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Phenology, Thermal Indices and Yield Prediction Models of Indigenous Aromatic Rice of West Bengal, India

Sibajee Banerjee[1*], Mrityunjay Ghosh[1*] and Debasis Mazumder[2]

[1]Department of Agronomy, [2]Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

**Corresponding author*

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A B S T R A C T

The phenological development and thermal unit requirements of seven aromatic rice landraces of West Bengal were studied in randomized block design (RBD) with 3 replications at ‘C’ Block Farm (22^o 99’ N, 88^o 45’ E, 9.75 m.s.l.), Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India during *kharif* (wet) season of 2008 and 2009. All seven indigenous scented rice cultivars were long-duration types (140.0 – 148.3 days) and differed slightly among themselves towards attainment of different phenophases and accumulation of heat units. Mean cultivar days from sowing to emergence, 4th leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 3.9, 21.4, 47.1, 73.6, 111.3, 122.5, 133.6, 122.5, 133.6 and 144.6 days, respectively. Mean growing degree days (GDD), heliothermal units (HTU) and photohermal units (PTU) were 1449±83, 6473±453 and 18439±999 during vegetative stage, 729±10, 4465±223 and 8679±167 during reproductive stage and 530±23, 4389±254 and 6035±255 during ripening stage, respectively. Based on accumulated GDD, HTU and PTU for entire life cycle, the cultivars could be arranged as: Radhunipagal > Chinikamini > Mohanbhog > Badshabhog > Khasdhan > Gobindabhog > Kalojira. The correlation studies revealed that GDD and HTU at tiller production stage had positive influence on number of panicle m^{-2}, while HTU at ripening stage showed positive impact on grain filling and development leading to higher grain yield. The regression model for grain yield (Y= 3.93 – 0.0138 GDDM-D** – 0.000724 HTUM-D*) showed associations with GDD and HTU both during milk to dough stage and accounted for 34 % variation at 1 % level of significance.

Introduction

There are about 25-30 aromatic rice landraces in West Bengal, which are cultivated by the farmers in different parts of the state for hundreds of years. It is estimated that about 3,00,000 tonnes of such premium rices are produced every year (Bhattacharya, 2003), which have different end-uses like cooked table rice, dessert (*payas*), biriyani, etc. With the introduction of high-yielding varieties, the cultivation of such scented rice cultivars is being marginalized, but they are still grown by the farmers mainly for domestic consumption, social and religions functions. Weather variability is considered as one of the major factors of inter-annual variability in crop growth and yield in all environments. In the event of unpredictable weather conditions during *kharif* season (south-west monsoon period, June–October), agro-meteorological indices such as growing degree days (GDD), heliothermal units (HTU), etc. can be quite useful in predicting the growth and yield of these aromatic rice landraces in the region. Thus, it is necessary to generate information on phenological development and effects of weather parameters on indigenous aromatic rice as well as development of yield prediction models for necessary refinement of production technologies in future.

Materials and Methods

A field experiment was conducted to study the phenological development and thermal unit requirements of aromatic rice landraces of West Bengal at ‘C’ Block Farm (22^0 $5'$ N, 89^0 0' E and 9.75 m.s.l.) of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India during *kharif* (wet) season of 2008 and 2009. Seven indigenous scented rice cultivars (*viz.* Gobindabhog, Badshabhog, Mohanbhog, Radhunipagal, Kalojira, Chinikamini and Khasdhan) were transplanted in 4 m × 3 m plots with a spacing of 15 cm × 15 cm in a randomized block design (RBD) with 3 replications. A uniform fertilizer dose consisting of FYM @ 5 t ha^{-1} as basal and mustard cake @ 0.25 and 0.25 t ha^{-1} were applied to all experimental plots at 3 and 6 weeks after transplanting.

A total of eight phenophases (*viz.* P_1 = sowing to emergence, P_2 = emergence to 4^{th} leaf emergence, P_3 = 4^{th} leaf emergence to active tillering, P_4= active tillering to panicle initiation, P_5= panicle initiation to 50% flowering, P_6= 50% flowering to milk, P_7= milk to dough and P_8= dough to maturity) were studied by visiting the field at every 2-3 days intervals. Daily weather data was collected from Agromet Observatory of AICRP on Agrometeorology, B.C.K.V. Centre, Kalyani, Nadia and thermal indices were calculated by the following formulae.

Growing degree days (GDD) = [(Tmax. + Tmin.) / 2] - 10 ^{0}C

Heliothermal units (HTU) = GDD* Bright sunshine hour

Photothermal units (PTU) = GDD* Day length

The correlation studies between thermal indices and yield associated characters were made and yield prediction models were developed for scented rice in the investigation.

Results and Discussion

Phenology

Among seven aromatic rice landraces, number of days to maturity pooled over two years varied between 140.0 days (Kalojira) and 148.3 days (Radhunipagal) (Table 1). So, all the cultivars in the study were long-duration types and the differences in growth duration were mainly due to variation in length of vegetative phase from 69.5 to 78.0 days. The finding was in conformity with the opinion of Oldeman *et al.,* (1987). Mean cultivar days from sowing to emergence, 4^{th} leaf emergence, active tillering, panicle initiation, 50% flowering, milk, dough and maturity stages were 3.9, 21.4, 47.1, 73.6, 111.3, 122.5, 133.6, 122.5, 133.6 and 144.6 days, respectively.

