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Influence of Sowing Windows on Phenology, Growing Degree Days and Yield Traits of Rice Genotypes

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An investigation was carried out during *Kharif* season of 2014-15 at Department of Rice, Tamil Nadu Agricultural University, Coimbatore-3 to study the influence of sowing dates on phenology and yield traits of some rice genotypes. Among the three sowing dates (9th June, 23rd June and 7th July) and twelve rice genotypes were used in this study revealed that, rice genotypes sown on 9th June and the long duration rice genotype (CB-05-022) consumed more number of days to reach different growth stages *viz.,* active tillering, panicle initiation, 50 per cent flowering and physiological maturity stages 42, 87, 126, 141 days where it took longer vegetative growth duration to produce more productive tillers and provided higher grain yield. The GDD (Growing Degree Day) was accumulated more in rice genotypes sown on June 9th at active tillering, panicle initiation, 50 per cent flowering and physiological maturity stages where it can efficiently utilize the available natural resources for its growth and development. The maximum grain yield of 9764 kg ha^{-1} was registered by the genotype CB-05-022 sown on 9th June with an increase of 16.4 per cent over other sowing dates. To conclude, sowing date (9th June) favoured better growth and yield in rice genotypes and the long duration genotype, (CB-05-022) showed desired phenological characters which utilize heat units efficiently under favourable environment to provide better yield than other genotypes used.

Key Words: Rice, Phenology, Growing degree days, Yield

Rice (*Oryza sativa* L.) is the most important cereal food crop in the world. During the past decades, rice yield has been significantly improved due to the development of new cultivars, but still there is a desperate need to enhance rice production as the estimated number of new rice consumers will increase to 1.2 million by 2020 (Babar *et al*., 2007). Climate varies from one region to another region, which affects the crop development and yield of rice. A strategy is there to maintain the optimum yield of rice under changing climate, which is a cause of yield reduction in rice is adjusting sowing dates. Adjusting phenological properties of rice cultivars according to environment and changing climate will takes place when they tend to face different date of sowing for maintaining optimum yield. The optimum sowing time and selection of improved cultivars plays a key role in exploiting their yield potential of the crop under particular agro climatic condition. Knowledge about length of total growing season and relative duration of vital phenophases is important as both are critical determinants of final grain yield of crop (Kantolic and Slafer, 2005). Temperature plays a key role in determining the sowing time and consequently the duration of different phenophases to influence crop productivity (Tewari and Singh, 1995). GDD can also be used to assess the suitability of a region for production of a particular crop and to estimate the growth stages and heat stress on crop. Thus, awareness of correct timing of phenological events and their connection with yield determinants is pre-requisite to boost up rice productivity (Gbmez-Macpherson and Richards, 1997). So, there is a need to identify such rice genotypes which can provide optimum yield under diverse climatic conditions. The duration of each phenophases determines the accumulation and partitioning of dry matter in different organs (Dalton, 1967). Hence, studies were conducted to know the influence of sowing windows on phenology and yield traits of rice genotypes with GDD.

Materials and Methods

The experiment was carried out in the research field of Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore during *Kharif* 2014-15. The experiment was laid out in split-plot design with three replications. Twelve genotypes *viz.,* IET 20924 (G_1), IET 22569 (G_2), IET 22580 (G_3), IET 23275 (G_4), IET 23299 (G_5), IET 23324 (G_6), MTU 1010 (G_7), CB-08-504 (G_8), CB-08-513 (G_9), CB-06-123 (G_{10}), CB-05-022 (G_{11}), and CO51 (G_{12}) were allocated in the sub-plots and three sowing dates *viz.,* 9th June (D_1), 23rd June (D_2) and 7th July (D_3) in the main-plots. The net plot size was 8 m^2 and the spacing between plants and rows was 20×20 cm. Nitrogen, phosphorus and potassium was

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*Corresponding author's email : ravilux@rediffmail.com applied at the rate of 150-50-50 kg ha^{-1} respectively. All other cultural practices were followed as per the crop production guide (TNAU CPG, 2012). The date when occurrence of different phenological events *viz.,* active tillering, panicle initiation, 50 per cent flowering and physiological maturity were recorded when 50% of the plants in each replication and treatment reached the respective stages. The agro climatic indice namely, heat unit or GDD were determined as per Nuttonson, (1955). GDD has been expressed in °C day.

