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Determination of Growth Stages of Some Rice Varieties as Affected by Sowing Time

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ABSTRACT

Identification of growth stages of rice is important for proper crop management and yield estimation. Appropriate planting time is a prerequisite for a decent harvest. The study aimed to determine the growth stages of different rice varieties and how they are affected by the sowing time. We evaluated four selected boro season rice varieties (BRRI dhan81, BRRI dhan86, BRRI dhan88, and BRRI dhan89) under five sowing times for growth stage study and yield following a completely randomized block design (RCBD) with three replications. Each variety showed considerable variation in different growth stages and yield at various sowing dates. All tested rice varieties took 40 days to reach the seedling stage on 15 December sowing. With the advancement or preceding this sowing date, the days required to attain this stage decreased. In mid-November sowing, the maximum period (33-34 days) was needed for tiller development and then reduced with the advancement of sowing dates irrespective of variety. Among the rice varieties, BRRI dhan89 required the highest time for panicle initiation (PI) on all sowing dates. The other three rice varieties took more or less similar time for panicle initiation. Among the rice varieties, BRRI dhan89 needed the highest, and BRRI dhan86 needed the lowest degree days for PI and flowering. BRRI dhan81 and BRRI dhan89 produced a higher grain yield from 15 November and 1 December sowing. BRRI dhan88 produced consistent grain yield throughout the sowing time. The fluctuations in PI stages' commencement indicate varietal characteristics, environmental conditions, and interaction between variety and environment.

Key words: Sowing time, growing degree-days, rice growth stage, phenological development

INTRODUCTION

Rice is the leading food crop and the primary source of nutrition for 3,500 million people world wide (Vivek *et al.*, 2004, Mahadi *et al.*, 2006, Liu *et al.*, 2011). The population is predicted to reach 8000 million by 2030, necessitating a 50% boost in rice yield to fulfil rising global demand (Khush and Brar, 2002; Kim and Krishnan, 2002). Poverty alleviation and food security can be achieved through a rapid increase in rice production in Bangladesh. Understanding the effect of the environmental factors on rice growth stages is essential for optimizing rice production in Bangladesh.

An optimum date for rice planting is region specific and varies with genotypes and environmental interactions (Bashir *et al.*, 2010). Bruns and Abbas (2006) and Yoshida (1981) stated that rice plants need a specific temperature for their phenological development, such as panicle initiation, flowering, panicle exertion and maturity.

The phenological development of crops greatly influenced by heat accumulation is expressed as growing degree-days (GDD). GDD is a summation of the mean daily temperatures over a certain period of growth or development. Additionally, the amount of heat is needed for a variety to bloom. We cannot track rice plants' flowering and panicle initiation stage using

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calendar days because of large differences in temperature in different months within a year and year to year. The development of crops can be better followed and projected by the amount of heat accumulated during each growing period. Regardless of differences in temperatures from year to year, GDD predicts that a variety will flower and reach maturity. Rice seed sown before the optimum time typically has poor germination and seedling establishment, more damage from insects and diseases, and preharvest losses by rats and birds (Linscombe *et al.*, 1999). Due to higher disease and insect infestations, storm-related lodging and probable heat or cold damage during the heading and filling stages, rice grown after the recommended dates may result in poor yields (Groth and Lee, 2003 and Reza *et al.*, 2011). Seedling age during transplanting is vital for seedling establishment. If the seedling age is lower, the seedling may die due to transplanting shock. On the other hand, older seedlings may influence fewer productive and more unproductive tillers, resulting in a low yield. The prerequisites that allow the crop to complete its life phase in a timely and fruitful manner are proper seeding time and technique. (Vange and Obi, 2006). According to Khalifa (2009), an early sowing date is ideal for obtaining important characteristics like the maximum number of tillers, the highest number of panicles per square meter, the highest number of grains in each panicle, and finally grain yield. A high number of spikelets in panicle indicates a better response with an early sowing. Late planting minimizes the plant's growth cycle and reduces panicle length, and spikelet number and leaf area. According to Dhaliwal *et al.* (1986) and Bashir *et al.* (2010), the weight of one thousand grains decreased progressively with late planting time. Khakwani *et al.* (2006) explained that sowing time significantly influenced grain yield. Several studies investigated the effect of sowing time and GDD on rice growth stages in Bangladesh. Hossain *et al.* (2020) observed that some rice varieties performed better under early sowing conditions while others performed better under late sowing conditions.

