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Research Article

PLANTING TIME AND DENSITY EFFECTS ON PHENOLOGY, THERMAL INDICES, YIELD AND QUALITY OF POPULAR SMALL-GRAIN AROMATIC RICE (CV. GOBINDABHOG) OF WEST BENGAL

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Abstract: The influence of four planting dates [10th July (D_{10J}), 25th July (D_{25J}), 10th August (D_{10A}) and 25th August (D_{25A})] and three spacings [20 × 10 cm ($S_{20\times10}$), 15 × 15 cm ($S_{15\times15}$), and 20 × 15 cm ($S_{20\times15}$)] on small-grain non-Basmati aromatic rice (cv. Gobindabhog) was studied during *kharif* season at BCKV, West Bengal. Gobindabhog rice planted on 10 July required 152.0 days to maturity, which was reduced by 8.2, 13.3 and 19.7 days for delayed plantings on D_{25J}, D_{10A} and D_{25A}, respectively. Mean accumulated GDD, HTU and PTU for entire life cycle were 2608ºC day, 15554ºC day hour and 31598ºC day hour. With positive correlations ($P<0.01$) of GDD, HTU and PTU with number of filled grains/panicle at ripening stage, Gobindabhog rice planted on 25th July produced the highest grain yield (3.02 t/ha), which was 4.1, 14.4 and 17.5% greater over D_{10A}, D_{25A} and D_{10J} plantings, respectively. Planting in second fortnight of July could be adopted for better yield (3.02 t/ha), moderate duration (143.8 days), greater head rice recovery (62.7%) and amylose content (18.1%); while square planting ($S_{15\times15}$, 44 hills/m^2) improved grain yield (2.89 t/ha) and aroma (score 2.7) over closer ($S_{20\times10}$, 50 hills/m^2) and wider spacing ($S_{20\times15}$, 33 hills/m^2).

Keywords: *Aromatic rice, Planting time, Spacing, Yield, Grain quality*

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Introduction

Gobindabhog, a small-grain non-Basmati type aromatic rice, is a native cultivar of gangetic and vindya alluvial region of West Bengal. It was named probably for its use in preparation of bhog offered to the God 'Gobinda' by the Hindus as a religious tradition for a long time. It is presently cultivated in about 35,000 ha land in the districts of Burdwan, Bankura, Hooghly, Nadia, Murshidabad, Birbhum and North 24 Parganas in South Bengal due to its popularity and demand in domestic and regional markets [1]. With the recommendation of Parliament of India for export [2], registration as a Farmers' Variety (No. 233/2014) under Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA) and Geographical Indication (GI No. 531/2017) of India, its scope for marketing has been expanded in recent times.

Farmers in local areas cultivate Gobindabhog rice using age-old production methods intermixed with a few modern techniques nowadays during wet (*kharif*) season. Gobindabhog is an indigenous photo-sensitive rice crop and highly affected by temperature, day length and sunshine hours to its performance in respect of growth, yield and quality. Too early or too late transplanting causes yield reduction due to crop sterility and lower number of productive tillers, respectively [3]; and grain filling during milder autumn temperatures causes good grain quality [4, 5]. Late planting coinciding with flowering and maturity in cooler days has been reported to enhance the grain quality but reduction in grain yield in Basmati rice growing belts in North India. Therefore, sowing or planting period is an important non-monetary practice considering the weather dependent correlations with yield and quality parameters of aromatic rice. Spacing determines the plant population in unit area, thereby influencing the input-use-efficiency and yield of the crop.

Plant population above optimum increases competition among plants for light and nutrients that weakens the plant and ultimately low yield is obtained [6], while plant population below optimum causes resources wastage. Thus, optimization of planting time and spacing is needed for increased yield and better grain quality of Gobindabhog rice, hopefully leading to timely accommodation of Gobindabhog rice in multiple crop sequence in lower gangetic plains of West Bengal.