$$GDD = \frac{\Sigma \ Tmax + Tmin}{2} \ - \text{Base temperature}$$

where,

T_{max} - Daily maximum temperature (°C)

T_{min} - Daily minimum temperature (°C)

Base temperature of rice is 10° C

For assessing the relationship between yield and its components were recorded as suggested by Yoshida (1972). Meteorological data *viz.,* rainfall, relative humidity, maximum and minimum temperature, bright sun shine hours and day length prevailed during the entire cropping period were recorded from Davis Vantage Pro2 wireless weather station Tamil Nadu Agricultural University, Coimbatore. The data collected were subjected to statistical analysis in split plot design as per Gomez and Gomez (1984).

Results and Discussion

Phenological traits

Phenological properties of a plant are measured in time duration between distinct critical changes in its life cycle. Phenological properties of rice cultivars determine their yield potential, local agronomic suitability and ability to escape from drought and natural calamities (Bagchi *et al.*, 1995). In the present study, variation in the length of different phases and stages in the life cycle of twelve rice genotypes under different sowing windows were assessed and

Table 1. Effect of sowing windows on different phenological stages of rice genotypes (2014-15)

Treatments	AT	PI	50 % F	PM	Treatments	AT	PI	50 % F	PM
Sowing dates					D_1G_1	41.0	80.0	106.0	136.0
D_1-June 6	36.0	74.0	98.5	130.0	D_1G_2	40.0	79.0	106.0	135.0
D_2- June 23	35.3	72.4	97.4	128.0	D_1G_3	39.0	78.0	100.0	134.0
D_3-July 7	35.2	70.1	96.3	125.0	D_1G_4	35.0	76.0	102.0	139.0
Mean	35.5	72.5	97.4	127.6	D_1G_5	34.0	78.0	97.0	122.0
SEd	0.050	0.063	0.010	0.020	D_1G_6	33.0	69.0	91.0	124.0
CD (P=0.05)	0.140	0.173	0.027	0.055	D_1G_7	33.0	60.0	83.0	115.0
Genotypes					D_1G_8	34.0	65.0	91.0	128.0
G_1 - IET 20924	38.0	75.3	99.3	130.0	D_1G_9	33.0	68.0	91.0	122.0
G_2 - IET 22569	35.3	74.7	98.7	129.7	D_1G_{10}	38.0	83.0	100.0	138.0
G_3 - IET 22580	36.0	72.7	97.3	129.3	D_1G_{11}	42.0	87.0	118.0	141.0
G_4 - IET 23275	35.7	73.3	100.7	133.7	D_1G_{12}	30.0	60.0	85.0	115.0
G_5 - IET 23299	34.3	77.3	93.3	123.7	D_2G_1	37.0	74.0	96.0	129.0
G_6 - IET 23324	34.0	70.3	96.0	126.3	D_2G_2	32.0	72.0	97.0	128.0
G_7 - MTU 1010	34.3	66.0	88.0	120.7	D_2G_3	33.0	72.0	95.0	128.0
G_8 - CB-08-504	34.3	71.0	95.7	129.0	D_2G_4	35.0	72.0	97.0	130.0
G_9 - CB-08-513	33.7	71.7	93.0	124.0	D_2G_5	33.0	81.0	94.0	122.0
G_{10} - CB-06-123	40.0	78.3	105.3	136.0	D_2G_6	36.0	71.0	98.0	126.0
G_{11}- CB-05-022	40.0	81.3	113.7	138.0	D_2G_7	35.0	66.0	93.0	121.0
G_{12}- CO51	30.3	58.0	88.0	115.0	D_2G_8	35.0	72.0	100.0	130.0
Mean	35.5	72.5	97.4	127.6	D_2G_9	34.0	73.0	91.0	125.0
SEd	0.213	0.466	0.535	0.494	D_2G_{10}	41.0	79.0	105.0	139.0
CD (=0.05)	0.426	0.929	1.067	0.986	D_2G_{11}	40.0	79.0	113.0	138.0
					D_2G_{12}	31.0	58.0	90.0	120.0
					D_3G_1	36.0	72.0	96.0	125.0
					D_3G_2	34.0	73.0	93.0	126.0
					D_3G_3	36.0	68.0	97.0	126.0
					D_3G_4	37.0	72.0	103.0	132.0
					D_3G_5	36.0	73.0	89.0	127.0
					D_3G_6	33.0	71.0	99.0	129.0
					D_3G_7	35.0	72.0	88.0	126.0
					D_3G_8	34.0	76.0	96.0	129.0
					D_3G_9	34.0	74.0	97.0	125.0
					D_3G_{10}	41.0	73.0	111.0	130.0
					D_3G_{11}	38.0	78.0	110.0	132.0
					D_3G_{12}	30.0	56.0	89.0	110.0
					Mean	35.5	72.5	97.4	127.6
					D x G SEd	0.357	0.775	0.886	0.819
					CD (=0.05)	0. 719	1.550	1.770	1.636
					G x D SEd	0.369	0.806	0.926	0.855
					CD (=0.05)	0.737	1.610	1.848	1.708