So, using four recently released Boro rice varieties—BRRI dhan81, BRRI dhan86, BRRI dhan88, and BRRI dhan89—we designed the current study to examine and assess the impact of different planting dates on phenological development and grain yield.

MATERIALS AND METHODS

Plant materials

Four popular Boro rice varieties: BRRI dhan81, BRRI dhan86, BRRI dhan88, and BRRI dhan89, which were taken into account to conduct the experiment on five different sowing dates.

Growing rice plants in the field

We experimented in the Plant Physiology Division's research field located at Bangladesh Rice Research Institute (BRRI) farm Gazipur, Bangladesh, during Boro season in 2019. The latitude longitude coordinates for the experimental field were 23.98985°N, 90.40205°E. The soil of the experimental field was clay loam. Five different sowing dates were 15 November, 1 December, 15 December, 1 January and 15 January. When seedlings had five leaves, these were uprooted for transplantation after being nurtured in the ideal seedbed. After being transplanted most of the seedlings were destroyed by a flock of whistling duck at night when the seedlings of last set was transplanted (sowing was done on mid-January) in the main field. They destroyed the seedlings again and again when gap filling was done in the main field. So only the phenological data were taken from the remaining seedlings for mid-January sowing. Treatments consisted of five sowing dates and four rice varieties were laid out in a randomized complete block design with three replications. Each treatment was assigned to an experimental plot of 9 m^2. Urea, triple superphosphate, muriate of potash, and gypsum fertilizer were applied at the rates of 80-50-50-10 kg per hectare for N, P_2O_5, K_2O, and S, respectively. At the end of the land preparation process, full doses of triple superphosphate, muriate of potash, and gypsum were incorporated. The three equal splits of urea were applied concurrently at 15 days after transplanting, mid tillering and at PI stage. The intercultural operation was carried out as required during the period of growth. The experimental field was irrigated using flood irrigation, and the crop management practices were carried out following the BRRI recommended procedures.

Evaluation of agronomic traits

Observations were made on days taken from seed sowing to five-leaf stage, days taken from transplanting to 1st tiller formation, days to panicle initiation (PI), days to 1st heading, days to 50% flowering, and days to maturity. For determining PI stage, the mother tiller section was done every alternate day from the active tiller stage. Grain yield was measured from an area of $5m^2$ and adjusted to 14% moisture level.

Measuring the heat accumulated over time provides a more accurate physiological estimate than counting calendar days. "Growing degree days" (GDD) is a way of assigning a heat value to each day. The temperature are added together to estimate the amount of seasonal growth of plants has achieved. A mathematical accumulation of daily mean temperatures above a predetermined threshold temperature is known as the GDD, also known as the accumulated degree days or effective heat unit. GDD was calculated following Iwata (1984).

GDD = Σ [(Tmax+Tmin)/2-Tb].

GDD = (Tmean - Tb)

Where Tmean = (Tmax + Tmean)/2

Tmax = Daily maximum temp.

Tmin = Daily minimum temp.

Tb is the base temperature taken as 10.0 °C for rice (Yoshida, 1981)

Data analysis

The International Rice Research Institute's Statistical Tool for Agricultural Research (STAR), version 2.0.1, was used to analyze the data.

RESULTS AND DISCUSSION

Seedling stage: The days required to attain the seedling stage (5 leaves) varied from 30 to 40 days irrespective of varieties (Table 1). All the tested rice varieties took 40 days to reach the seedling stage when seeds were sown on 15 December. With the advancement or preceding this sowing date, the days required to attain this stage decreased. When sowing time was shifted from mid-December to mid-January, the seedling stage was shortened from 40 to 30 days for most of the varieties. The variation in the duration of the seedling stage was reflecting the temperature variation during that period. Vange and Obi (2006) observed the impact of early and late seeding dates on grain yield and several agronomic traits. These results suggested that the planting date had a big impact on the duration of seedling stage under variation of temperature.

Tiller formation: After transplanting, the time required for tiller formation varied from 17 to 34 days irrespective of variety (Table 1). In mid-November sowing, the highest time (33-34 days) was needed for tiller initiation and then decreased with the advancement of sowing dates irrespective of variety. Due to cold weather in January, under the 15 November sowing, seedling took more time to establish and tiller production. With the advancement of sowing date, The relatively warmer temperature in late January to February, seedling establishment and tiller production was much quicker. Mannan *et al.*, 2009 observed that plant height, tillers number, and days to tiller initiation varied significantly due to variation of transplanting dates.