Materials and Methods

Experimental site: A field experiment was conducted during wet (*kharif*) seasons of 2010 and 2011 at 'C' Block Farm (22°58' N latitude, 88°26' E longitude and 15.9 m altitude) of Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani, Nadia, West Bengal. The soil was sandy-loam (order Entisol), neutral in reaction (pH 6.8), medium in organic C (0.61%), available N (287.3 kg/ha), P (48.5 kg/ha) and K (234.7 kg/ha). Monthly maximum and minimum temperature throughout the crop season varied between 12.2 and 34.3°C and 13.4 and 33.2°C in 2010 and 2011 and the rainfall received for the seasons were 826.4 mm and 1720.3 mm, respectively. The bright sunshine ranged between 5.1 (June) and 7.5 hours (November) in 2010, and between 3.3 (August) and 8.2 hours (October) in 2011. It was lower in high rainfall months mainly due to cloud-cast days.

Treatment details and crop husbandry

The experiment was laid out in a split-plot design replicated thrice comprising four planting dates [10 July (D10J), 25 July (D25J), 10 August (D10A) and 25 August (D25A)] in main plots and three spacings [20 cm × 10 cm (S20×10), 15 cm × 15 cm (S15×15), and 20 cm × 15 cm (S20×15)] in sub plots.

Table-1 *Meteorological parameters at ripening phases under different planting dates of aromatic Gobindabhog rice during kharif season*

Year	Planting time	Flowering to Milk				Milk to Dough				Dough to Maturity			
		T_{max} (°C)	T_{min} (°C)	BS (h)	R_{total} (mm)	T_{max} (°C)	T_{min} (°C)	BS (h)	R_{total} (mm)	T_{max} (°C)	T_{min} (°C)	BS (h)	R_{total} (mm)
2010	10 July	33.3	24.9	7.3	27.0	30.8	21.2	6.9	0.7	32.2	20.7	8.7	0
	25 July	32.0	23.1	6.3	0	31.3	20.4	8.4	0.7	31.8	21.1	7.2	0
	10 August	30.9	20.8	7.4	0.7	32.0	21.2	7.3	0	30.1	17.9	7.7	0
	25 August	32.0	21.2	7.3	0	30.1	17.9	7.7	0	25.4	15.8	4.1	19.5
2011	10 July	31.7	23.5	7.2	60.6	30.7	19.2	7.7	0	30.6	19.4	7.4	8.0
	25 July	31.3	21.5	8.0	59.0	30.6	19.0	7.7	0	29.9	19.3	6.3	8.0
	10 August	30.7	18.9	7.7	0	29.6	19.2	6.0	8.0	29.2	15.8	8.1	0
	25 August	29.6	19.2	6.0	8.0	29.2	15.8	8.1	0	28.7	16.2	7.0	0

T_{max}, Maximum temperature; T_{min}, Minimum temperature; BS, Bright sunshine; R_{total}, Total rainfall

Table-2 *Effect of planting time and spacing on accumulated growing degree days at phenophases of aromatic Gobindabhog rice during kharif season (pooled data of 2 years)*

Treatment	Vegetative (°C day)				Reproductive (°C day)	Ripening (°C day)			Life cycle (°C day)
	S-E	E- 4LE	4LE-AT	AT-PI	PI-F	F-Mi	Mi-D	D-M	
Planting time									
10 July (D_{10J})	78^{a} (4.0)	361^{a} (18.5)	578^{a} (29.6)	616^{a} (30.8)	714^{a} (37.4)	202^{a} (11.2)	169^{a} (10.3)	166^{a} (10.1)	2885^{a} (152.0)
25 July (D_{25J})	66^{b} (3.3)	362^{a} (18.2)	553^{b} (28.5)	550^{b} (28.0)	653^{b} (34.5)	183^{b} (10.9)	163^{b} (10.1)	166^{a} (10.1)	2696^{b} (143.8)
10 August (D_{10A})	68^{b} (3.0)	343^{b} (17.8)	549^{b} (27.9)	504^{c} (25.9)	603^{c} (33.4)	168^{c} (10.4)	160^{b} (10.1)	125^{b} (9.9)	2520^{c} (138.7)
25 August (D_{25A})	66^{b} 3.0)	347^{b} (17.5)	511^{c} (26.1)	472^{d} (24.6)	541^{d} (31.6)	164^{c} (10.1)	125^{c} (10.0)	104^{c} (9.6)	2330^{d} (132.3)
Spacing									
20 cm × 10 cm ($S_{20\times10}$)	70^{a} (3.5)	354^{a} (18.0)	550^{a} (28.2)	539^{a} (27.5)	628^{a} (34.3)	180^{a} (10.7)	153^{a} (10.1)	139^{a} (9.9)	2612^{a} (142.1)
15 cm × 15 cm ($S_{15\times15}$)	69^{a} (3.5)	353^{a} (18.0)	549^{a} (28.0)	532^{a} (27.1)	628^{a} (34.2)	180^{a} (10.7)	155^{a} (10.1)	142^{a} (10.0)	2609^{a} (141.6)
20 cm × 15 cm ($S_{20\times15}$)	70^{a} (3.5)	354^{a} (18.0)	544^{a} (27.8)	535^{a} (27.3)	627^{a} (34.2)	179^{a} (10.6)	155^{a} (10.2)	139^{a} (9.8)	2602^{a} (141.4)

