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Effect of Plant Spacing and Fertilizer Management on the Yield Performance of BRRI dhan39 under Old Brahmaputra Floodplain Soil

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An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh from June to December 2015 to investigate the effect of spacing and fertilizer management on the yield of transplanted *Aman rice* cv. BRRI dhan39. The experiment comprised of five spacings *viz*. 25 × 5 cm, 25 × 10 cm, 25 × 15 cm, 25 × 20 cm, 25 × 25 cm and four fertilizer schedules *viz*. no manure and no fertilizer (control), recommended dose of inorganic fertilizer (80-60-40 kg N, P_2O_5, K_2O ha^{-1}, respectively + 60 kg ha^{-1} gypsum + 10 kg ha^{-1} $ZnSO_4$), 75% recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1}, 75% recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications. Plant height (104.60 cm), number of total tillers $hill^{-1}$ (11.03), panicle length (22.25 cm), grains $panicle^{-1}$ (109.00) and grain yield (4.42 t ha^{-1}) were found to be the highest in 25 × 15 cm spacing. Regarding nutrient management, 75% recommended dose of inorganic fertilizers + cow dung at 5 t ha^{-1} superseded other treatments in terms of plant height (107.50 cm), number of total tillers $hill^{-1}$ (10.40), number of effective tillers $hill^{-1}$ (7.68), panicle length (22.26 cm), grains $panicle^{-1}$ (111.70) and grain yield (4.14 t ha^{-1}). The control treatment (no manures and no fertilizers) gave the lowest values for all these parameters. The highest grain yield (4.57 t ha^{-1}) was found in 25 × 15 cm spacing combined with 75% recommended dose of inorganic fertilizers + cow dung at 5 t ha^{-1} and the lowest grain yield (2.50 t ha^{-1}) was found in 25 × 5 cm spacing combined with control (no manures and fertilizers). Therefore, 25 × 15 cm spacing combined with 75% recommended dose of inorganic fertilizers + cow dung at 5 t ha^{-1} appeared as the promising practice in transplant *Aman* rice cv. BRRI dhan39 cultivation.

Key words: Spacing, Transplant *Aman* rice, Fertilizer management, Yield

Rice is the staple food for the people of Bangladesh. Besides, about half of the world's population depends on rice as staple food. Bangladesh has three types of rice according to growing seasons within a year *viz*. *Aus, Aman* and *Boro*. *Aman* rice of the country covers an area of 55,32,477 ha with a production of 1,31,90,163 metric tons (BBS, 2015). The yield of transplant *Aman* rice can be increased with improved cultivation practices like proper spacing of planting and proper fertilizer management. Plant spacing is an important factor which plays a significant role on growth, development and yield of rice. Spacing provides scope to the plants for efficient utilization of solar radiation and nutrients (Paul *et al*., 2017). Proper spacing supports the plants to uptake more nutrients from the soil. It may help to receive maximum LAI and light interceptions which facilitate efficient photosynthesis and ultimately yield of rice. Proper fertilizer management also plays an important role on yield and quality of rice crop. Pal *et al*. (2016) reported that grain yield and grain protein content of aromatic rice increased due to application 75% of recommended dose of inorganic fertilizers supplemented with cowdung 10 t ha^{-1}. Similar results were also reported elsewhere (Sarkar *et al*., 2014; Ray *et al*., 2015 and Biswas *et al*., 2016).

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Soil fertility status of Bangladesh is gradually declining. Most of the soil of Bangladesh has organic matter less than 1.5% and in many cases it is less than 1% (BARC 2005). Nutrient mining and depletion of soil organic matter have been identified as reasons of yield stagnation or decline in the productivity of crops. Improper soil management practices and the use of chemical fertilizer with no or very little use of manure throughout the year may be responsible for this. It has already been indicated that the imbalanced use of fertilizer has tremendous pressure on the soil organic matter and nutrients resulting in the decrease of crop production. Among the cultural practices, integrated nutrient management like application of cow dung, poultry manure along with other inorganic fertilizers is very much important (Marzia *et al.,* 2016) which can improve the grain yield of rice. In order to improve crop productivity more emphasis should be given on spacing and suitable fertilizer management.