AT – Active Tillering PI – Panicle Initiation 50% F – 50 per cent FloweringPM – Physiological Maturity the data presented in Table 1. Duration required for attaining active tillering stage varied from 30-42 days. Treatment D_1G_{11} (June 9th sowing + CB-05-022) required the longest period (42 days) to attain active tillering stage followed by D_1G_1 (June 9th sowing + IET 20924) (41 days) and these two genotypes are long duration genotypes which require the longest duration of vegetative phase. In D_3G_{12} (July 7th sowing + CO 51) a short duration genotype requires 30 days to attain active tillering stage, which showed shortest duration of vegetative phase.

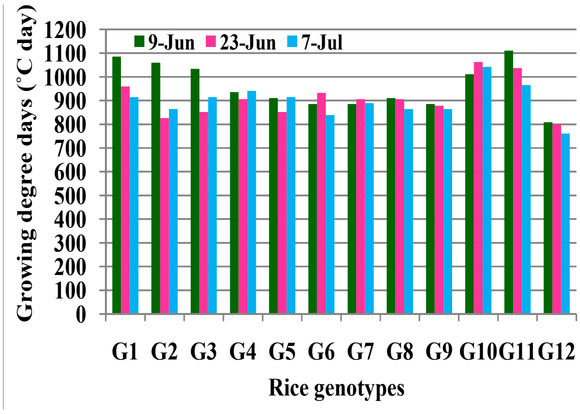

Fig.1. Effect of sowing windows on GDD (°C day) of rice genotypes at Active tillering stage of rice genotypes

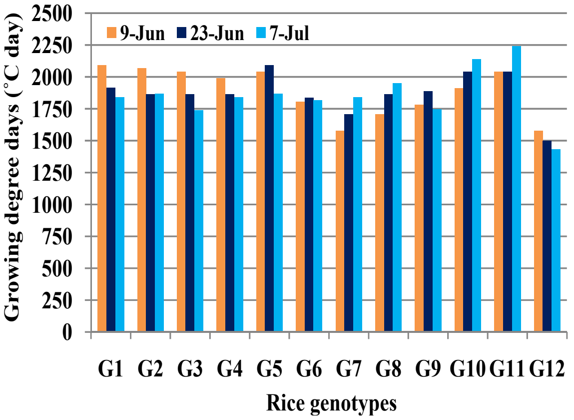

Fig.2. Effect of sowing windows on GDD (°C day) at Panicle initiation stage of rice genotypes

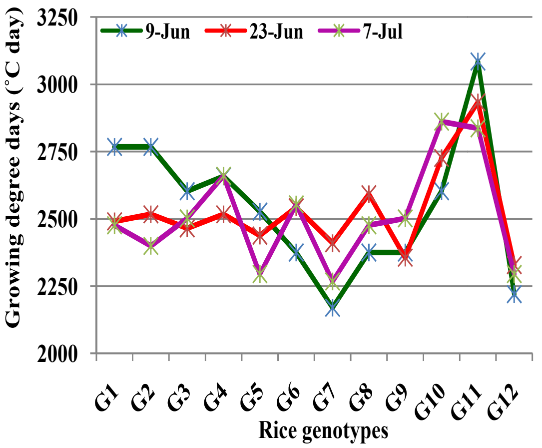

Fig.3. Effect of sowing windows on GDD (°C day) at 50% flowering stage of rice genotypes