**Values in parentheses indicate the phenophase duration (days). Values followed by the same letter in the same case in each column are not significantly different (P <0.05).*
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; and D-M; Dough to Maturity

Gobindabhog paddy seeds were collected from RKVY Project on 'Bengal Aromatic Rice' of BCKV and sown @ 18-20 kg/ha in wet nursery at three different times of 15 days interval. 24-25 days old seedlings @ 2-3/hill was transplanted as per planting time and spacing schedule at a shallow depth (3-4 cm) in puddled field. A uniform fertilizer dose consisting of 2 t FYM, 40 kg N, 20 kg P_2O_5 and 20 kg K_2O/ha was given to all experimental plots in the study. Manual weeding was done at 3 and 6 weeks after transplanting (WAT), and other crop management practices were adopted as per standard recommendations. The crop was raised with south-west monsoon rain, but need-based irrigation was given at critical stages. Plants were manually harvested, when 80-85% panicles became mature in the field.

Analysis of crop growing environment

The daily meteorological data were collected from the AICRP on Agro-meteorology, BCKV, Kalyani, West Bengal, and the weather parameters during the ripening phases are given in [Table-1]. Growing degree days (GDD) at different phenophases as well as for entire life cycle was determined as the difference between the mean daily temperature and the base temperature of crop [7], where 10°C was the base temperature for rice. The heliothermal units (HTU) and photothermal units (PTU) were calculated by the following formulae of Singh *et al*. [8] and Nuttonson [9], respectively.

$$\mathrm{GDD} = \sum_{i=1}^{n}\left[\left(\frac{\mathrm{T\,max.} + \mathrm{T\,min.}}{2}\right) - \mathrm{Tb}\right]$$

$$\mathrm{HTU} = \sum_{i=1}^{n}[\mathrm{GDD} \times \mathrm{Bright\ sunshine\ hour}]$$

$$\mathrm{PTU} = \sum_{i=1}^{n}[\mathrm{GDD} \times \mathrm{Average\ day\ length\ (hour)}]$$

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Materials and Methods

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Table-3 *Effect of planting time and spacing on thermal indices and growth attributes of aromatic Gobindabhog rice during kharif season (pooled data of 2 years)*

Treatment	Heliothermal units (ºC day hour)	Photothermal units (ºC day hour)	Plant height at harvest (cm)	Lodging at dough stage (score)	Pre-flowering stage		
					Tillers/m^2	LAI	Light transmission ratio
Planting time							
10 July (D_{10J})	16194^{a}	35641^{a}	136.9^{a}	4.8^{a}	282^{b}	4.61^{c}	20.1^{a}
25 July (D_{25J})	15988^{b}	32730^{b}	132.4^{b}	4.7^{a}	307^{ab}	4.78^{b}	19.5^{a}
10 August (D_{10A})	15464^{c}	30319^{c}	131.0^{b}	4.6^{a}	316^{a}	4.84^{a}	19.4^{a}
25 August (D_{25A})	14568^{d}	27701^{d}	127.8^{c}	4.2^{b}	296^{b}	4.49^{d}	20.7^{a}
Spacing							
20 cm × 10 cm ($S_{20×10}$)	15584^{a}	31641^{a}	132.0^{a}	4.4^{a}	321^{a}	4.69^{b}	19.7^{b}
15 cm × 15 cm ($S_{15×15}$)	15550^{a}	31560^{a}	132.3^{a}	4.6^{a}	311^{a}	4.73^{a}	19.6^{b}
20 cm × 15 cm ($S_{20×15}$)	15527^{a}	31594^{a}	131.8^{a}	4.7^{a}	270^{b}	4.61^{c}	20.5^{a}