Material and Methods

The experiment was conducted at the Agronomy

Field Laboratory, Bangladesh Agricultural University, Mymensingh, during July to December 2015 to study the effect of spacing of transplanted rice and fertilizer management on *Aman* rice cv. BRRI dhan39. The experimental site belongs to the Sonatola Soil Series of Old Brahmaputra Floodplain (AEZ 9) having non-calcareous dark grey floodplain soil. The land was medium high with sandy loam texture having pH 5.9. The experiment comprised of five spacings *viz*. 25 × 5 cm (S_1), 25 × 10 cm (S_2), 25 × 15 cm (S_3), 25 × 20 cm (S_4), 25 × 25 cm (S_5) and four fertilizer treatments *viz.* no manure and no fertilizer (control) (N0), recommended dose of chemical fertilizer (80-60-40 kg N, P_2O_5, K_2O ha^{-1} + 60 kg ha^{-1} gypsum + 10 kg ha^{-1} $ZnSO_4$) (N_1), 75% recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1} (N_2), 75% recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1} (N_3). The experiment was laid out in a Randomized Complete Block Design with three replications. The size of unit plot was 4.0 × 2.5 m. The experimental plots were fertilized according to the treatments at final land preparation. Nitrogen was applied as per experimental specification in the form of urea in three equal splits at 15, 30 and 45 days after sowing. Prior to harvest, five hills plot^{-1} were randomly selected excluding border hills and at centre of the plot one square metre harvest area from each unit plot was selected for recording data on yield components. The crop was harvested at full maturity and threshed by pedal thresher to record the fresh weight of grain and straw 1 m^{-2} plot-wise. Grains were cleaned and sun dried to a moisture content of 14%. Straws were also sundried properly. Grain and straw yields were then converted to t ha^{-1}. The recorded data were analyzed statistically using "Analysis of Variance Technique and the differences among treatment means were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Effect of plant spacing

Spacing in transplanted rice significantly influenced on crop characters, yield and yield components except 1000-grain weight (Table 1).

Table 1. Effect of spacing of transplanting on crop characters, yield components and yield of transplant Aman rice cv. BRRI dhan39

Spacing of transplanting (cm × cm)	Plant height (cm)	No. of 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 spikelets panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1	96.13^{c}	6.41^{e}	4.057^{d}	2.36^{d}	20.67^{c}	97.58^{d}	19.03^{a}	23.58	2.69^{d}	4.20^{d}	6.89^{d}	39.18^{b}
S_2	100.00^{b}	9.00^{d}	5.805^{c}	3.19^{c}	20.85^{c}	103.90^{c}	18.42^{ab}	23.80	4.04^{c}	4.82^{c}	8.87^{c}	44.92^{a}
S_3	104.60^{a}	11.03^{a}	7.77^{a}	3.25^{bc}	22.25^{a}	109.00^{a}	16.67^{c}	24.29	4.42^{a}	5.45^{a}	9.88^{a}	45.58^{a}
S_4	102.8^{ab}	10.47^{b}	7.00^{b}	3.47^{a}	21.60^{ab}	106.1^{bc}	17.68^{b}	24.11	4.24^{b}	5.24^{b}	9.49^{b}	44.83^{a}
S_5	101.9^{ab}	10.00^{c}	6.66^{b}	3.33^{b}	20.97^{bc}	107.6^{ab}	17.94^{b}	24.04	4.22^{b}	5.14^{b}	9.37^{b}	45.11^{a}
Level of significance	**	**	**	**	**	**	**	NS	**	**	**	**
CV (%)	4.51	3.26	10.19	4.60	3.96	3.06	6.17	4.19	3.35	3.38	2.54	4.02

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). S_1 = 25 × 5 m, S_2 = 25 × 10 cm, S_3 = 25 × 15 cm, S_4 = 25 × 20 cm, S_5 = 25 × 25 cm, ** =Significant at 1% level of probability, NS = Not significant.

The tallest plant (104.60 cm) was obtained in 25 × 15 cm spacing followed by 25 × 20 cm spacing (102.40 cm) and the shortest plant (96.13 cm) was obtained in 25 × 5 cm spacing. The highest plant height might have resulted due to inception of optimum solar radiation in 25 × 15 cm spacing facilitating better photosynthesis.

