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Pant Characters, Yield Components and Yield of Late Transplanted *Aman* Rice as Affected by Plant Spacing and Number of Seedling per Hill

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Abstract: A field experiment was carried out at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during August, 2008 to January, 2009 in view to find out the optimum plant spacing and no. of seedlings hill^{-1} for a late transplanted *aman* rice variety BRRI dhan46. The experiment was carried out with three plant spacings (S_1=15 cm × 20 cm, S_2= 20 cm × 20 cm and S_3= 25 cm × 20 cm) and four different seedling numbers (H_1= 1 seedling hill^{-1}, H_2= 2 seedlings hill^{-1}, H_3= 3 seedlings hill^{-1} and H_4= 4 seedlings hill^{-1}). It was observed that almost all the plant characters, yield components and yield was significantly affected by both plant spacings and no. of seedlings hill^{-1}. Wider spaced plants showed better results in terms of yield components and yield except plant height. No. of seedlings hill^{-1} also greatly affected the rice plants in terms of yield components and yield. It was observed that transplanting more than 2 seedling hill^{-1} did not show any significant result. The maximum grain yield (4.47 t ha^{-1}) was observed from 20 cm × 20 cm (S_2) which was statistically at per with 25 cm × 20 cm (S_3). In this experiment grain yield was obtained maximum (4.49 t ha^{-1}) with 2 seedling hill^{-1} which statistically identical with 1 seedling hill^{-1} (4.39 t ha^{-1}). Grain yield was decreased with transplanting of higher number of seedling (3 and 4) hill^{-1}. Transplanting 2 seedling hill^{-1} produced 17.82% grain yield than transplanting 4 seedlings hill^{-1}. Plant spaced at 20 cm × 20 cm coupled 2 seedlings hill^{-1}was observed the best treatment for grain yield of rice in the present study.

Key words: Tillering · Paddy · Harvest index · Grain yield · Plant density

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world. There are 111 rice-growing countries in the world that occupies about 146.5 million hectares more than 90% is in Asia [1]. It is the staple food for more than two billion people in Asia and many millions in Africa and Latin America. About 95% of the world rice is consumed in Asia [2]. Rice (*Oryza sativa* L.) production constitutes the major economic activity and a key source of employment for the rural population of Bangladesh. Agriculture in Bangladesh is predominantly rice based and Bangladesh is the fourth rice producing country in the world. It is grown in 10.5 million hectares of land with a total production of 26.5 million tons in the year 2005-2006. Although rice is the staple food of her people, the average rice production is 2.52 t ha^{-1} [3], which is very poor compared to other advanced rice growing countries. Bangladesh lacks arable land to extend rice production. Besides, rice production is decreasing day by day due to high population pressure, continuing drought and flood in farming areas and conversion of farmlands to grow cash crops instead of rice. Because of these problems, the price of rice raised up to 49 to 60 percent in recent year [4]. Therefore, it is an urgent need of the time to increase rice yield in Bangladesh.

Rice is grown in three seasons namely *Aus* (mid March to mid August), *Aman* (mid June to November) and *Boro* (Mid December to mid June). T. *aman* rice covers about 46.76% of the rice areas of Bangladesh [3] of which modern T. *aman* varieties covers 64.86% [3]. Improved cultural practices can play an important role in augmenting yield of rice crop. For successful rice production, timely planting, appropriate control of vegetative growth throughout the duration of the crop, suitable transplanting densities for optimum

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tillering and control of leaf growth by controlling water, fertilizer and chemical inputs are essential for improving the growth variables responsible for high yield [4]. The maximum benefit to rice can be obtained from a field if it is properly spaced between the plants. Optimum plant spacing ensures the plants to grow properly both in their aerial and underground parts through different utilization of solar radiation and nutrients. When the plant density exceeds an optimum level, competition among plants for light above ground or for nutrients below the ground become severe, consequently the plant growth slows down and the grain yield decreases.

