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Thermal indices and growth attributes of rice hybrids under varied planting time and spacing during *boro* season

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ABSTRACT

The phenophase-wise thermal indices and growth attributes of two rice hybrids under varied planting environment and spacing were studied at Instructional Farm (22°93'N, 88°53'E and 9.75 m.s.l), Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India during boro season of 2012-2013. Mean summed growing degree days (GDD) from sowing to emergence, fourth leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 38.2, 227.1, 514.6, 838.6, 1423.0, 1624.3, 1820.1, 2030.2°C day, respectively. Rice hybrids planted on 29 January accumulated lower total GDD (2003.7°C day), heliothermal units (16966.1°C day hour) and vigour index (1063.1) compared to two later plantings (12 and 27 February). Close spacing (15 × 15 cm) resulted in greater leaf area index (2.22 and 4.72) and dry matter production (109.4 and 462.9 g m^{-2}) at 28 and 70 days after transplanting (DAT) than wider spacing (20 × 15 cm). Both hybrids (KRH 2 and Kumud) had more upright leaves (low light extinction coefficient, k = 0.28 – 0.29) at mid growth phase. There was negative correlations between GDD and HTU during reproductive stage (panicle initiation to 50% flowering) and grain yield, but GDD during 50 per cent flowering to milk showed positive (P<0.05) effect on economic yield of hybrid rice.

Keywords: Growth attributes, phenology, rice hybrids, thermal indices

Hybrid rice is presently cultivated in about 2 million ha land, mainly in northern and central India; which accounts for about 4% of total rice area in the country. The advantage of heterosis can be achieved to the fullest extent, when hybrid rice is supported by better cultivation practices and favourable weather conditions. Spacing determines the planting density in unit area, thereby influencing the input-use efficiency, growth and yield of the crop. In the context, the growth parameters can serve as useful indices for rapid selection of hybrid rice varieties for adoption in target regions (Om *et. al.*, 1997). As the relationships between the crops and environments are complex in nature, the thermal indices are important agro-meteorological tools for better understanding of the phonological development and growth of crops in the present day agricultural research system.

A field experiment was conducted during *boro* season (December – April) of 2011 – 2012 on a low land sandy-loam soil at Instructional Farm (22°93'N, 88°53'E and 9.75 mast) of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India. Treatments replicated twice, were arranged in a split-split plot design with three planting dates (29 January, 12 February and 27 February, with the seedlings sown on 26 December, 10 January and 25 January, respectively) in main plots, two spacings (20 × 15 cm and 15 × 15 cm) in sub-plots and two varieties (KRH 2 and Kumud) in sub-sub plots. 33–34 days old seedlings were transplanted @ 1–2 $hill^{-1}$ in puddled field. Standard agronomic practices including a fertilizer dose of 120:60:60 (N: P_2O_5: K_2O) kg ha^{-1} were adopted.

Growing degree days (GDD) for each phenophase were calculated by taking a base temperature of 10°C (Nuttonson, 1955), while heliothermal units (HTU) were determined ("GDD x Bright sunshine hour) following Singh *et al.*, (1990). The growth parameters like vigour index (Jha *et al.*, 2001), leaf area index, light transmission ratio (Yoshida *et al.*, 1972), light extinction coefficient (Saeki, 1963) and dry matter production were recorded in the investigation.

Thermal indices

Rice hybrids planted on 29 January took 140.6 days from sowing to maturity, which was decreased by 6.7 days in 12 February and 16.6 days in 27 February planting during *boro* season (data not shown). It was mainly due to the difference in vegetative phase owing to variability in planting dates, as the number of days required for reproductive and ripening phases were more or less same. However, early planting accumulated lower total GDD (2003.7°C day) for entire life cycle compared to two late plantings (12 February, 2045.8°C day and 27 February, 2041.1°C day) in the investigation (Table 1). This could be explained by the fact that the mean air temperature and bright sunshine hour over the cropping

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Table 1: Effect of planting time and spacing on thermal indices of two rice hybrids during *boro* season in West Bengal