Values followed by the same letter in the same case in each column are not significantly different (P<0.05)

Table-4 *Effect of planting time and spacing on yield and grain quality of aromatic Gobindabhog rice during kharif season (pooled data of 2 years)*

Treatment	Panicles/ m^2	Filled grains/panicle	1000 grain weight(g)	Grain yield (t/ha)	Head rice (%)	Amylose (%)	Alkali value (score)	Cooked kernel length(mm)	Elongation ratio	Aroma* (score)
Planting time										
10 July (D_{10J})	254^{c}	126^{c}	10.2^{c}	2.57^{c}	62.3^{ab}	17.8^{b}	3.8^{a}	6.9^{b}	1.7^{c}	2.6^{a}
25 July (D_{25J})	283^{a}	134^{a}	10.3^{b}	3.02^{a}	62.7^{a}	18.1^{a}	3.7^{b}	7.2^{a}	1.8^{b}	2.6^{a}
10 August (D_{10A})	272^{b}	129^{b}	10.4^{a}	2.90^{b}	61.7^{b}	18.0^{a}	3.4^{c}	7.2^{a}	1.8^{b}	2.7^{a}
25 August (D_{25A})	247^{d}	121^{d}	10.2^{c}	2.64^{c}	61.2^{b}	18.0^{a}	3.4^{c}	7.3^{a}	1.9^{a}	2.7^{a}
Spacing										
20 cm × 10 cm ($S_{20×10}$)	284^{a}	124^{c}	10.2^{c}	2.83^{a}	62.2^{a}	18.0^{a}	3.6^{a}	3.6^{a}	7.1^{a}	2.6^{a}
15 cm × 15 cm ($S_{15×15}$)	263^{b}	127^{b}	10.4^{a}	2.89^{a}	61.8^{a}	18.0^{a}	3.5^{a}	3.5^{a}	7.2^{a}	2.7^{a}
20 cm × 15 cm ($S_{20×15}$)	245^{c}	131^{a}	10.3^{b}	2.63^{b}	62.0^{a}	18.0^{a}	3.6^{a}	3.6^{a}	7.1^{a}	2.6^{a}

**Intensity of aroma: 0, no aroma; 1, Mild; 2, Medium; 3, Strong Values followed by the same letter in the same case in each column are not significantly different (P <0.05).*

The soil was sandy-loam (order Entisol), neutral in reaction (pH 6.8), medium in organic C (0.61%), available N (287.3 kg/ha), P (48.5 kg/ha) and K (234.7 kg/ha). Monthly maximum and minimum temperature throughout the crop season varied between 12.2 and 34.3°C and 13.4 and 33.2°C in 2010 and 2011 and the rainfall received for the seasons were 826.4 mm and 1720.3 mm, respectively. The bright sunshine ranged between 5.1 (June) and 7.5 hours (November) in 2010, and between 3.3 (August) and 8.2 hours (October) in 2011. It was lower in high rainfall months mainly due to cloud-cast days.

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Determination of plant characters and grain quality: The tillering habit, leaf area index [10] and light transmission ratio (LTR) were recorded at pre-flowering stage. The light intensity at top of canopy and ground level was noted using a lux meter (Lutron make, Thailand) and LTR was calculated by the formula of [11]. The rating of lodging was done at dough stage [12]; while plant height, yield attributes and grain yield at maturity.