Among the improved cultural practices, number of seedling $hill^{-1}$ can play important roles in boosting yield of rice. Number of seedlings $hill^{-1}$ is another important factor for successful rice production because it influences the tiller formation, solar radiation interception, total sunshine reception, nutrient uptake, rate of photosynthesis and other physiological phenomena and ultimately affects the growth and development of rice plant. In densely populated rice field the inter-specific competition between the plants is high in which sometimes results in gradual shading and lodging and thus favour increased production of straw instead of grain. It is, therefore, necessary to determine the optimum plant spacing and number of seeding $hill^{-1}$ for high yield [5,6].

In view of above facts, the present study was carried out to determine the effect of plant spacing and number of seedling $hill^{-1}$ on the plant characters, yield components and yield of late transplanted *aman* rice cv. BRRI Dhan 46.

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during August, 2008 to January 2009. The soil of the experimental field belongs to the Shallow Red Brown Terrace Soils. The experimental site was under the Agro-ecological zone of Modhupur Tract-AEZ-28, situated at 23°41′N latitude and 90°22′E longitude at with an elevation of 8.6 m from the mean sea level. The experiment was carried out with three plant spacings (S_1=15 cm × 20 cm, S_2= 20 cm × 20 cm and S_3= 25 cm×20cm) and four different seedling numbers (H_1= 1 seedling $hill^{-1}$, H_2= 2 seedlings $hill^{-1}$, H_3= 3 seedlings $hill^{-1}$ and H_4= 4 seedlings $hill^{-1}$). The rice variety used in this experiment was BRRI dhan46 which is a late variety for *aman* season. The experiment was laid out in a randomized completely block design (RCBD) with three replications.

A common procedure was followed in raising of seedling in seed bed. Seedlings of 25 days old were uprooted from the nursery beds carefully. Seedlings were transplanted according to the treatments in the well-puddled experimental plots on 15 September 2008. Spacing's were given as per treatments. A fertilizer dose of 80-50-50-10 kg ha^{-1} of N, P_2O_5, K_2O and S were applied as urea, triple superphosphate, muriate of potash and gypsum were applied in the field. One-third urea and full dose of triple super phosphate, muriate of potash and gypsum were applied as basal dose at the time of final land preparation and incorporated well into the soil. Besides, cowdung at the rate of 10 t ha^{-1} was applied before final ploughing. Rest two-third of urea was applied in two equal splits at 30 and 55 days after transplanting (DAT).

All intercultural operations were done carefully. The first weeding was done at 15 days after transplanting (DAT) followed by second and third weeding were done at 15 days interval after first and second weeding. Irrigation was done by alternate wetting and drying from transplanting to maximum tillering stage. From panicle initiation (PI) to hard dough stage, a thin layer of water (2-3 cm) was kept on the plots. Water was removed from the plots during ripening stage. The crop of each plot was harvested separately on different dates when 90% of the grains become golden yellow in color. The number of tillers $hill^{-1}$ was recorded at the maximum tillering stage. Ten samples hills were collected from each plot for collection of data on plant characters and yield components. The grain and straw weights for each plot were recorded after proper sun drying and then converted into t ha^{-1}. The grain yield was adjusted at 12% moisture level. The data was analyzed using MSTAT-C [7] programme. The mean differences among the treatments were compared by multiple comparison tests using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Effect on Plant Characters: Variation of plant spacing showed significant differences in plant height of rice in this study (Table 1). Maximum plant height was observed with closest plants (S_1) where the lowest plant height was observed with widest spaced plants. The plant tended to be taller for getting the light in closed place. Sharma and Thakur [8] reported that the highest plant height was observed from the closest row spacing of 20 cm. The closest row spacing caused the plants to compete more nutrient, water and light required for their growth and

Table 1: Effect of plant spacing and number of seedling hill^{-1} on the plant characters of transplanted *aman* rice cv. BRRI dhan46