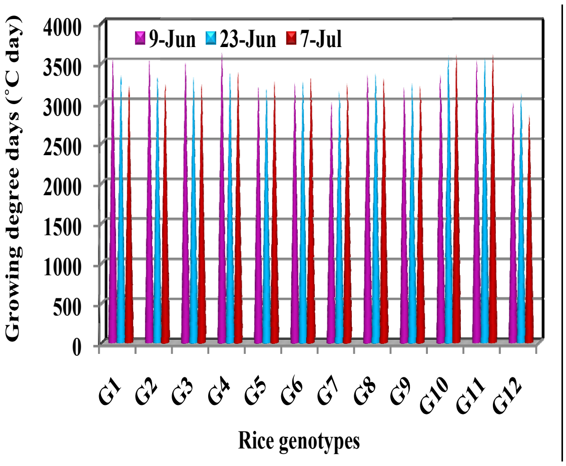

Fig.4. Effect of sowing windows on GDD (°C day) at Physiological maturity stage of rice genotypes

Flowering duration is an important character that is frequently considered before release of a variety for commercial cultivation. In current study, the time interval between sowing to 50 per cent flowering stage of the rice genotypes ranges from 85-118 days (Table 1). The flower transition of crops depends mainly on the accurate measurement changes in the day length and temperature, which is regulated by both endogenous genes and environmental factors. In our study D_1 (9th June) sowing and the genotype CB-05-022 required 118 days to reach 50 per cent flowering stage which the duration was shortened consequently under delayed sowing (23rd June and 7th July) of the same rice genotypes proofed that there was an effect of different sowing windows and environmental conditions on crops. The same treatment required 106 days to attain 50 per cent flowering stage was obtained in late sowing 7th July clearly exhibit the influence of environment and sowing date on rice genotypes. The increased flowering duration in early sowing June 9th was due to optimum temperature and solar radiation which prisoner flowering process. These findings are also in line with report of De Datta (1981). For physiological maturity stage the treatment, D_1G_{11} (9th June sowing + CB-05-022) required 126, 141 days when sown on 9th June but this duration was reduced with delayed sowing i.e. under late sowing 7th July and it requires 110, 135 days for physiological maturity stage (Table. 1). This reduction in duration of rice genotypes under late sown 7th July exhibits that the crop was affected by unfavourable environmental conditions like high temperature, rainfall during flowering phase, cloudy weather, changes in temperature above or below

Table 2. Effect of sowing dates on yield and yield components of rice genotypes (2014-15)

Treatments	No. of productive tillers plant^{-1}	No. of grains panicle^{-1}	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index
Sowing dates					
D_1- June 9	20	166	8126.7	14483.3	40.98
D_2- June 23	18	154	7675.8	11850.0	37.87
D_3- July 7	16	139	6412.5	11225.8	33.34
Mean	18	153	7405	12519.7	37.40
SEd	0.1859	1.5636	101.57	197.633	0.4392
CD (P=0.05)	0.5163	4.3414	282.02	548.728	1.2195
Genotypes					
G_1 - IET 20924	20	128	7323.3	13630.0	34.85
G_2 - IET 22569	17	172	6690.0	12410.0	41.99
G_3 - IET 22580	18	129	8406.6	14010.0	37.27
G_4 - IET 23275	19	105	7886.6	11840.0	40.05
G_5 - IET 23299	18	145	6410.0	12640.0	35.84
G_6 - IET 23324	18	127	6873.3	12330.0	35.11
G_7 - MTU 1010	16	126	8076.6	12426.6	38.91
G_8 - CB-08-504	17	233	7936.6	10190.0	44.01
G_9 - CB-08-513	19	194	7166.6	17066.6	32.68
G_{10} - CB-06-123	22	175	5900.0	13353.3	30.82
G_{11}- CB-05-022	24	244	8696.0	10256.6	45.01
G_{12}- CO51	18	157	7910.0	10083.3	44.01
Mean	18	153	7404.9	12519.7	37.40
SEd	0.090	2.410	75.783	137.616	0.335
CD (=0.05)	0.179	4.813	151.31	274.762	0.670