More number of total tillers hill^{-1} (11.03) as well as effective tillers hill^{-1} (7.77) were found in 25 × 15 cm spacing, might be due to the capturing more solar radiation. The lowest number of total tillers hill^{-1} (6.41) and effective tillers hill^{-1} (4.05) were found in 25 × 5 cm spacing. Wider spacing produced higher number of effective tillers hill^{-1}, where the plant could exploit more sunlight for photosynthesis resulting in the accumulation of more carbohydrate, thereby increasing the number of effective tillers hill^{-1}. This result is in agreement with the findings of Salahuddin *et al.* (2009). The highest panicle length (22.25 cm) was observed in 25 × 15 cm spacing followed by 25 × 20 cm (21.60 cm) and the shortest one (20.67 cm) was found in 25 × 5 cm spacing. Panicle length varied due to spacing was observed by Ray *et al*. (2015) and Tari *et al*. (2009). The highest number of grains panicle^{-1} (109.00) was recorded in 25 × 15 cm spacing followed by 25 × 25 cm (107.60) and the lowest number of grains panicle^{-1} (97.58) was recorded in 25 × 5 cm spacing. The highest number of sterile spikelets panicle^{-1} (19.03) was observed in 25 × 5 cm spacing and the lowest number (16.67) was observed in 25 × 15 cm spacing. Similar results were reported by Verma *et al.* (2002). The highest grain yield (4.42 t ha^{-1}) was recorded in 25 × 15 cm spacing followed by 25 × 20 cm spacing (4.24 t ha^{-1}) and the lowest grain yield (2.69 t ha^{-1}) was obtained from 25 × 5 cm spacing. The highest number of effective tillers hill^{-1} and the highest number of grains panicle^{-1} were recorded in 25 × 15 cm spacing were mainly responsible for the highest grain yield. Lower grain yield obtained in closer spacing might be due to improper utilization of nutrient and space. Similar results were recorded by Salahuddin *et al*. (2009). Results revealed that straw yield (5.45 t ha^{-1}) and biological yield (9.88 t ha^{-1}) were the highest in 25 × 15 cm spacing, while 25 × 5 cm spacing produced

the lowest straw yield (4.20 t ha^{-1}). The highest harvest index (45.58%) was obtained from 25 × 15 cm spacing, which was statistically identical to 25 × 10 cm, 25 × 20 cm and 25 × 25 cm.

Table 2. Effect of fertilizer management on crop characters, yield components and yield of transplant *Aman* rice cv. BRRI dhan39

Nutrient management	Plant height (cm)	No. of 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 spikelets panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_0	94.84^{c}	8.15^{d}	3.667^{d}	4.489^{a}	20.40^{c}	95.99^{c}	19.84^{a}	23.29^{c}	3.57c	4.24^{c}	7.82^{d}	45.44^{a}
N_1	100.4^{b}	9.22^{c}	6.556^{c}	2.667^{b}	21.05^{b}	105.2^{b}	18.53^{b}	23.67^{bc}	3.96b	5.07^{b}	9.03^{c}	43.55^{b}
N_2	107.50^{a}	10.40^{a}	7.686^{a}	2.718^{b}	22.26^{a}	111.7^{a}	16.36^{c}	24.82^{a}	4.14a	5.39^{a}	9.53^{a}	43.29^{b}
N_3	101.60^{b}	9.75^{b}	7.134^{b}	2.624^{b}	21.38^{b}	106.5^{b}	17.06^{c}	24.09^{ab}	4.03b	5.18^{b}	9.21^{b}	43.42^{b}
Level of significance	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	4.51	3.26	10.19	4.60	3.96	3.06	6.17	4.19	3.35	3.38	2.54	4.02

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). N_0 = No manure and no fertilizer (control), N_1= Recommended dose of chemical fertilizer (80-60-40 kg N, P_2O_5, K_2O ha^{-1}, respectively + 60 kg ha^{-1} gypsum + 10 kg ha^{-1} $ZnSO_4$), N_2= 75% recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1}, N_3= 75% recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}. ** = Significant at 1% level of probability.

Either decreasing or increasing plant spacing other than 25 × 15cm showed decreased trend in harvest index. The lowest harvest index (39.18%) was recorded in 25 × 5 cm spacing (Table 1).

Table 3. Effect of interaction between spacing of transplanting and fertilizer management on crop characters, yield components and yield of transplant Aman rice cv. BRRI dhan39