The grain quality parameters were determined during post-harvest period (2010-11 and 2011-12) at 'Aromatic Rice Laboratory', BCKV, Mohanpur, Nadia. 100 g clean paddy sample of each experimental unit was used to determine the head rice recovery (Rice Mill, Satake make, Japan), and milled rice was used to estimate amylose content [13], alkali spreading value [14], elongation ratio and aroma [15].

$$\text{Head rice}(\%) = \frac{\text{Weight of head rice}(g)}{\text{Weight of rough rice}(g)} \times 100$$

$$\text{ER} = \frac{\text{Length of cooked rice kernel (mm)}}{\text{Length of rice kernel (mm)}}$$

Statistical analysis

The data recorded in the study were analysed using Fisher's 'Analysis of Variance' technique as per the procedures described by Gomez and Gomez [16], and the mean differences were compared at 5% level of significance. The correlations among thermal indices and plant parameters at ripening stage were determined.

Results and Discussion

Phenology

Mean days from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity of Gobindabhog rice were 3.6, 20.9, 48.1, 83.8, 115.0, 124.6, 134.9 and 144.5 days, respectively; which could be summarized as 76.8±5.9 days for vegetative, 34.2±2.8 days for reproductive, and 30.7±0.9 days for ripening stage [Table-2] and [Fig-1]. 10 July planted crop required 152.0 days to maturity, and further reduced with delayed in planting by 8.2, 13.3 and 19.7 days for 25th July, 10th August and 25th August planting in the study. This might be due to the differences in length of vegetative stage, as the time required for both reproductive and ripening phases were more or less similar among three planting periods adopted in the study. The number of days to anthesis and physiological maturity of Basmati 515 was decreased with succeeding transplanting dates at 3 locations in Pakistan[17]. Spacing could not influence the phenophase duration and accumulated heat units of Gobindabhog rice in the study.

Growth environment and thermal indices

Mean air temperature throughout life cycle of Gobindabhog paddy ranged among planting time as: D10J (28.7, and 27.7°C), D25J (28.5 and 27.5°C), D10A (28.0 and 27.1°C) and D25A (27.0 and 26.7°C) during 2010 and 2011 (data not shown), *Table-5 Correlations of thermal indices at post-anthesis stages with yield and quality parameters of aromatic Gobindabhog rice*

Yield and quality parameter	Flowering to Milk			Milk to Dough			Dough to Maturity		
	GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU
Filled grains/panicle	0.220	0.127	0.243*	0.473**	0.401*	0.491**	0.473**	0.370*	0.432*
1000 grain weight	-0.298*	-0.256*	-0.291*	0.032	0.143	0.013	-0.099	-0.122	-0.143
Grain yield	-0.317*	-0.024	0.296*	-0.066	0.140	-0.040	0.061	0.032	0.062
Head rice recovery	0.001	0.216	0.032	-0.050	0.098	-0.034	0.225	0.319*	0.268*
Amylose	-0.110	-0.121	-0.121	-0.142	-0.035	-0.123	-0.081	-0.160	-0.119
Alkali value	-0.118	0.150	-0.100	-0.043	0.044	-0.005	0.060	0.107	0.089
Cooked kernel length	-0.208	-0.247*	-0.220	-0.176	-0.137	-0.188	-0.215	-0.225	-0.231
Elongation ratio	-0.048	-0.166	-0.064	-0.078	-0.150	-0.080	-0.127	-0.194	-0.145
Aroma	-0.125	-0.I168	-0.132	-0.084	-0.050	-0.083	-0.149	-0.135	-0.164

Sample size: n=72; r value=0.232 and 0.302** at 5% and 1% level of significance, respectively*