Treatment	Vegetative				Reproductive	Ripening			Life cycle
	S – E*	E – 4LE*	4LE – AT	AT – PI	PI – F	F – Mi	Mi – D	D – M	S – M
	Growing degree days (°C days)								
Planting time									
29 January	50.8	200.7	228.6	329.7	568.6	208.1	201.2	216.0	2003.7
12 February	27.3	173.9	287.1	339.9	585.4	212.1	194.2	225.9	2045.8
27 February	36.6	192.1	322.7	302.5	599.1	183.7	192.1	212.3	2041.1
LSD (0.05)			5.25	14.85	26.31	19.2	NS	14.77	NS
Spacing									
20 x 15 cm	38.2	188.9	281.0	325.5	584.7	201.4	193.8	218.0	2031.5
15 x 15 cm	38.2	188.9	277.9	322.5	584.0	201.2	197.8	218.1	2028.6
LSD (0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Variety									
KRH2	34.6	181.7	275.5	299.9	556.8	198.0	196.5	216.7	1959.7
Kumud	41.8	196.1	284.4	343.1	612.0	204.6	195.2	219.4	2096.4
LSD (0.05)			**7.55**	**8.04**	**13.64**	**NS**	**NS**	**NS**	**26.06**
	Heliothermal units (°C days hour)								
Planting time									
29 January	362.7	796.8	1922.6	3063.2	4792.4	1944.1	1915.3	2189.0	16986.1
12 February	97.6	1349.6	2522.3	3001.4	5113.2	1939.2	1958.0	2122.0	18103.3
27 February	303.7	1567.7	3055.4	2593.4	5313.1	1811.8	1867.8	1838.0	18350.9
LSD (0.05)			53.51	115.15	188.17	114.10	NS	176.64	506.19
Spacing									
20 x 15 cm	254.5	1238.0	2515.1	2893.6	5073.1	1924.5	1897.8	2034.6	17831.2
15 x 15 cm	254.5	1238.0	2485.1	2878.4	5072.8	1872.2	1929.5	2064.7	17795.2
LSD (0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Variety									
KRH2	234.7	1161.4	2417.9	2670.3	4791.8	1837.4	1962.3	2103.7	17179.5
Kumud	274.3	1314.6	2582.3	3101.7	5354.1	1959.3	1865.0	1995.6	18446.9
LSD (0.05)			**64.99**	**66.19**	**129.21**	**79.26**	**NS**	**84.12**	**223.56**

Note : S – E = Sowing to emergence, E – 4LE = Emergence to 4th leaf emergence, 4LE – AT = 4th leaf emergence to active tillering, AT – PI = Active tillering to panicle initiation, PI – F = Panicle initiation to flowering, F – Mi = Flowering to milk, Mi – D = Milk to dough, D – M = Dough to maturity

** The rice seedlings during S – E and E – 4LE stages were in the nursery beds, so the average values were taken without any scope for statistical analysis*

Table 2: Effect of planting time and spacing on growth parameters of rice hybrids during *boro* season in West Bengal

Treatment	Vigour Index *	Leaf area index (LAI)		Light transmission ratio (%)	Light extinction coefficient (k)	Dry matter accumulation (g m^{-2})	
		28 DAT	70 DAT	49 DAT	49 DAT	28 DAT	70 DAT
Planting time							
29 January	1063.1	2.28	4.67	34.9	0.29	112.5	478.4
12 February	1231.4	2.13	4.61	35.8	0.29	100.6	452.2
27 February	1502.9	1.95	4.52	38.2	0.28	94.9	429.0
LSD (0.05)		**0.09**	**0.11**	**1.23**		**2.98**	**7.71**
Spacing							
20 × 15 cm		2.02	4.47	37.0	0.29	95.9	443.4
15 cm × 15 cm		2.22	4.72	35.6	0.29	109.4	462.9
LSD (0.05)		**0.07**	**0.08**	**1.38**		**2.86**	**6.90**
Variety							
KRH 2	1218.0	2.16	4.66	36.2	0.28	104.3	456.3
Kumud	1313.6	2.08	4.54	36.5	0.29	101.0	450.1
LSD (0.05)		**0.08**	**0.06**		**NS**	**4.54**	**9.48**

*Note : * The vigour index was determined, when the seedlings were raised in wet nursery. Thus, the average values were used without any scope for statistical analysis.*

Table 3: Correlations between phenophase-wise thermal indices and yield associated characters of hybrid rice

Phenological stage	Plant height	No. of panicles m^{-2}	No. of filled grains $panicle^{-1}$	1000 grain weight	Grain yield	Straw yield
Growing degree days (GDD)						
S – E*	0.526**	0.396	0.108	0.081	0.410*	0.371*
E – 4LE*	0.338*	0.186	-0.155	-0.096	0.152	0.135
4LE – AT	-0.753**	-0.749	-0.716**	-0.578**	-0.909**	-0.543**
AT – PI	0.347*	0.246	-0.171	-0.329	0.194	0.407*
PI – F	-0.184	-0.267	-0.645**	-0.523**	-0.392*	-0.03
F – Mi	0.331*	0.28	0.213	0.013	0.335*	0.396*
Mi – D	0.309	0.278	0.19	0.164	0.328	-0.034
D – M	0.024	-0.064	0.013	-0.141	-0.025	0.276
Heliothermal units (HTU)						
S – E*	0.253	0.135	-0.027	0.047	0.117	0.074
E – 4LE*	-0.773**	-0.715**	-0.677**	-0.575**	-0.876**	-0.539**
4LE – AT	-0.766**	-0.765**	-0.691**	-0.525**	-0.922**	-0.610**
AT – PI	0.531**	-0.456**	0.021	-0.163	0.445**	0.575**
PI – F	-0.329*	-0.414*	-0.730**	-0.609**	-0.559**	-0.195
F – Mi	0.26	0.192	0.109	-0.051	0.233	0.350*
Mi – D	0.03	0.101	0.258	0.141	0.174	-0.107
D – M	0.401*	0.423*	0.503**	0.292	-0.539**	0.517**

