	Sterile spikelets/ panicle	Grain yield (t /ha)	Biological yield (t/ha)	Harvest index (%)
Control × T_1	13.43	9.07	23.27	96.83 j	24.51 abc	4.92	11.78	41.70
Control × T_2	10.13	7.54	21.41	82.20 l	26.52 a	4.23	10.64	39.72
Control × T_3	14.30	10.23	24.52	112.12 i	23.38 bcd	5.02	11.88	42.11
Control × T_4	12.63	8.55	22.24	93.82 j	24.81 ab	4.55	11.24	40.43
$N_1 \times T_1$	14.67	10.63	23.65	120.31 fg	22.45 cd	5.10	12.22	41.57
$N_1 \times T_2$	11.20	8.19	22.38	88.85 k	24.05 bc	4.65	11.17	41.65
$N_1 \times T_3$	16.53	11.47	25.07	128.30 cd	21.58 de	5.60	13.20	42.48
$N_1 \times T_4$	14.13	9.70	23.45	115.90 h	21.54 de	5.05	11.99	42.01
$N_2 \times T_1$	16.40	12.20	23.68	125.71 de	21.42 de	5.27	12.26	42.88
$N_2 \times T_2$	13.30	9.47	22.73	117.93 gh	24.17 bc	4.76	11.19	42.52
$N_2 \times T_3$	16.93	14.27	25.28	133.78 b	17.72 g	5.73	13.30	42.47
$N_2 \times T_4$	15.87	11.30	24.46	124.75 e	23.35 bcd	5.13	12.00	42.77
$N_3 \times T_1$	17.27	13.37	24.00	130.72 bc	18.48 fg	5.50	12.87	42.74
$N_3 \times T_2$	14.30	10.11	22.33	123.27 ef	25.52 ab	4.91	11.91	41.26
$N_3 \times T_3$	18.03	14.97	25.00	137.48 a	19.93 ef	5.77	13.08	44.10
$N_3 \times T_4$	16.40	12.30	24.00	129.95 c	17.55 g	5.40	12.80	42.19
Sx	0.431	0.469	0.515	1.154	0.691	0.271	0.539	0.761
LS	NS	NS	NS	**	**	NS	NS	NS
CV (%)	5.07	7.51	3.78	1.72	5.37	9.21	7.71	3.14

In each column, mean with same or without letter do not differ significantly.
LS = Level of significance; ** = Significant at $P \leq 0.01$, NS = Non-significant.
Sx = Standard deviation, CV = Coefficient of variation.

Effect of split application of nitrogen on rice yield

The split application of N had a significant effect on all yield attributing parameters except for HI (Table 2). The highest number of total tillers/hill (16.45), number of effective tillers/hill (12.73), panicle length (24.97 cm), number of grains/panicle (127.92), biological yield (12.87 t/ha), and HI (42.79%) were noted when N was applied in three equal splits, ⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at 45 DAT (Table 2). N application in three splits gave the highest number of tillers/hill (25.11); (Islam *et al.*, 2009), panicle length (25.9), (Kaushal *et al.,* 2010 (20.1), (Hasanuzzaman *et al.*, 2009), grains/panicle (124), (Kaushal *et al.,* 2010), and biological yield (11.99 t/ha; Kaushal *et al.*, 2010), identical to other findings (Hirzel *et al.*, 2011). Highest grain yield (5.53 t/ha) was obtained when N was applied in three equal splits viz., ⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at 45 DAT and the lowest (4.64 t/ha) was noted when N was applied in two splits, viz. ½ at 25 DAT+ ½ at 50 DAT (Table 2), which is in agreement with the findings of Kaushal *et al.* (2010) who found highest productive tillers/m^{-2} (76), panicle length (26 cm), grain yield (4.2 t/ha), and biological yield (9.5 t/ha) from three splits of N viz., ½ basal, ¼ at tillering, and ¼ at panicle initiation. The variation in results caused by the same number of splits might be due to different locations and environments. The highest number of sterile spiketets/panicle (25.06) was found in two splits of N viz., ½ N at 25 DAT + ½ N at 50 DAT (Table 2) indicates that the N requirement of aman rice is dependent on quantity and varies with the growth stage.

Interaction effect of different levels and split application of N on rice yield

N_3 (120 kg N/ha) gave the highest grain yield (5.77 t/ha) when splited as T_3 (⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at 45 DAT) (Table 3). The control (0 kg N/ha) gave lowest grain yield (4.23 t/ha) with a split application of T_2 (½ at 25 DAT+ ½ at 50 DAT). Biological yield followed a similar trend as grain yield. The combination of N_3 and T_3 gave the highest number of total tillers/hill (18.03), number of effective tillers/hill (14.97), number of grains/panicle (137.48), and HI (44.10%). The highest number of sterile spikelets/panicle (26.52) was recorded in the control. The lowest number of sterile spikelets/panicle (17.55) was recorded in the N_3T_4 combination, which was statistically identical to the N_3T_3 and N_3T_1 interactions.

Conclusion

The results revealed that application of 120 kg N/ha produced highest number of tillers/hill, grain and straw yield. However, among the split applications, the highest grain and straw yield was obtained from three equal splits of N, i.e., ⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at 45 DAT. In case of interaction effect of different levels and split application of N, highest grain yield was obtained from treatment 120 kg N/ha combined with three equal splits i.e., ⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at 45 DAT. Hence, for higher grain yield of transplanted aman rice, N fertilization at 120 kg/ha should be applied in three equal splits viz., ⅓ at 15 DAT + ⅓ at 30 DAT + ⅓ at 45 DAT.

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