Table 1. Effect of sowing time on the number of days required to reach different growth stage in boro season, Plant Physiology, BRRI, 2019.

Sowing date	Variety	Seedling stage (days required to grow 5 leaves)	Tiller formation (DAT)	PI (DAT)	1st Heading (DAT)	Days to 50% flowering (DAT)	Days to Maturity (DAS)
15 Nov 2019	BRRI dhan81	35	34	59	89	95	152
	BRRI dhan86	35	33	55	85	92	152
	BRRI dhan88	35	34	57	87	93	152
	BRRI dhan89	35	34	66	96	104	167
1 Dec 2018	BRRI dhan81	34	28	49	78	84	149
	BRRI dhan86	34	28	47	76	82	149
	BRRI dhan88	34	28	49	78	84	146
	BRRI dhan89	34	27	60	89	96	158
15 Dec 2018	BRRI dhan81	40	21	43	69	73	138
	BRRI dhan86	40	20	40	66	72	138
	BRRI dhan88	40	23	42	69	76	138
	BRRI dhan89	40	21	55	81	88	158
1 Jan 2019	BRRI dhan81	31	23	43	69	74	126
	BRRI dhan86	31	22	39	68	73	126
	BRRI dhan88	31	23	40	69	73	126
	BRRI dhan89	31	22	55	80	86	142
15 Jan 2019	BRRI dhan81	30	18	39	62	68	124
	BRRI dhan86	30	20	39	62	67	124
	BRRI dhan88	30	19	37	60	65	124
	BRRI dhan89	31	17	51	74	80	138

DAS: Days after sowing
DAT: Days after transplanting

Panicle initiation (PI) and heading stage: Irrespective of varieties, there was a decrease in days requiring the panicle initiation in the progress of sowing time. Among the rice varieties, BRRI dhan89 took the highest time for panicle initiation on all sowing dates. The other three rice varieties took more or less similar time for panicle initiation. The time needed for heading varied markedly. It was the highest during mid-November sowing and the lowest when seeded in mid-January (Table 1). Biswas *et al.*, 2019 reported that late planting causes significant variation in agronomic traits like PI, days to flowering, and days to maturity

Flowering stage and growth duration: With the advancement of the sowing date from mid-November to onward, days to flowering decreased gradually irrespective of variety (Table 1). The highest time for flowering was exhibited by BRRI dhan89 in all sets of sowing. In mid-November sowing, all rice varieties took the highest days for flowering. As the sowing date was shifted from mid-November to mid-January, the reduction of flowering time (from transplanting) was 27, 25, 28, and 24 days for BRRI dhan81, BRRI dhan86, BRRI dhan88, and BRRI dhan89, respectively. These findings agreed with those of Wani *et al.* (2016), who found that the time required to attain flowering and harvest varied significantly between sowing dates. Growth duration followed the same trend. The growth duration ranged from 124 to 152 days in BRRI dhan81, BRRI dhan86, BRRI dhan88, and 138 to 167 days in BRRI dhan89 over sowing dates (Table 1). In mid-November sowing, growth duration was the highest in all tested varieties. As sowing dates were advanced, the growth duration decreased gradually irrespective of rice variety. With the advancement of sowing dates, rice crops' elevated temperature affects the crop duration by attaining the phenological stages earlier.

Growing degree-days (GDD): Degree-days expresses the influence of mean temperature on the developmental rate. We used GDD for phenological forecasting of a rice crop. Tables 2 and 3 present the phenology of four rice varieties at the four sowing times. Results indicated that phenology was significantly influenced by the interaction effect of sowing time and varieties. The tested varieties varied in growing degree days (°Cd) requirements for panicle initiation and flowering (Tables 2 and 3). Among the rice varieties, BRRI dhan89 needed the highest, and BRRI dhan86 needed the lowest degree-days for both PI and flowering in all sowing dates. The results reflected that heat requirement for phenological development was the highest for BRRI dhan89 and for BRRI dhan86 it was the lowest. Mid November sowing needed the highest Degree days (°Cd) requirements for panicle initiation and flowering and decreased gradually when sowing dates were shifted onward. The required GDD from PI (from (transplanting) were 959 ± 39.9, 912.8 ± 42.6, 935.8 ± 42.7, 1121.3 ± 22.3 while for flowering (from transplanting) 1492.5 ± 43.2, 1466.5 ± 32.3, 1483.5 ± 33.6, 1712.8 ± 22.2 for BRRI dhan81, BRRI dhan86, BRRI dhan88 and BRRI dhan89, respectively.

