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Original Article

Growth and yield descriptors of rice influenced by transplanting date

A. K. M. G. Sarwar* and S. C. Chanda

Laboratory of Plant Systematics, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.

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***Corresponding Author**

A. K. M. G. Sarwar, E-mail: drsarwar@bau.edu.bd

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A B S T R A C T

Boro rice faces two-way challenges – cold injury at different stages of growth due to early transplanting and early or pre-monsoon rain and flash flood for the late transplanting. An experiment was conducted to investigate the yield loss percentage of hybrid boro rice cultivars due to late transplanting. A two-factor experiment *viz.* two rice cultivars and three transplanting dates, was laid out in a randomized complete block design with three replications. All the studied morphological descriptors *viz.* plant height, number of tillers (total, effective and non-effective) and leaf size (length and width), and some of the yield and yield contributing descriptors *viz.* panicle length, length of primary branch, number and length of secondary branch, grain and straw yield and harvest index, were significantly influenced by both cultivars and transplanting times. Transplanting time had a little/insignificant effect on grain descriptors e.g., number panicle^{-1}, size (length, breadth and thickness), 1000-grain weight, etc. Although the cultivar Saru Madina produced longer panicle, higher number of primary and secondary branches panicle^{-1} and number of filled grains panicle^{-1}; it also produced higher number of unfilled grain in primary and secondary branches (5 and 10 folds, respectively) compared to Ispahani-2. The maximum grain yield (7.81 t ha^{-1}) was harvested from Ispahani-2 at 1st January transplanting and the lowest (6.29 t ha^{-1}) from Saru Madina at 30th January transplanting. Boro rice cultivars should be transplanted on or before 15th January for grain yield maximization; the grain yield reduction reached up to 17% when transplanting operation done on 30th January.

Introduction

Rice (*Oryza sativa* L.) is the staple food for millions across the globe including Bangladesh. More than 96% of its land area for "Cereal Agriculture" (i.e., cultivation of rice, wheat, maize and other cereals) was occupied by rice (BBS 2019). The country is now on the threshold of attaining self-sufficiency in food grain production and the third-largest rice producer in the world (Anon., 2020). In Bangladesh, rice is grown all the year-round in three growing periods *viz.* Aus (summer rice), Aman (monsoon rice) and Boro (winter rice). Boro rice cultivation plays the most important role in the food and nutritional security of Bangladesh. It contributes 54% of total rice production in the country, stands at about 20 m tons in 4.7 m hectares of land (BBS 2019). However, Boro rice also faces many challenges due to climate change-related natural calamities e.g., cold injury at different stages of growth, early or pre-monsoon rain, flash flood, insect and disease pests and weeds, etc. (Singh, 2002).

The "Haor Agriculture" is characterized by mono-cropped agriculture (i.e., Boro rice) and rest of the time animal agriculture i.e., fisheries and/or duck farming. Farmers of this area sometimes started to prepare the seedbed early during October soon after the removal of the (rain/flood) water from the inundated land area and go for early transplanting of rice seedlings to avoid the flash flood. However, this crop is generally vulnerable to cold injury of various degree. On contrary, the rice transplanting sometimes became delayed due to late removal of water from the land area; and the crop is subjected to early or pre-monsoon rain and flash flood. As a part of our project entitled "Screening of hybrid rice cultivars against low temperature-induced spikelet sterility", we had also tried to study the effect of late transplanting on the yield of hybrid Boro rice cultivars. The Boro rice seed sowing (in the seedbed) could be started from 31st October (15th Kartik) (BRRI 2017). Biswas (2017) reported that the transplanting of 20 days old seedling between 15–31 December had produced maximum grain yield in Gazipur area. He also reported that the hybrid “Heera 2” produced the maximum grain yield when it was transplanted at the beginning of Boro season (15–30 December; 30 days old seedling). Moreover, the transplantation should be completed within 30th January (15th Magh) to avoid a massive yield loss (BRRI 2017). Delay in planting usually results in yield reduction which cannot be complied by other means (Chendge *et al*., 2017: Hasan *et al*., 2018). Recently, Roy *et al*. (2019) concluded that the optimum transplanting time for inbred Boro rice studied was 15th January. Different rice cultivars (groups), *viz*. traditional vs. modern – inbred and hybrids, responded differently in grain filling (yielding) descriptors (Islam *et al*., 2016). The present study was, therefore, carried out to know the yield loss percentage of hybrid Boro rice cultivars due to late transplanting.