Kalojira was the earliest cultivar (68.0 and 71.0 days) to complete the vegetative stage in both the years of experimentation; while Badshabhog and Radhunipagal required minimum days (37.0 days) for reproductive stage during 2008 and 2009, respectively and

Gobindabhog completed the ripening stage in lowest number of days (32.0 and 30.3 days) during both the years of investigation (data not shown).

Thermal indices

Mean air temperature and bright sunshine hours at eight phenophases were: 30.8^{0}C and 4.0 hours (sowing to emergence), 29.3^{0}C and 3.2 hours (emergence to 4th leaf emergence), 29.9^{0}C and 4.6 hours (4th leaf emergence to active tillering), 29.5^{0}C and 5.0 hours (active tillering to panicle initiation), 29.4^{0}C and 6.1 hours (panicle initiation to 50% flowering), 26.5^{0}C and 7.7 hours (50% flowering to milk), 25.9^{0}C and 9.1 hours (milk to dough) and 25.4^{0}C and 8.0 hours (dough to maturity).

The meteorological parameters indicated that mean air temperature was near-plateau stage both during vegetative and reproductive phases, which declined in ripening phase. On the other hand, bright sunshine hours per day were less in vegetative stage mainly due to cloudy weather during south-west monsoon season, which increased progressively during reproductive and ripening stages of rice crop.

Mean growing degree days, heliothermal units and photohermal units were 1449±83, 6473±453 and 18439±999 during vegetative stage, 729±10, 4465±223 and 8679±167 during reproductive stage and 530±23, 4389±254 and 6035±255 during ripening stage, respectively (Table 2). The accumulated GDD and HTU from emergence to maturity of seven long-duration aromatic rice cultivars were 2708 and 15327, respectively in the study; which were somewhat greater than 2102 and 12031 in a medium duration variety *cv.* Polasa Prabha in Hyderabad, Andhra Pradesh (Sreenivas *et al.*, 2010). The summed growing degree days for entire life cycle varied between 2628 (Kalojira) and 2759 (Radhunipagal), which could be supported by the fact that lengthening in growth duration (140.0 *vs.* 148.3 days) generally resulted in higher amount of accumulated heat. Similar findings on summed GDD for entire growth duration of scented rice cultivars were reported by Ghosh *et al.*, (2005).

Table.1 Effect of cultivars on phenological development of indigenous aromatic rice during *kharif* season (pooled over two years)

Cultivar	Vegetative				Repro ductive	Ripening			Life cycle
	S-E	E-4LE	4LE-AT	AT-PI	PI-F	F-Mi	Mi-D	D-M	S-M
Gobindabhog	3.5	7.5	25.0	26.5	37.8	10.5	10.5	10.2	141.5
Badshabhog	3.8	18.2	26.0	25.0	37.5	11.5	11.5	11.0	144.5
Mohanbhog	4.0	17.5	26.2	27.5	37.7	11.2	11.0	11.2	146.3
Radhunipagal	4.5	17.0	25.8	30.7	37.2	11.0	11.2	11.0	148.4
Kalojira	3.2	17.3	25.5	23.5	38.0	11.0	10.8	10.7	140.0
Chinikamini	4.0	18.0	26.0	27.8	37.8	11.2	11.2	11.3	147.3
Khasdhan	4.0	18.0	25.5	24.8	38.0	11.2	11.8	11.2	144.5
Mean	3.9	17.6	25.7	26.5	37.7	11.1	11.1	10.9	144.6
S.Em.(±)	0.42	0.42	0.40	2.39	0.13	0.13	0.15	0.14	0.34
CD at 5%	1.24	1.24	NS	6.96	0.39	0.39	0.45	0.42	0.95

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 50% flowering,
F-Mi = 50% flowering to milk, Mi-D = milk to dough and D-M = dough to maturity and
S-M = sowing to maturity

Table.2 Accumulated thermal indices at growth stages of indigenous aromatic rice (Pooled over two years)

Cultivar	Vegetative stage	Reproductive stage	Ripening Stage	Life cycle
Growing degree days (GDD)				
Gobindabhog	1424	734	509	**2667**
Badshabhog	1436	724	554	**2714**
Mohanbhog	1476	726	528	**2730**
Radhunipagal	1530	718	511	**2759**
Kalojira	1365	738	525	**2628**
Chinikamini	1488	729	526	**2743**
Khasdhan	1423	734	554	**2711**
Mean	1449	729	530	**2708**
Heliothermal units (HTU)				
Gobindabhog	6327	4435	4278	**15040**
Badshabhog	6502	4271	4627	**15400**
Mohanbhog	6616	4565	4298	**15479**
Radhunipagal	6842	4717	4119	**15678**
Kalojira	5936	4275	4538	**14749**
Chni Kamini	6658	4669	4241	**15568**
Khasdhan	6427	4326	4624	**15377**
Mean	6473	4465	4389	**15327**
Photothermal units (PTU)				
Gobindabhog	18134	8741	5800	**32675**
Badshabhog	18282	8625	6310	**33217**
Mohanbhog	18768	8644	5991	**33403**
Radhunipagal	19421	8493	5826	**33740**
Kalojira	17424	8827	6069	**32320**
Chinikamini	18922	8673	5961	**33556**
Khasdhan	18125	8750	6291	**33166**
Mean	**18439**	**8679**	**6035**	**33153**