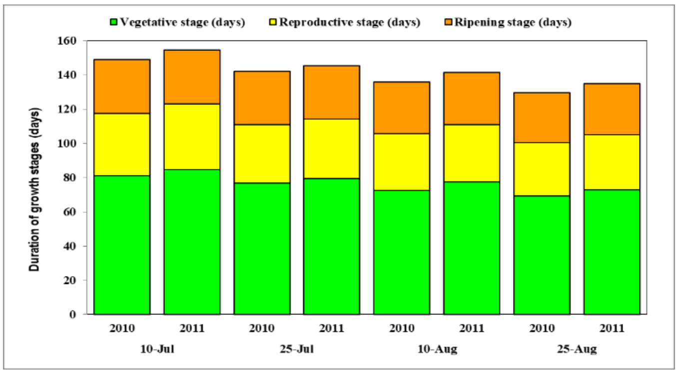

Fig-1 Effect of planting time on duration of growth stages of aromatic Gobindabhog rice

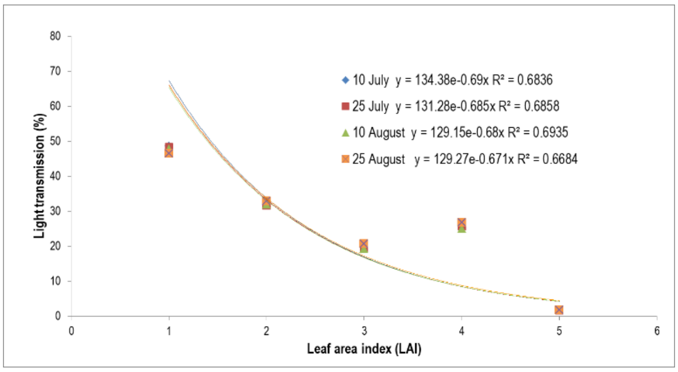

Fig-2 Effect of planting time on relationship between LAI and LTR of Gobindabhog rice during *kharif* season (pooled data of two years)

which showed that average temperature of entire crop period declined gradually with late sowing or planting during wet season. Mean summed GDD of Gobindabhog rice from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 70, 423, 971, 1506, 2134, 2313, 2468 and 2608°C day, respectively. The summed GDD for entire life cycle was reduced by 594.9°C day for delay in planting from 10 July (2927°C day) to 25 August (2332°C day) in the study. The accumulated GDD during vegetative, reproductive and ripening phases showed variations due to planting times as: D10J (1634, 714 and 537°C day), D25J (1531, 653 and 511°C day), D10A (1464, 603 and 453°C day) and D25A (1396, 541 and 393°C day). Based on total summed HTU, four planting dates could be arranged as: D10J (16194°C day hour) > D25J (15988°C day hour) > D10A (15464°C day hour) > D25A (14568°C day hour) [Table-3].

Gobindabhog rice planted on 10th July noted the highest total summed PTU of 35641°C day hour, which was 2911, 5322 and 7940°C day hour greater over 25th July, 10th August and 25th August plantings, respectively. The accumulated thermal indices like GDD, HTU and PTU for entire life cycle were decreased due to successive delay in sowing or planting of the crop. This could be described by the fact that both temperature and day length showed a linear declining trend after autumnal equinox (23 September), so the late planted crops (25th July, 10th August and 25th August) received lower temperature and day length during late vegetative, reproductive and ripening phases compared to early planted crop (D10J). Planting density could not affect the phenophase duration and accumulated thermal indices of Gobindabhog paddy in both years of study, except for total GDD, HTU and PTU for life cycle in 2011 only.

Tillering, leaf growth and light transmission

Early planted Gobindabhog rice (10 July) produced tallest plants throughout the season and at harvest (136.9 cm), but 10 August planted crop recorded maximum tillers in 1 m^2 area (316.4) and LAI (4.84) at pre-flowering stage (84 DAT) [Table-3]. Plant height of Gobindabhog paddy was not significantly influenced by planting density in the study, but widely spaced plants (25 cm × 25 cm) of four fine rice varieties (Basmati 370, BRRI dhan 37, BRRI dhan 38 and Kalijira) were tallest ones (147.5 cm) followed by spacings of 20 cm × 20 cm and 20 cm × 15 cm because they could get more light, water and nutrients due to less inter-space competition than closely spaced plants during aman season at Mymensingh, Bangladesh [18]. Although closer spacing (S20×10) resulted in significantly greater number of tillers/m^2 (320.8) at pre-flowering stage, which might be due to more number of hills per unit area (50 hills/m^2) than wider spacings with accommodation of 44 hills/m^2 (S15×15) and 33 hills/m^2 (S20×15). LAI was found significant in 2010, 2011 and pooled values in the investigation. The LTR values within plants under two closer spacings (S20×10 and S15×15), usually being at par, were significantly lower than wide plant density (S20×15).