Materials and Methods

Study location

The experiment was conducted at the Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University during the period of December to May (Boro season) 2017–2018. The experimental field was located at 24°43′9.6″ N, 90°25 ′29.7″ E and an altitude of 18 m above the sea level. The experimental area belongs to the non-calcareous dark grey soil under Old Brahmaputra Floodplain Agro-ecological Zone (AEZ 9) of Bangladesh. The region covers a large area of the Brahmaputra river-borne sediments which were laid down before the river-shifted into its Jamuna Channel about 200 years ago (UNDP/FAO, 1988). The agro-climatic conditions i.e. monthly values of maximum, minimum and average temperature (°C), relative humidity (%), monthly total rainfall (mm) and sunshine (h) received at the experimental site during the study period have been presented Table 1.

Table 1. Weather data of experimental site during the period of the experiment in 2017-2018§

Month	Air Temperature (^{0}C) †			Rainfall (mm) †	RH (%) †	Sunshine (hr)
	Maximum	Minimum	Average			
December 2017	27.5	14.4	21.1	0	81.4	180.3
January 2018	22.6	10.8	16.7	0	83.5	152.9
February 2018	26.4	16.0	21.2	0	76.8	169.4
March 2018	31.1	20.0	25.6	33.0	76.1	192.4
April 2018	30.4	21.4	25.9	915.2	79.1	183.0
May 2018	30.2	23.5	26.8	488.5	83.2	148.6

Monthly average; ‡ Monthly total; RH = Relative humidity; § Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University.

Experimental treatment

Two-hybrid rice cultivars *viz*. Ishpahani-2 and Saru Madina-2 were used as experimental materials. Seeds (certified) were collected from the local market. Three transplanting dates *viz*. 1st January, 15th January and 30th January, were used as experimental treatments.

Field experimentation

The experiment was laid out in a factorial randomized complete block design with three replications. The size of a unit plot was 4.0 m × 2.5 m. Healthy sprouted seeds were sown in nursery bed on 1 December, 15 December and 30 December 2017 with proper care. The field layout was made on 25th December according to experimental specification immediately after final land preparation. Recommended doses of Triple superphosphate (TSP), Muriate of potash (MoP), Gypsum and Zinc sulphate (ZnSO4) were applied at the rate of 90 kg, 150 kg, 115 kg and 12 kg ha^{-1}, respectively at the time of final land preparation (BRRI 2017). Urea (@ 260 kg ha$^{-1)}$ was top-dressed in three equal splits at 15, 30 and 45 days after transplanting (DAT). Thirty-day old seedlings were transplanted on 1 January, 15 January and 30 January 2018, respectively in the well-puddled plot. Transplanting was done by using two seedlings hill^{-1} with 25 cm × 15 cm spacing between rows and hills, respectively. Different intercultural operations namely gap filling, thinning, weeding, irrigation, drainage and bund repairing were done whenever needed.

Data collection

Data on yield contributing characters and yield were recorded from five randomly selected hills from each plot. The yield parameters recorded are plant height (cm), number of total, effective and non-effective tillers hill^{-1}, length and width of flag leaf, panicle length (cm), number of total, filled and unfilled grains panicle^{-1}, length and number of primary branches panicle^{-1}, number of filled and unfilled grains in a primary branch, length and number of secondary branches in a primary branch, number of filled and unfilled grains in secondary branch and 1000-grain weight (g). The grain yield (g 10-hill^{-1}) and straw yield (g 10-hill^{-1}) were recorded, and biological yield (g 10-hill^{-1}), grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%) were calculated. Harvest index (%) was calculated using the following formula:

$$\mathrm{HI} = \frac{\mathrm{YE}}{\mathrm{YB}} \mathrm{X}\ 100$$

Where, HI Harvest index (%), YE and YB designate economic and biological yields (t ha^{-1}), respectively.

Statistical analysis

Data were analyzed statistically following the analysis of variance (ANOVA) technique, using Statistix 10 software package and means were separated by Duncan’s new multiple range test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

Results

The morphological descriptors *viz*. plant height, number of total tillers hill^{-1}, number of effective and non-effective tillers hill^{-1} and flag leaf size, differed significantly between cultivars and among the treatments as well (Table 2). The plant height varied from 77.83 cm to 85.67 cm both observed in Saru Madina at different transplanting time. The largest number of total and effective tillers hill^{-1} (9.67 and 8.83, respectively) were also found in Saru Madina at 1st January transplanting (Table 2). The highest number of non-effective tillers hill^{-1} (1.83) produced in 30th January transplanting. Transplanting at 15th January (or before) plants produced the largest flag leaf, both length (27.67 mm) and width (12.17 mm) (Table 2).