Treatment	Plant height (cm)	No. of tillers hill^{-1}	No. of effective tillers hill^{-1}	Leaf area index
Plant spacing				
15 cm × 20 cm (S_1)	110.5a	12.32a	8.7b	4.5c
20 cm × 20 cm (S_2)	106.7ab	12.36a	10.9a	5.0b
25 cm × 20 cm (S_3)	104.5b	13.42a	11.5a	5.5a
$LSD_{0.05}$	4.31	NS	1.12	0.32
No. of Seedling hill^{-1}				
1	109.5a	11.03b	8.8b	3.4c
2	107.8a	12.66a	10.5a	4.5b
3	105.7ab	13.21a	10.2a	5.7a
4	102.4b	13.42a	10.4a	5.9a
$LSD_{0.05}$	3.44	1.22	1.07	0.54
CV (%)	7.76	8.76	5.67	10.21

Means separation in columns followed by the same letter(s) are not significantly different at P=<0.05

Table 2: Interaction effect of plant spacing and number of seedling hill^{-1} on the plant characters of transplanted *aman* rice cv. BRRI dhan46

Treatment	Plant height (cm)	No. of tillers hill^{-1}	No. of effective tillers hill^{-1}	Leaf area index
S_1H_1	110.00a	11.66d	8.75e	3.91gh
S_1H_2	109.14ab	12.49a-d	9.56cde	4.50ef
S_1H_3	108.07abc	12.76a-d	9.42de	5.06bcd
S_1H_4	106.3b-e	12.86abc	9.51de	5.15bcd
S_2H_1	108.09abc	11.68cd	9.79b-e	4.12fgh
S_2H_2	107.25a-d	12.51a-d	10.70ab	4.74de
S_2H_3	106.20b-e	12.78a-d	10.54a-d	5.34abc
S_2H_4	104.53de	12.88ab	10.65abc	5.43ab
S_3H_1	106.97a-d	12.17bcd	10.06a-d	4.32efg
S_3H_2	106.14b-e	13.03ab	10.99a	4.97cd
S_3H_3	105.10cde	13.31ab	10.83ab	5.60ab
S_3H_4	103.44e	13.42a	10.94a	5.70a
$LSD_{0.05}$	3.34	1.18	1.12	0.43
CV (%)	7.76	8.76	5.67	10.21

Means separation in columns followed by the same letter(s) are not significantly different at P=<0.05

development. This competition for space might have elongated the densely populated plants [9]. Plant height also significantly affected by the number of seedlings per hill (Table 1). Plant height was decreased with the increase of number of seedling per hill. The maximum plant height was observed with 1 seedling hill^{-1} which was statistically similar with 2 and 3 seedlings per hill. Three and 4 seedlings per hill also gave identical result. The changes in plant height due to the increased seedling number per hill also observed by Nakano and Mizushima [10].

Interaction of plant spacing and no. of seedling hill^{-1} also affected the plant height of rice (Table 2). In this study maximum plant height was observed with S_1H_1 where the lowest plant height was observed with S_3H_4.

Tiller number was not significantly influenced by plant spacing in this study (Table 1). However the number of tillers hill^{-1} height increased with increased plant spacing. Tiller production was however significantly affected with number of seedling hill^{-1}. The maximum number of tillers was observed with 2 seedlings hill^{-1}. Significant changes in tiller number were observed between 1 and 2 seedling hill^{-1} and thereafter the result was identical (Table 1). It reveals that planting excess seedlings (more than 2) in a single hill does not affect the tiller production in rice. Nakano and Mizushima [10] also observed similar findings.

The effective tillers i.e. ear bearing tillers is an important parameter which affect the yield of rice. The number of effective tiller of increased significantly increased with wiser plant spacing (Table 1). The maximum number of effective tillers were observed with S3 which was statistically identical with S_2. However, the closest plant spacing (S_1) resulted the lowest number of effective tillers hill^{-1}. Number of seedling hill^{-1} also affected the effective tiller number (Table 1). The effective tillers were significantly increased with up to 2 seedlings per hill and then it decreased. Transplanting 2, 3 and 4 seedling hill^{-1} gave statistically identical result in terms of effective tillers in this experiment. Inaba and Kitano [11] observed similar results. However, the interaction effect of plant spacing and seedling no hill^{-1} influenced the effective tillers of rice significantly. The maximum number of effective tillers hill^{-1} was observed with S_3H_2 which was statistically identical with S_3H_4. The treatments S_3H_3, S_2H_2, S_2H_4, S_2H_3 and S_2H_1 also showed similar result. The lowest number of effective tillers was observed with S_1H_1 (Table 2).