Note : S – E = Sowing to emergence, E – 4LE = Emergence to 4^{th} leaf emergence, 4LE – AT = 4^{th} leaf emergence to active tillering, AT – PI = Active tillering to panicle initiation, PI – F = Panicle initiation to flowering, F – Mi = Flowering to milk, Mi – D = Milk to dough, D – M = Dough to maturity

Sample size: n = 42; r value = 0.304 and 0.393** at 5% and 1% level of significance, respectively*

period were progressively increased with delay in sowing of hybrids like 24.20°C and 8.2 hours (29 January), 25.17°C and 8.7 hours (12 February) and 26.49°C and 8.9 hours (27 February), which accelerated the phenological development of the crop but resulted in higher accumulation of heat units.

Among two rice hybrids, Kumud recorded higher GDD at almost all phenophases than KRH 2, but differences were not significant during the ripening stage. Mean cultivar GDD for eight phenophases were recorded as: 38.2°C day (S – E), 188.9°C day (E – 4LE), 279.5°C day (4LE – AT), 324.0°C day (AT – PT), 584.4°C day (PI – F), 201.3°C day (F – Mi), 195.8°C day (Mi – D), 218.1°C day (D – M), and 2028.1°C day (S – M) for life cycle.

Mean summed total HTU for the entire cropping period was 17813.2°C day hour with a range between 17179.5°C day hour (KRH 2) and 18446.9°C day hour (Kumud) in the study, which was greater than the average (16983.0°C day hour) of nine hybrids grown at Coochbehar, West Bengal during *boro* season (Nag, 2002).

Rice hybrids sown late (25 January) experienced higher mean air temperature during first two weeks after emergence compared to earlier two sowings (26 December and 10 January) in the study. The late sown hybrids recorded greater vigour index (1502.9) due to better seedling growth and germination than early (1063.1) and mid sowings (1231.4) (Table 2). Among two hybrids, the seedlings of Kumud were more vigorous (1313.6) than KRH 2 (1218.0) in the experiment.

Growth attributes

Leaf area index (LAI) showed an increasing trend up to 70 DAT *i.e.* a little before heading in all three planting dates, which is consistent with Thakur and Patel (1999). Close spacing (15 × 15 cm) recorded greater foliage growth at both 28 and 70 DAT mainly due to accommodation of more hills m^{-2} than wide spacing

(20 × 15 cm) (Table 2). The greater values of light transmission ratio (LTR) for late planted crop (27 February) against lower LAI values at 49 DAT suggested an inverse relationship between these two parameters. The reduced light extinction coefficient (k) values (0.28 – 0.29) indicated more upright leaves of rice hybrids tested in the study.

Correlations between thermal indices and yield associated characters

The correlation studies indicated that thermal indices like GDD (r = 0.347*) and HTU (r = 0.531**) during active tillering to panicle initiation (AT – PI) had positive influence on plant height, but the negative correlations (P<0.01) of GDD and HTU with number of panicles m^{-2}, number of filled grains $panicle^{-1}$ and 1000 grain weight during mid vegetative (fourth leaf emergence to active tillering) and reproductive (panicle initiation to 50% flowering) stages were noted in the study (Table 3). Besides, GDD and HTU during reproductive stage (panicle initiation to 50 per cent flowering) had negative influence on grain yield, while GDD during 50% flowering to milk showed positive (P<0.05) effect on economic yield of hybrid rice.

Thus, it can be concluded that mean cultivar total GDD and HTU for entire life cycle of hybrid rice were 2028.1ºC day and 17813.2ºC day hour, respectively. Rice hybrids planted on 29 January accumulated lower total GDD (2003.7ºC day), heliothermal units (16966.1ºC day hour) and vigour index (1063.1) compared to two later plantings (12 and 27 February). Close spacing (15 ×15 cm) resulted in greater leaf area index (2.22 and 4.72) and dry matter production (109.4 and 462.9 g m^{-2}) at 28 and 70 DAT than wider spacing (20 × 15 cm). Both hybrids (KRH 2 and Kumud) had low light extinction coefficient (k = 0.28 – 0.29), but KRH 2 recorded lower vigour index (1218.0), GDD (1953.5ºC day) and HTU (17157.0ºC day hour) than Kumud in the study. The correlation studies indicated that thermal indices like GDD and HTU during reproductive stage (panicle initiation to 50 per cent flowering) had negative influence on grain yield, while GDD during 50 per cent flowering to milk showed positive (P<0.05) effect on economic yield of hybrid rice.

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