Table 2. Morphological descriptors of two hybrid rice cultivar

Treatments		Plant height (cm)	Tiller/ Hill (no.)	Effective tiller/Hill (no.)	Non-effective tiller/Hill (no.)	Flag leaf	
						Length (mm)	Width (mm)
Ispahani-2	1 January	84.67 ab	7.00 b	7.00 ab	0.17 bc	22.83 bc	12.17 a
	15 January	84.33 ab	8.17 ab	8.17 ab	0.00 c	22.00 bc	11.83 a
	30 January	80.17 bc	7.17 b	7.00 ab	0.17 bc	20.17 c	10.83 ab
Saru Madina	1 January	85.67 a	9.67 a	8.83 a	0.83 b	23.33 bc	8.50 c
	15 January	83.67 ab	8.17 ab	7.50 ab	0.67 bc	27.67 a	10.67 ab
	30 January	77.83 c	8.33 ab	6.50 b	1.83 a	25.00 ab	9.33 bc
LSD (0.05)		5.35	2.17	2.18	0.76	3.56	1.74
CV (%)		5.44	22.62	24.49	14.07	12.74	13.89

In a column, figures bearing dissimilar letter differ significantly at 5% level of significance.

Among the panicle morphological descriptors, the largest panicle (26.83 cm) was observed in Saru Madina when transplanted at 15th January and the smallest in Ishphahani-2 at 30th January transplanting (Table 3). The number of secondary branches panicle^{-1}, length of primary and secondary branches varied between cultivars and among the transplanting dates. Although a wide and significant variation observed in total, filled and un-filled grains panicle^{-1}, filled and unfilled grain in primary and secondary branches between cultivars, no significant difference was observed among the transplanting dates (Table 3). These descriptors might mostly be genetically controlled; the surrounding environment has little/no effect on these. More interestingly, the number of primary branches panicle^{-1} did not vary between cultivars and among the transplanting dates (Table 3).

Table 3. Panicle structure of two hybrid rice cultivars

Treatment	Panicle length (cm)	Primary branch/ Panicle (no.)	Secondary branch/ Panicle (no.)	Primary branch length (cm)	Secondary branch length (cm)	Total grain / Panicle (no.)	Filled grain/ Panicle (no.)	Unfilled grain/ Panicle (no.)	Filled grain/Pri. branch (no.)	Unfilled grain/Pri. branch (no.)	Filled grain/Sec. branch (no.)	Unfilled grain/Sec. branch (no.)
V_1T_1	23.67 a-c	11.17	16.17 bc	10.50 ab	3.33 c	139.17 b	131.67 b	4.33 b	13.17 b	3.33 b	0.50 b	0.17 b
V_1T_2	22.17 bc	11.67	16.17 bc	9.67 ab	3.33 c	128.83 b	122.50 b	6.33 b	11.33 b	3.33 b	0.83 b	0.33 b
V_1T_3	21.67 c	11.33	16.00 bc	9.33 b	3.00 c	116.00 b	111.83 b	4.17 b	11.50 b	3.17 b	0.50 b	0.17 b
V_2T_1	25.50 ab	11.17	14.83 c	10.67 ab	5.50 b	200.83 a	175.33 a	25.50 a	25.00 a	13.17 a	3.33 a	2.17 a
V_2T_2	26.83 a	12.83	20.50 ab	11.17 a	6.67 a	227.50 a	196.00 a	31.50 a	29.83 a	16.00 a	3.17 a	2.50 a
V_2T_3	22.50 bc	13.00	21.83 a	10.00 ab	6.83 a	219.00 a	193.83 a	25.17 a	29.00 a	16.17 a	3.00 a	1.83 a
LSD	3.45	3.69	4.89	1.62	1.10	41.63	38.62	9.64	6.10	4.76	1.64	1.19
CV	12.22	26.18	23.38	13.33	19.38	20.37	20.93	50.13	25.69	73.19	43.51	83.77

V_1 = Ispahani-2, V_2 = Saru Madina, T_1= Transplanting on 01/01/2018, T_2= Transplanting on 15/01/2018, T_3= Transplanting on 30/01/2018
In a column, figures bearing dissimilar letter differ significantly at 5% level of significance.

The seed length, breadth, thickness and 1000-grains weight significantly varied between cultivars, though a little variation was observed among the transplanting dates (Table 4). Moreover, grain (/straw) yield (both g 10-hill^{-1} and t ha^{-1}) and harvest index (%) varied between cultivars and among the transplanting dates. The harvest indices varied from 28.57% to 45.56%. The cultivar Ishphahani-2 produced the maximum grain yield (7.81 t ha^{-1}) at 1st January transplanting and the grain yield loss reached up to 17% due to later transplanting. On the other hand, the cultivar Saru Madina produced the minimum grain yield (6.29 t ha^{-1}) at 30th January transplanting and the grain yield loss reached up to 8% due to late transplanting (Table 4).