Table.3 Correlations between GDD and HTU at different growth stages and yield associated parameters of indigenous aromatic rice

Thermal indices at phenophases	Panicle length	No. of panicles m^{-2}	No. of filled grains $panicle^{-1}$	1000 grain weight	Grain yield
Growing degree days (GDD)					
AT - PI	-0.106	0.348*	0.159	-0.186	**-0.270**
PI - F	0.166	-0.288	0.034	0.012	**0.141**
F - Mi	0.069	-0.532**	0.101	-0.119	**-0.116**
Mi - D	-0.492**	-0.020	-0.599**	-0.141	**-0.395****
D - M	-0.072	-0.330*	0.010	-0.218	**-0.309***
Heliothermal units (HTU)					
AT - PI	-0.339*	0.453**	-0.303	0.115	**-0.020**
PI - F	-0.099	0.581**	-0.118	0.229	**-0.089**
F - Mi	0.149	-0.390	0.235	-0.213	**-0.181**
Mi - D	-0.245	-0.024	-0.436**	0.031	**0.087**
D - M	**0.0474****	**0.071**	**0.138**	**0.386***	**0.333***

Sample size; n = 42

r value = 0.304* and 0.393** at 5% and 1% level of significance, respectively

Table.4 Multiple regression equations for prediction of yield associated characteristics and yield of aromatic rice

Parameter	Equation	R^2
Panicle length	$Y = 31.08 – 0.048\ GDD_{Mi-D}** + 0.0014\ HTU_{D-M}**$	0.46**
No. of panicles m^{-2}	$Y = 499.89 + 0.05\ HTU_{PI-F}** – 0.59\ GDD_{PI-F}*$	0.41*
No. of filled grains $panicle^{-1}$	$Y = 224.05 – 0.66\ GDD_{Mi-D}**$	0.36**
1000 grain weight	$Y = 10.08 + 0.0004\ HTU_{D-M}*$	0.15*
Grain yield	$Y = 3.93 – 0.0138\ GDD_{Mi-D}** – 0.000724\ HTU_{Mi-D}*$	0.34**
Straw yield	$Y = 1.14 + 0.00087\ HTU_{PI-F}**$	0.41**

GDD_{PI-F} = GDD (panicle initiationto 50% flowering); GDD_{Mi-D} = GDD (milk to dough)
HTU_{PI-F} = HTU (panicle initiation to 50% flowering); HTU_{Mi-D} = HTU (milk to dough); HTU_{D-M} = HTU (dough to maturity)

The summed GDD and PTU for all seven cultivars were slightly higher during 2009 than 2008 mainly due to longer vegetative phase accompanied with greater air temperature and photoperiod during the period; while summed HTU was greater in earlier year due to more sunshine hours during vegetative phase than the later year of study. Based on accumulated GDD, HTU and PTU for entire life cycle, the cultivars could be arranged as: Radhunipagal > Chinikamini > Mohanbhog > Badshabhog > Khasdhan > Gobindabhog > Kalojira.

Correlations and yield prediction models

The correlation studies revealed that GDD influenced tiller production positively (r = 0.348*) during active tillering to panicle initiation stage, which ultimately led to greater number of panicles m^{-2} at maturity (Table 3). But HTU during both tiller production and panicle determination stages (i.e. active tillering to panicle initiation and panicle initiation to 50% flowering) had positive influence ($P < 0.01$) on number of panicles m^{-2} Mean bright sunshine hours during milk to dough (9.56 *vs.* 8.58 hours) and dough to maturity (8.67 *vs.* 7.15 hours) were higher in 2008 than 2009, which resulted in better grain filling and development during earlier than later year of investigation. Accordingly, HTU during dough to maturity stage had positive influence (r = 0.386*) on 1000 grain weight. Grain yield was negatively correlated with GDD at milk to dough and dough to maturity stage, while positively correlated with HTU during dough to maturity stage in the study. The regression model for grain yield (Y= 3.93 – 0.0138 GDDM-D** – 0.000724 HTUM-D*) showed associations with GDD and HTU both during milk to dough stage and accounted for 34 % variation at 1 % level of significance (Table 4). Mandal and Ghosh (2003) reported similar yield prediction models for hybrid rice in West Bengal.

Aromatic rice landraces of West Bengal were long-duration types (>140 days) and they required mean GDD, HTU and PTU of 2708, 15327 and 33153 for entire life cycle, respectively.

GDD and HTU at tiller production stage had positive influence on number of panicle m^{-2}, while HTU at ripening stage showed positive impact on grain filling and development leading to higher grain yield.

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