Leaf area of rice plants were greatly influenced by plant spacing. It this study it was observed that leaf area index were the highest when the plant spacing was widest (Table 1). The maximum leaf area index (5.5) was observed with S_3 where the lowest leaf area index (4.5) was observed from S_1. These results revealed that plant spacing should be kept wider to increase the photosynthesis as the leaf area index is directly related to photosynthesis capacity of plant. These results were corroborated with the results observed by Hossain *et al.* [5]. Among the number of seedlings hill^{-1}, 4 seedlings hill^{-1} gave the highest leaf area index which was statistically at per with 3 seedling hill^{-1} (Table 1). When no. of seedling decreased leaf area decreased. It was due to the lower tiller number produced by lower number of seedlings hill^{-1}. These results were supported by Miah *et al.* [12]. The interaction effect of plant spacing and no. of seedling hill^{-1} also affected the leaf area significantly. In this experiment the highest leaf area index was observed with the treatment S_3H_4 which was identical with S_3H3, S_2H_4 and S_2H_3. The treatment S_1H_1 showed the lowest leaf area index.

Effect on Yield Components: All the yield components except panicle length were significantly influenced by different plant spacing (Table 3). In this study the highest number of panicle hill^{-1} (11.5), panicle length (23.1 cm), no. of spikelets panicle (140.2) and 1000-grain weight (24.6 g) was observed from widest spacing of 25 cm×20 cm (S_3). The lowest values of all of these components were observed from 15 cm × 20 cm (S_1). The increased rate of panicle hill^{-1}, panicle length, no. of spikelets panicle and 1000-grain weight with S_3 was 71.64%, 8.45%, 9.18 and 10.31% greater than produced by S_1. The more number of panicles per hill with wider spacing might be due to the production of increased number of effective tillers and accumulation of more photosynthate. Same reason also influenced the spikelet generation in rice plants. In the closely spaced plants more intra-competetion occurred and hence lower number of spikelets per panicle was observed. Weight of grain was also greater with widest spacing due to production of healthy and bold grain. Hossain *et al.* [5] also observed the better performance of transplanted *aman* rice varieties with wiser plant spacing. These results were also supported by Islam *et al.* [13].

Table 3: Effect of plant spacing and number of seedling hill^{-1} on the yield attributes of transplanted *aman* rice cv. BRRI dhan46

Treatment	No. of panicles hill^{-1}	Panicle length (cm)	No. of spikelets panicle^{-1}	1000-grain weight (g)
Plant spacing				
15 cm × 20 cm (S_1)	6.7c	21.3	128.4b	22.3b
20 cm × 20 cm (S_2)	9.8b	22.6	131.2b	22.5ab
25 cm × 20 cm (S_3)	11.5a	23.1	140.2a	24.6a
$LSD_{0.05}$	0.66	NS	6.76	2.12
No. of Seedling hill^{-1}				
1	5.7d	24.1a	138.5a	23.9a
2	7.1c	23.6ab	134.5ab	22.5ab
3	10.5b	21.5bc	132.1ab	21.4ab
4	12.2a	21.2c	129.7b	20.4b
$LSD_{0.05}$	0.98	2.12	6.67	2.55
CV (%)	9.12	10.11	6.67	8.76

Means separation in columns followed by the same letter(s) are not significantly different at P=0.05

Table 4: Interaction effect of plant spacing and number of seedling hill^{-1} on the plant characters of transplanted *aman* rice cv. BRRI dhan46