Yield components and correlations with thermal indices

The yield components (*viz.* number of panicles/m^2, number of filled grains/panicle and 1000 grain weight) and grain yield of Gobindabhog rice usually differed significantly among planting dates and spacings adopted in the study [Table-4]. Gobindabhog paddy transplanted on 25 July produced maximum number of panicles (283/m^2) and number of filled grains/panicle (134) than both early (D10J) or late plantings (D10A and D25A). However, earlier planting (25 June) could record higher yield attributes of Basmati rice compared to the latter plantings (10 and 25 July) at Hisar, Haryana. Besides, maximum number of filled grains/panicle irrespective of planting time was recorded in first year than the second year of study[19].

The late July or early August planting caused improvement in yield components of Gobindabhog rice due to favourable growth environment compared to early July and late August plantings during wet season. Similarly, maximum number of grains/panicle (102.1) and 1000 grain weight (13.35 g) were recorded of five scented rice varieties planted on 25 July compared to other three plantings on 15 July, 4 August and 14 August at Dinajpur, Bangladesh [20]. The positive correlations ($P<0.01$) of GDD, HTU and PTU with number of filled grains/panicle at mid and late maturity stage [Table-5] showed that air temperature, bright sunshine hour and day length had positive effect on grain filling (*i.e.* translocation of photosynthesis to the sink) and development towards maturity during wet season in West Bengal.

1000 grain weight was increased with late planting from 10 July (10.2 g) to 10 August (10.4 g), which declined thereafter (10.2 g). Negative correlations ($P<0.01$) of GDD, HTU and PTU were noted with 1000 grain weight at 50% flowering to milk stage in the experiment.

Grain yield

Gobindabhog transplanted on 25 July recorded maximum grain yield (3.02 t/ha), and was 4.1, 14.4 and 17.5% higher over D10A, D25A and D10J, respectively. Significant improvement was found in grain yield production from early (D10J) to medium (D25J) planting time, which decreased afterwards in late transplanting upto 25 August in the experiment. The transplanting dates for Basmati 515 with regard to grain yield as: 30 June > 20 June > 10 July > 20 July > 10 June > 30 July averaged over 3 locations (Gujranwala, Hafizabad and Faisalabad) in Pakistan. In case of spacing square planting method (S15×15 or 44 hills/m^2) resulted in highest grain yield (2.89 t/ha) which was at par with similar planting density (S20×10, 50 hills/m^2), but significantly greater over wide spacing (S20×15, 33 hills/m^2) adopted in the experiment [17]. All four planting times in 2011 were recorded a little higher grain yield than those in 2010, which might be due to the combined influence of greater number of panicles/m^2 and 1000 grain weight during second year than first year of study. Higher planting density (50 hills/m^2 and 44 hills/m^2) resulted in greater grain yield compared to low density (33 hills/m^2) in the study. Similar type of finding was reported with the adoption of 25 cm × 25 cm spacing in scented rice field compared to wider planting density (30 cm × 25 cm) at New Delhi, India [8].

Lodging

The field-based observation indicated that most (>50%) Gobindabhog rice plants had a propensity to lodge down slightly (score 3.0) to totally (score 5.0) at dough stage. The crop grown during 2011 was more prone to lodging, irrespective of treatments than 2010 in the investigation. There was no significant influence of lodging at dough stage among planting dates during both 2010 and 2011, except pooled over two years. The lodging habit was found to decrease with delay in planting from 10 July (score 4.8) to 25th August (score 4.2), but spacing caused non-significant variation in lodging tendency of Gobindabhog rice in the investigation.