Interaction (S pacing × fertilizer management)	Plant height (cm)	No. of 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 spikelets panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
$S_1 \times N_0$	90.65	5.11^{l}	2.66^{j}	2.44^{hi}	20.18	93.33	20.22	22.79	2.50^{j}	3.56^{j}	6.06^{j}	38.19
$S_1 \times N_1$	94.93	6.56^{k}	4.22^{fg}	2.33^{ij}	20.47	96.89	19.22	23.21	2.65^{j}	4.30^{hi}	6.95^{k}	39.39
$S_1 \times N_2$	102.6	7.11^{j}	4.55^{fg}	2.56^{ghi}	21.49	105.3	17.89	24.42	2.92^{i}	4.55^{h}	7.47^{j}	39.11
$S_1 \times N_3$	96.33	6.89^{jk}	4.78^{fg}	2.11^{j}	20.54	94.78	18.78	23.89	2.71^{ij}	4.38^{hi}	7.09^{k}	38.20
$S_2 \times N_0$	93.17	8.00^{i}	3.00^{hi}	5.00^{b}	20.18	96.33	20.22	22.93	3.46^{h}	4.11^{i}	7.58^{j}	45.74
$S_2 \times N_1$	100.5	8.56^{h}	6.11^{e}	2.44^{hi}	20.48	103.7	19.22	23.58	4.13^{ef}	4.89^{fg}	9.02^{fg}	45.79
$S_2 \times N_2$	105.6	10.22^{d}	7.55^{bcd}	2.67^{fgh}	21.94	109.7	17.11	24.75	4.36^{abce}	5.21^{cde}	9.57^{cde}	45.56
$S_2 \times N_3$	100.7	9.22^{fg}	6.55^{de}	2.67^{fgh}	20.80	106.0	17.11	23.94	4.21^{cde}	5.10^{ef}	9.31^{ef}	45.22
$S_3 \times N_0$	97.77	9.44^{ef}	5.00^{f}	4.44^{c}	20.90	98.27	19.11	23.81	4.20^{de}	4.60^{gh}	8.80^{gh}	44.73
$S_3 \times N_1$	100.9	11.11^{c}	7.77^{bc}	3.33^{d}	21.87	109.9	16.44	23.92	4.45^{abc}	5.60^{b}	10.0^{b}	44.27
$S_3 \times N_2$	107.6	11.89^{a}	9.20^{a}	2.69^{fgh}	23.27	115.7	14.89	25.12	4.57^{a}	6.11^{a}	10.60^{a}	46.43
$S_3 \times N_3$	101.4	11.67^{ab}	9.11^{a}	2.56^{ghi}	22.96	112.2	16.22	24.32	4.48^{ab}	5.50^{bc}	9.98^{bc}	44.89
$S_4 \times N_0$	95.96	9.44^{ef}	3.67^{ghi}	5.78^{a}	20.41	95.33	19.67	23.37	3.77^{g}	4.35^{hi}	8.12^{i}	46.33
$S_4 \times N_1$	101.8	10.11^{d}	7.56^{bcd}	2.56^{ghi}	21.73	106.8	18.78	23.89	4.33^{abce}	5.43^{bcd}	9.76^{bcd}	44.36
$S_4 \times N_2$	109.8	11.44^{ac}	8.67^{ab}	2.78^{efg}	22.50	113.3	15.67	24.94	4.47^{ab}	5.60^{b}	10.0^{b}	44.39
$S_4 \times N_3$	103.7	10.89^{c}	8.11^{abc}	2.78^{efg}	21.78	109.0	16.61	24.25	4.42^{abcd}	5.59^{b}	10.0^{b}	44.16
$S_5 \times N_0$	96.67	8.78^{gh}	4.00^{fgh}	4.78^{b}	20.31	96.67	20.00	23.53	3.93^{fg}	4.60^{h}	8.53^{h}	46.09
$S_5 \times N_1$	103.9	9.78^{de}	7.11^{cde}	2.67^{fgh}	20.69	108.7	19.00	23.73	4.23^{bcde}	5.14^{def}	9.37^{def}	45.14
$S_5 \times N_2$	111.8	11.33^{bc}	8.44^{ab}	2.89^{ef}	22.09	114.7	16.22	24.86	4.41^{abcd}	5.48^{bc}	9.89^{bc}	44.59
$S_5 \times N_3$	106.0	10.11^{d}	7.11^{cde}	3.00^{e}	20.80	110.5	16.56	24.04	4.33^{abce}	5.37^{bcde}	9.70^{bcde}	44.64
Level of Significance	NS	**	*	**	NS	NS	NS	NS	*	*	*	NS
CV (%)	4.51	3.26	10.19	4.60	3.96	3.06	6.17	4.19	3.35	3.38	2.54	4.02

Figures in column under each factor of treatment having the same letter or without letter do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT. S_1 = 25 × 5 cm, S_2 = 25 × 10 cm, S_3 = 25 × 15 cm, S_4 = 25 × 20 cm, S_5 = 25 × 25 cm. N_0 = No manure and no fertilizer (control), N_1= Recommended dose of chemical fertilizer (80-60-40 kg N, P_2O_5, K_2O ha^{-1}, respectively + 60 kg ha^{-1} gypsum + 10 kg ha^{-1} $ZnSO_4$), N_2= 75% recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1}, N_3= 75% recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}. ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant.