Treatment	No. of panicles hill^{-1}	Panicle length (cm)	No. of spikelets panicle^{-1}	1000-grain weight (g)
S_1H_1	6.18f	22.66abc	133.35b-e	23.09ab
S_1H_2	6.90ef	22.42abc	131.41cde	22.40ab
S_1H_3	8.39cd	21.40bc	130.24de	21.85ab
S_1H_4	9.04c	21.25c	129.05e	21.33b
S_2H_1	7.47de	23.34ab	134.80a-d	23.19ab
S_2H_2	8.34cd	23.09abc	132.84b-e	22.50ab
S_2H_3	10.14b	22.04abc	131.65b-e	21.94ab
S_2H_4	10.93ab	21.89abc	130.45cde	21.42b
S_3H_1	8.10cd	23.59a	139.35a	24.25a
S_3H_2	9.04c	23.35ab	137.32ab	23.53ab
S_3H_3	10.99ab	22.29abc	136.09abc	22.94ab
S_3H_4	11.84a	22.13abc	134.85a-d	22.40ab
$LSD_{0.05}$	1.03	2.00	5.69	2.50
CV (%)	9.12	10.11	6.67	8.76

Means separation in columns followed by the same letter(s) are not significantly different at P=<0.05

Table 5: Effect of plant spacing and number of seedling hill^{-1} on the yield and harvest index of transplanted *aman* rice cv. BRRI dhan46

Treatment	Grain yield(t ha^{-1})	Straw yield(t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Plant spacing				
15 cm × 20 cm (S_1)	3.4b	6.2a	9.6	35.42b
20 cm × 20 cm (S_2)	4.47a	5.5b	9.97	44.83a
25 cm × 20 cm (S_3)	4.41a	4.8c	9.21	47.88a
$LSD_{0.05}$	0.23	0.45	1.11	6.45
No. of Seedling hill^{-1}				
1	4.39ab	6.7c	11.09	39.59a
2	4.49a	6.9c	11.39	39.42a
3	4.1bc	7.6b	11.7	35.04ab
4	3.87c	8.1a	11.97	32.33b
$LSD_{0.05}$	0.33	0.40	1.20	5.32
CV (%)	7.77	9.34	5.66	8.50

Means separation in columns followed by the same letter(s) are not significantly different at P=<0.05

Yield components of rice were also significantly influenced by number of seedling hill^{-1}. From Table 3 it was observed that except the no. of panicles hill^{-1} all the yield components showed lower performance with increased seedling number per hill (Table 2). The effect was significant in al the case. Among the treatments 4 seedlings hill^{-1} produced the highest number of panicles hill^{-1} which was significantly differed from others. In case of panicle length, no. of spikelets panicle^{-1} and 1000-grain weight the maximum values were observed with single seedling transplantation and after that the values decreased (Table 3). The lowest results were observed with 4 seedling hill^{-1} which was statistically different from other treatments. It reveals that use of extra seedling in a hill did not show any extra benefit to rice producer in terms of yield components.

Interaction effect of plant spacing and number of seedling hill^{-1} also influenced the yield components significantly. In this study it was observed that maximum number of panicles hill^{-1} (11.84) was observed with S_3H_4 where the lowest number (6.18) was observed with S_1H_1. The highest length of panicle (23.59 cm), highest number of spikelets panicle^{-1} (139.35) and maximum weight of 1000-grain (24.25) were observed with the treatment S_3H_1 where the lowest results was observed with S_3H_4 (Table 4). Among the parameters 1000-grain was less influenced by the treatment combinations because 1000- grain weight is more or less genetically controlled characteristics. This result was in agreement with Panikar *et al.* [14].