	No. of productive tillers plant^{-1}	No. of grains panicle^{-1}	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index
D_1G_1	22	146	8400.0	14280.0	37.91
D_1G_2	19	191	9490.0	17150.0	45.90
D_1G_3	20	141	9650.0	16140.0	42.14
D_1G_4	20	116	8400.0	13350.0	42.65
D_1G_5	19	152	6400.0	14770.0	37.21
D_1G_6	19	131	8340.0	13480.0	41.41
D_1G_7	18	139	7760.0	14430.0	43.83
D_1G_8	18	251	8330.0	12140.0	44.31
D_1G_9	21	191	7610.0	19550.0	31.77
D_1G_{10}	21	200	6300.0	15250.0	32.84
D_1G_{11}	23	280	9764.0	12240.0	48.37
D_1G_{12}	20	168	8280.0	11020.0	45.45
D_2G_1	19	125	7630.0	13760.0	37.26
D_2G_2	17	173	8910.0	10390.0	42.47
D_2G_3	17	136	9380.0	13010.0	37.42
D_2G_4	19	106	8010.0	11400.0	38.87
D_2G_5	18	148	6080.0	11760.0	34.08
D_2G_6	18	128	8120.0	12020.0	38.22
D_2G_7	16	127	7020.0	11560.0	40.35
D_2G_8	16	194	7900.0	9630.0	44.04
D_2G_9	19	204	7200.0	16190.0	29.24
D_2G_{10}	19	164	5790.0	12970.0	30.39
D_2G_{11}	16	153	8280.0	9630.0	38.39
D_2G_{12}	19	154	7790.0	9880.0	43.67
D_3G_1	18	112	5940.0	12850.0	29.38
D_3G_2	17	152	7670.0	9690.0	35.62
D_3G_3	16	110	6190.0	12880.0	32.24
D_3G_4	15	94	7250.0	10770.0	38.62
D_3G_5	18	136	6750.0	11390.0	30.23
D_3G_6	15	122	4160.0	11490.0	29.71
D_3G_7	14	112	5450.0	11290.0	32.56
D_3G_8	17	135	7580.0	8800.0	40.69
D_3G_9	18	186	6690.0	15460.0	28.02
D_3G_{10}	16	160	5610.0	11840.0	29.23
D_3G_{11}	14	130	6000.0	8900.0	34.89
D_3G_{12}	15	148	7660.0	9350.0	42.90
Mean	18	153	7405	12519.7	37.40
D x G SEd	0.238	4.293	161.588	301.893	0.709
CD (=0.05)	0.589	9.015	372.422	703.651	1.627
G x D SEd	0.156	4.175	131.260	238.35	0.581
CD (=0.05)	0.312	8.337	262.071	475.903	1.160

the optimum temperature at reproductive stage led to forced maturity and reduction in final yield (Sial *et al.*, 2005).

Physiological maturity is the final and cumulative result of all phenological responses. It determines the success of crop harvest by farmers in a vulnerable environmental situation. The crop harvest was started with G_{12} - CO 51 at 115 days after sowing (DAS) and ended at 145 (DAS) for G_{11} (CB-05-022). G_{11} (CB-05-022) required 145 days to complete its life cycle followed by G_{10} (CB-06-123), which requires 136 days. The shortest lifespan was spent by G_{12} (CO 51) and G_7 (MTU 1010) (115 days). All phenological characters were found to vary in a wide range depending on rice genotypes as well as micro and macro environments. Similar results were in line with the findings of Zhang *et al*. (2013) showed an average shortening of rice growth duration of 4.1–4.4 days for each additional increase in temperature over the full growth cycle of rice.