Table 2. Requirement of degree-days (°Cd) for panicle initiation (from transplanting) of some rice varieties in Boro season, Plant Physiology, BRRI, 2019.

Variety	Sowing date			
	15-Nov-18	1-Dec-18	15-Dec-18	1-Jan-19
BRRI dhan81	1076 b	932 b	933 b	895 b
BRRI dhan86	1027 c	906 b	897 c	821 c
BRRI dhan88	1050 bc	932 b	917 bc	844 c
BRRI dhan89	1169 a	1145 a	1102 a	1069a

Means with the same letter are not significantly different.

Table 3. Requirement of degree-days (°Cd) for flowering (from transplanting) of some rice varieties in Boro season, Plant Physiology, BRRI, 2019.

Variety	Sowing date			
	15-Nov-18	1-Dec-8	15-Dec-18	1-Jan-19
BRRI dhan81	1619 b	1476 b	1445 c	1430 b
BRRI dhan86	1563 c	1443 b	1432 c	1428 b
BRRI dhan88	1580 bc	1476 b	1450 b	1428 b
BRRI dhan89	1771 a	1722 a	1688 a	1670 a

Means with the same letter are not significantly different.

Grain yield: The interaction between sowing dates and varieties was significant on grain yield by the ANOVA test. Among the rice varieties, BRRI dhan81 and BRRI dhan89 produced the highest grain yield at 15 November seeding whereas BRRI dhan86 at early December and BRRI dhan88 at mid-December seeding (Fig. 1). With the advancement of sowing dates, the grain yield decreased remarkably for BRRI dhan81and BRRI dhan89. Although BRRI dhan88 produced the highest grain yield (6.18 tha^{-1}) at mid-December seeding, which was statistically similar to all the seeding dates. BRRI dhan86 produced the highest grain yield in early December seeding, and seeding before or after early December sharply decreased grain yield. BRRI dhan86 produced the lowest crop yield at mid-November seeding.

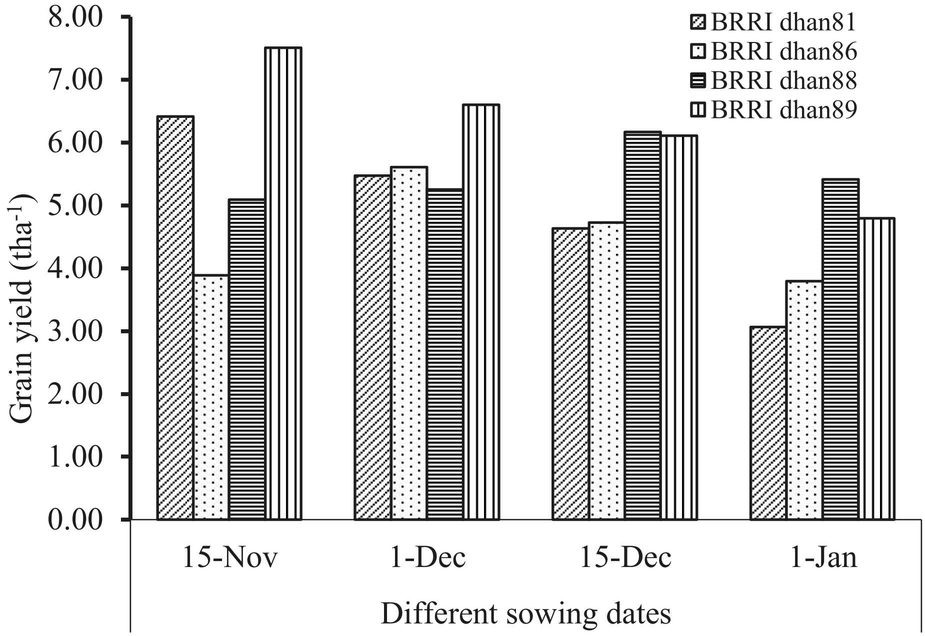

Fig. 1. Grain yield (tha^{-1}) of four rice varieties as affected by different sowing dates in Boro season.