Milling quality

25th July planted crop noted highest head rice recovery (62.7%), which was 0.4, 1.0 and 1.5% higher than D10J, D10A and D25A, respectively [Table-4]. Perusal of data revealed that non-significant rise in head rice recovery were recorded from 10th July to 25th July, which decreased in two delay transplanting in the month of August in the study. But the ideal planting time of aromatic rice varieties could be between 4th and 14th August for higher milling and head rice outcome compared to early (15th and 25th July) or late (2nd August and 3rd September) plantings during aman season at Mymensingh, Bangladesh [21]. The positive correlations of HTU ($r = 0.319^{**}$) and PTU ($r = 0.268^{*}$) with head rice recovery of Gobindabhog rice during dough to maturity stage [Table-5] indicated that both bright sunshine hour and day length preferred the development and ripening of rice grain thus making them less prone to breaking at milling.

Cooking quality

Mean amylose content in Gobindabhog rice grain either of planting times or spacing was 18.0%, which indicated that the variety belonged to low (9–20%) amylose group. July 25 transplanted crop noted highest amylose content (18.1%) being at par with 25 August and 10 August, but the lowest amylose content (17.8%) was recorded with first transplanted crop (10 July). Thus, planting of Gobindabhog paddy on or after 25 July upto 25 August improved the amylose content in grain compared to early planting on 10 July, which could be supported by low mean air temperature during ripening period for two August transplanted crops, *viz.*10 August (23.3°C) and 25 August (21.6°C) compared to two July planted crops like 10 July (25.7°C) and 25 July (25.6°C) in the investigation. The finding also confirmed the negative relationship between amylose content and temperature during the ripening period [22], specifically in low amylose rices[23].

There were significant differences for pooled values only in alkali value of Gobindabhog rice grain, though there was a steady decrease with delay in planting time from 10 July to 25 August. Thus, gelatinization temperature showed an increasing trend between intermediate (score 4.0) and high-intermediate (score 3.0) with delay in planting from early July to the end of August during wet season. Similarly, the KLAC of Gobindabhog rice was found to increase steadily (6.92 to 7.34 mm) with delay in planting from 10 July to 25 August. The maximum ER (1.85) was noted with D25A, while minimum ER (1.74) with D10J. Although planting date did not affect the aroma of Gobindabhog rice significantly, but the intensity of aroma was improved for delayed plantings during August (10 and 25) than July plantings (10 and 25), which might be due to low day-night temperature (29.2°C/17.7°C) compared to 10 July (31.6°C/21.5°C), 25 July (31.2°C/20.7°C) and August 10 (30.4°C/19.0°C) at grain filling and ripening period. Similarly, low temperature (<20°C) during grain filling period [24] as well as cooler day-night temperature (25°C/21°C) at crop maturity [13] favoured better retention of aroma in Basmati rice. Spacing had no significant effect on aroma in Gobindabhog rice grain in the investigation.

Conclusion

Mean summed GDD of Gobindabhog rice at different stages *viz.* sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 70, 423, 971, 1506, 2134, 2313, 2468 and 2608°C day, respectively. It can be concluded that second fortnight of July might be the optimum time for transplanting of Gobindabhog paddy for lesser duration (143.8 days), better yield (3.02 t/ha), maximum head rice recovery (62.7%) and amylose content (18.1%); while spacing (15 cm × 15 cm, 44 hills/m^2) improved the grain yield (2.89 t/ha) and aroma (score 2.7) over closer (20 cm × 10 cm, 50 hills/m^2) and wider spacing (20 cm × 15 cm, 33 hills/m^2) in lower gangetic plains of West Bengal, India.

Application of research: Study on optimum planting time for indigenous Gobindabhog paddy in respect to growth, yield and quality

Research Category: Agronomy

Abbreviations: GDD-Growing degree days, HTU-Heliothermal units,
PTU-Photothermal units, T_{max}-Maximum temperature,
T_{min}-Minimum temperature, BS-Bright sunshine,
R_{total}-Total rainfall, LTR-light transmission ratio,
ER-Elongation ratio

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Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: 'C' Block Farm, BCKV, Kalyani, Nadia, West Bengal

Cultivar / Variety / Breed name: Gobindabhog

Conflict of Interest: None declared

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Ethical Committee Approval Number: Nil

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