Effect of fertilizer management

Fertilizer management significantly influenced crop characters, yield components and yield except 1000-grain weight (Table 2). The application of 75% of recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1} showed superiority in terms of plant height (107.50 cm), number of total tillers hill^{-1} (10.40), number of effective tillers hill^{-1} (7.68), panicle length (22.26 cm) and grains panicle^{-1} (111.70), while the lowest values for those parameters were found in control plots. The highest grain yield (4.14 t ha^{-1}), straw yield (5.39 t ha^{-1}) and biological yield (9.53 t ha^{-1}) were obtained when the crop was fertilized with 75% of recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1}. Probably this treatment might have provided adequate nutrients to the plants and due to absorption of more nutrients, the crop produced the highest grain yield.

These results are in agreement with that of Shaha *et al*. (2014) and Sarkar *et al*. (2014) who found differences in yield and yield contributing characters due to different levels of nutrient management. The treatment control (no manures and fertilizers) gave the lowest values for the same parameters due to poor nutrient supply and it uptake by plant. The lowest number of non-effective tillers hill^{-1} (2.62)

was found in treatment 75% of recommended dose of inorganic fertilizers + poultry manure at 2.5 t ha^{-1}. Application of 75% of recommended dose of inorganic fertilizers + cow dung at 5 t ha^{-1} improved the yield contributing characters viz. number of effective tillers $hill^{-1}$ and number of grains $panicle^{-1}$, which ultimately resulted in the highest grain yield. The straw yield showed similar trend as that of grain yield due to nutrient management. Application of different doses of manures and fertilizers influenced the vegetative growth in terms of plant height and number of total tillers $hill^{-1}$, which resulted in differences of straw yield. The highest harvest index (45.44 %) was found in control treatment (no fertilizer and manure application). The lowest harvest index (39.44 %) was found in 75% recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1}.

Effect of interaction between spacing of transplanting and fertilizer management

Number of total tillers $hill^{-1}$, grain yield and straw yield of transplant *Aman* rice were significantly affected by interaction between spacing and fertilizer management. The highest number of effective tillers $hill^{-1}$ (9.20) was found in the treatment combination of 25 × 15 cm spacing and 75% recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1}, which was statistically identical (9.11) to 25 × 15 cm spacing and 75% recommended dose of inorganic fertilizer + poultry manure at 2.5 t ha^{-1}. The results showed superiority in terms of highest number of total tillers $hill^{-1}$ (11.89), grain yield (4.57 t ha^{-1}), straw yield (6.11 t ha^{-1}) and biological yield (10.60 t ha^{-1}) in the combination of 25 × 15 cm spacing fertilized with 75% recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1}. Sarkar *et al*. (2014) reported that BRRI dhan34 fertilized with 75% recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1} produced the highest grain yield. Integration of poultry manure @ 5 t ha^{-1} with 1.8 g USG at 25 × 20 cm spacing increased the yield components and grain yield of monsoon rice cv. BRRI dhan39 (Sarkar *et al*., 2016). The interaction of 25 × 5 cm spacing and control treatment (no manures and fertilizer) gave the lowest values in case of total tillers $hill^{-1}$ (5.11), effective tillers $hill^{-1}$ (2.66) and grain yield (2.50 t ha^{-1}) due to lack of proper nutrient supply and its uptake. The highest number of non-effective tillers $hill^{-1}$ was recorded from 25 × 20 cm with control fertilizers (5.78) and the lowest number of non-effective tillers $hill^{-1}$ (2.11) was recorded from 25 × 5 cm fertilized with 75% recommended dose of inorganic fertilizer + poultry manure @ 2.5 t ha^{-1}, which was statistically identical to 25 × 5 cm with recommended dose of chemical fertilizer (80-60-40 kg N, P_2O_5, K_2O ha^{-1}, respectively + 60 kg ha^{-1} gypsum + 10 kg ha^{-1} $ZnSO_4$.

Conclusion

Transplant Aman rice (cv. BRRI dhan39) can be cultivated using a spacing of 25 × 15 cm combined with 75% recommended dose of inorganic fertilizer + cow dung at 5 t ha^{-1} to obtain the highest grain and straw yields thereby curtailing 25% of the recommended dose of fertilizers.

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