Planting rice after the optimal dates may result in lower grain yield due to poor vegetative growth, higher disease and insect incidence, and possible heat or cold damage during heading and grain filling (Groth and Lee, 2003; Reza *et al.*, 2011; Biswas *et al.*, 2019).

Yield components

The interaction between variety and sowing date was not significant except for sterility. Among the varieties, the highest panicle number per unit area (310) was found in BRRI dhan88 and the lowest (260) in BRRI dhan81 (Table 4). BRRI dhan89 had the highest number of grain per panicle (114) and BRRI dhan86 had the lowest (92).The highest 1000-grain weight (23.62 g) was observed in BRRI dhan89 and the lowest (21.55 g) in BRRI dhan88. Number of panicle per unit area was the highest when seeds were sown at the beginning of January and the lowest when sowing date was mid-December (Table 5). Number of filled grain per panicle was the highest when seeds were sown at the beginning of December and decresed with the advancement of sowing date. Similar trend was observed for 1000 grain weight.

Table 4. Effect of different varieties on yield component, Plant Physiology, BRRI, 2019.

Variety	No. of panicle m^{-2}	No filled grain $panicle^{-1}$	1000 grain wt (g)
BRRI dhan81	260.42 c	100.75 bc	22.63 b
BRRI dhan86	273.75 bc	92.25 c	23.26 ab
BRRI dhan88	309.75 a	111.58 ab	21.55 c
BRRI dhan89	290.42 b	114.17 a	23.62 a
CV(%)	7.71	13.74	4.16

Means with the same letter are not significantly different.

Table 5. Effect of different sowing dates on yield component, Plant Physiology, BRRI, 2019.

Sowing date	No. of panicle m^{-2}	No. of filled grain $panicle^{-1}$	1000 grain wt (g)
15 Nov	275.50 b	112.25 a	23.16 a
1 Dec	278.75 b	115.75 a	23.60 a
15 Dec	272.75 b	99.42 b	22.98 a
1 Jan	307.33 a	91.33 b	21.32 b
CV(%)	7.71	13.74	4.16

Means with the same letter are not significantly different.

Table 6. Interaction effect of variety and sowing dates on sterility percent, Plant Physiology, BRRI, 2019.

	15 Nov	1 Dec	15 Dec	1 Jan
BRRI dhan81	14.54 b	25.80 a	36.31 a	43.05 a
BRRI dhan86	30.01 a	23.77 a	32.20ab	34.06 ab
BRRI dhan88	21.73 ab	23.50 a	15.75 c	28.64 b
BRRI dhan89	19.98 ab	23.40 a	22.07 bc	38.99 ab
		CV% = 24.69		

Means with the same letter are not significantly different.

Irrespectictive of varieti highest sterility was observed when seeds were sown at the beginning of January. Due to high sterility grain yield reduced irrespective of varieti and when critical stage (flowering stage) faced high temperature due to shifted sowing date. It is the number of filled spikelets and the spikelet size that govern grain yield of rice (Yoshida, 1981). BRRI dhan81 and BRRI dhan89 showed the lowest sterility when seeds were sown on mid November; while BRRI dhan86 and BRRI dhan88 showed lowest sterility when seeds were sown at the beginning of December and mid December, respectively.

CONCLUSION

Among the four seeding dates, significant variation of evaluated growth stage and yield indicated higher variability in tested rice varieties' performance. Among the rice varieties, BRRI dhan81 and BRRI dhan89 produced a higher harvest from 15 November and 1 December sowing. BRRI dhan88 produced consistent yield throughout the sowing time. BRRI dhan86 did not perform well under low-temperature conditions. So BRRI dhan86 should not be cultivated in cold prone northern part and haor region of the country. The variation in the occurrences of PI stages, heading of different varieties, and sowing dates indicated the dependence of PI and heading stages on varietal characteristics, environmental conditions, and variety × environment interaction. The rice varieties showed a wide variation in degree-days' requirement to develop panicle initiation and flower for sowing time. The adverse effects of late planting were reflected in the lower yield in Boro season. The study highlights the importance of selecting appropriate sowing time for a variety to obtain maximum yield.

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