Table 4. Seed and yield descriptors of two hybrid rice cultivars

Treatment		Seed length (mm)	Seed breadth (mm)	Seed thickness (mm)	1000-grain weight (g)	Grain yield (g/10 hill)	Straw yield (g/10 hill)	Biomass yield (g/10 hill)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index
Ispahani-2	1st January	9.02 b	3.23 a	2.18 a	36.10 a	293.0 a	350.0 c	643.0	7.81 a	9.33	45.56 a
	15th January	8.87 b	3.10 b	2.22 a	36.28 a	225.0 c	500.0 a	725.0	6.60 b	13.33	31.03 b
	30th January	8.57 b	3.15 ab	2.12 a	35.12 a	160.0 e	320.0 c	480.0	6.51 b	8.53	33.33 b
Saru Madina	1st January	9.72 a	2.52 c	1.98 b	28.68 b	180.0 d	450.0 b	630.0	6.60 b	11.99	28.57 c
	15th January	9.68 a	2.53 c	1.97 b	28.30 b	250.0 b	500.0 a	750.0	6.80 b	13.33	33.33 b
	30th January	9.82 a	2.43 c	1.97 b	28.17 b	175.0 d	340.0 c	515.0	6.29 bc	9.06	33.98 b
LSD		0.51	0.13	0.11	1.88	14.72	47.59	n.d.	0.67	n.d.	3.65
CV		4.61	3.75	4.33	3.22	3.78	6.38	n.d.	8.42	n.d.	4.79

In a column, figures bearing dissimilar letter differ significantly at 5% level of significance.

Discussion

The growth and yield of a crop (rice) depend upon its genetic potential and growing (environmental) condition (Yoshida, 1981). Morphological descriptors influenced largely on environmental factors (Table 2) and panicle (yield contributing) descriptors largely on the genetic make-up of the plant (Table 3). The plant height decreases with delayed transplanting (Table 2). This result was supported by previous workers (Mannan *et al*., 2012; Ray *et al*., 2019). The delayed transplanting enhances premature flowering because of photoperiod sensitivity of (some) cultivars which forced the plants to switch from vegetative stage to the reproductive stage, thus might be responsible for the decrease of plant height (Mannan *et al*., 2012). The number of total and effective tillers hill^{-1} varied among the cultivars and transplanting dates. These variations might be due to genetic make-up of the cultivar, temperature and the level of sunlight (Yoshida, 1981; BRRI 2017; Sarwar *et al*., 2017; Roy *et al*., 2019). The leaf area i.e., leaf length and leaf width, varied with among the cultivars and transplanting time was also reported by Roy *et al*. (2019). The longer and wider flag leaf may be active and produced more photosynthetic product (starch) which may help crop growth and development. Source and sink relationship may be increased, as result grain filling rate may be increased.

Panicle length, number and length of primary and secondary branches, and the number of filled spikelets are the most imperative characters which influenced the yields of rice crop. Variations in panicle length, number and length of primary and secondary branches on the rachis of different cultivars were also observed by Sarwar and Ali (1998) and Kuddus *et al*. (2020). Dawadi and Chaudhary (2013) stated that late sowing, shortened growth period of the plant which reduced length of panicle, number of effective tillers than early sowing of rice. Yoshida (1981) reported that spikelet number per unit land area is affected by cultural practices (*viz*. spacing (seeding density) and nitrogen application), growth characteristics (i.e., tillering or seedling emergence) and climatic conditions (*viz*. solar radiation and temperature). In the present study, the variation spikelet number and (grain) size might be caused by the genetic make-up of the cultivars, the climatic condition did not affect significantly (Table 3). These results were with consonance with Ray *et al*. (2019) who reported that biomass production hill^{-1} differed due to cultivars and different transplanting dates, which might be due to variation in the crop growth rate of different cultivars at different growth stages. The grain yield in rice is determined by carbohydrate accumulation in the plant before heading and after heading (Dawadi and Chaudhary, 2013). Fageria (2007) stated that carbohydrates produced before heading mainly accumulated in the leaf (especially flag leaf), sheath and stem and trans-located to the panicle during grain filling period. The amount of dry matter production and assimilate partitioning from the source (leaf and non-laminar organ *viz*. leaf sheath, stem, flag leaf) to the sink (panicle) might be caused of yield difference between these two cultivars (Dawadi and Chaudhary, 2013; Islam *et al*., 2016). Results revealed that higher harvest index was related to higher grain yield and lower straw yield. The grain yield reduction in this study reached up to 17% when the transplanting operation was done after 15th January (Table 4). Moreover, the reduction in grain yield and biomass yield could be reached up to 33% and 56%, respectively due to late transplanting after 30th January (Roy *et al*., 2019).

Conclusion

The maximum grain yield (7.81 t ha^{-1}) was harvested from Ispahani-2 at 1st January transplanting and the lowest (6.29 t ha^{-1}) from Saru Madina at 30 January transplanting. Boro rice cultivars should be transplanted on or before 15th January for grain yield maximization; the grain yield reduction reached up to 17% when transplanting operation done on 30th January.

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