Effect on Yield and Harvest Index: In the present study, plant spacing greatly influenced the yields of rice. From the Table 5 it was observed that grain yield and straw yield was significantly affected by different row spacing where the biological yield was insignificant in terms of

Table 6: Interaction effect of plant spacing and number of seedling hill^{-1} on the yield and harvest index of transplanted *aman* rice cv. BRRI dhan46

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1H_1	3.86 bc	6.45 b-d	10.32	37.44 cde
S_1H_2	3.91 bc	6.54 bcd	10.46	37.37 def
S_1H_3	3.73 c	6.86 ab	10.60	35.23 ef
S_1H_4	3.63 c	7.09 a	10.72	33.84 f
S_2H_1	4.43 a	6.07 e-h	10.52	42.13 ab
S_2H_2	4.48 a	6.16 d-g	10.66	42.04 ab
S_2H_3	4.28 a	6.47 b-e	10.80	39.64 bcd
S_2H_4	4.16 ab	6.67 abc	10.92	38.07 cde
S_3H_1	4.40 a	5.67 h	10.11	43.54 a
S_3H_2	4.45 a	5.75 gh	10.24	43.45 a
S_3H_3	4.25 ab	6.04 fgh	10.38	40.96 abc
S_3H_4	4.13 ab	6.24 c-f	10.50	39.35 bcd
$LSD_{0.05}$	0.39	0.45	1.03	3.54
CV (%)	7.77	9.34	5.66	8.50

Means separation in columns followed by the same letter(s) are not significantly different at P=0.05

different plant spacing. The maximum grain yield (4.47 t ha^{-1}) was observed from 20 cm × 20 cm (S_2) which was statistically at per with 25 cm × 20 cm (S_3) that produced grain yield of 4.41 t ha^{-1}. The seed yield observed with S_2 was 31.47% higher than S_1. Straw yield was inversely related with spacing. The highest straw yield (6.2 t ha^{-1}) was observed with S_1 and after that it decreased with the increase in plant spacing. The lowest straw yield was obtained with widest spacing (S_3). The lower plant spacing with wider spacing was due to lower plant population tiller production per unit area as well as lower plant height. These results were supported by Hossain *et al.* [5]. Biological yield was also highest with the wider spacing though it was statistically insignificant. The harvest index of BRRI dhan46 was greater with wider spacing (Table 5). From this study it was observed that S_3 produced the highest harvest index (47.88%) which was statistically identical with S_2 (44.83%). However, the lowest HI was observed with the closest spacing (S_1).

Yield of rice was also significantly affected by number of seedling hill^{-1} (Table 5). In this experiment grain yield was obtained maximum (4.49 t ha^{-1}) with 2 seedling hill^{-1} which statistically identical with 1 seedling hill^{-1} (4.39 t ha^{-1}). Grain yield was decreased with transplanting of higher number of seedling (3 and 4). Transplanting 2 seedling hill^{-1} produced 17.82% grain yield than transplanting 4 seedlings hill^{-1}. It was due to greater competition and lower production of yield components from higher no. of seedlings hill^{-1}. Straw yield was showed inverse results. Islam *et al.* [15] observed similar findings. It was observed the significantly highest straw yield (8.1 t ha^{-1}) obtained with 4 seedlings hill^{-1}. Transplanting more number of seedlings hill^{-1} produced more tillers and others vegetative organs per unit area which resulted higher straw yield per hectare. However, biological yield of rice was not affected significantly with variable no. of seedling hill^{-1}. Harvest index was significantly affected by the no. of seedling hill^{-1} and in this study the maximum harvest index (39.59%) was obtained from 1 seedling hill^{-1}. Harvest indices significantly decreased with the transplanting of 3 or more seedling. This result was in agreement with Miah *et al.* [12].

Yield of transplanted rice was also affected by the interaction of plant spacing and number of seedling hill^{-1} (Table 6). The highest grain yield (4.48 t ha^{-1}) was observed from the treatment S_2H_2 which was statistically identical with S_2H_1, S_2H_3, S_3H_1 and S_3H_2. However, the lowest grain yield was obtained with S_1H_4. Straw yield was found highest with S_1H_4 which revealed closer spacing coupled with more number of seedlings per hill produced higher straw yield. Biological yield was not significantly affected by the combination of spacing and no. of seedling hill^{-1}. In this study harvest index was found significantly highest with S_3H_1 where the lowest HI was obtained with S_1H_4 (Table 4).

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