Grain yield and yield components

Among the yield components, productive tillers are very important and it is a main function of number of panicle bearing tillers per unit area. In our study, productive tillers plant^{-1} were significantly more in 9th June sown crop by 39.1 per cent than late sown 7th July respectively (Table 2). The higher and total productive tillers plant^{-1} in 9th June sown crop might be due to availability of more time for the growth period with optimum photoperiod as well as optimum temperature for the growth of crop plant which may result in more nitrogen absorption by the roots for the synthesis of protoplasm responsible for rapid cell division which may increase plant shape and size, ultimately the production of tillers may be more. The findings have also been supported by the evidence of Pandey *et al*. (2010) and Nayak *et al*. (2003) also reported significant reduction in total tillers production with delay in sowing. However, rice genotypes sown on 9th June switched into tillering earlier due to prevailing low temperature causes enhanced tiller production, while high temperature favours main stem growth and therefore tillering starts normally late. Therefore, early sown crop enjoyed more time with suitable temperature for tillering and ultimately exhibited high tillering capacity (Shahzad *et al*., 2002). Long duration genotypes G_{11} (CB-05-022), G_{10} (CB-06-123) and G_1 (IET 20924) had been recorded higher grain yield (Fig.5) due to their high tillering capacity whereas short duration genotypes G_{12} (CO 51), G_7 (MTU 1010) performed poor due to its low tillering capacity. Rice genotypes sown on 9th June utilized maximum GDD owing to longer growing duration. The mother reason in the wake of this entire story is of varying temperature at different growth stages of twelve rice genotypes. Similar results were also obtained by Sial *et al*., (2005).

In this study, the rice genotypes sown on 9th June provided the highest value on number of grains panicle^{-1} (166), grain yield (8127 kg ha^{-1}), straw yield (14483 kg ha^{-1}) was due to optimum photoperiod availed during their growth and development (Table 2). While rice genotypes sown on 7th July provided the lowest value on yield and yield components. The long duration rice genotypes, CB-05-022, CB-06-123 and IET 20924 surpassed other varieties under study on phenological and yield attributes while the short duration genotype CO 51 and MTU 1010 recorded the lowest on yield and yield related parameters due to shortening of the growth period, reduced photosynthetic process and finally reduction in number of grains panicle^{-1}. These results are in agreement with the findings of Singh and Prasad (1999) and Pirdashry *et al*. (2000).

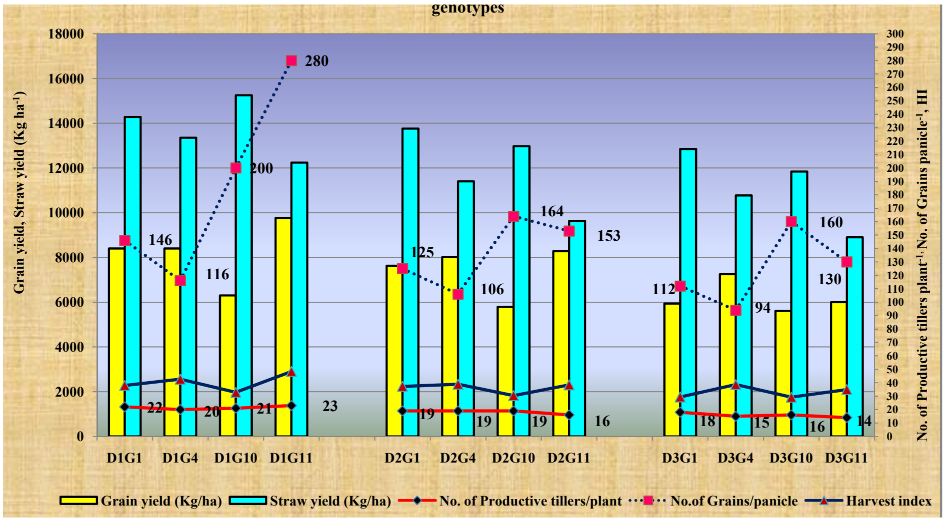

Fig.5. Effect of sowing windows on yield and yield components of best performed long duration rice genotypes

Growing Degree Days

Growing degree days (GDD) is a way of assigning a heat value to each day. Heat units or GDD are involved in several physiological processes like specific amount of heat units required for the plant at each growth stage from its germination to harvest of the crop would vary and it is an important process for growth and development, growth parameters, metabolism, biomass, physiological maturity and yield. In case of our study, maximum GDD was accumulated when the rice genotypes sown on 9th June than 23rd June and 7th July for all the crop growth stages *viz.,* active tillering stage, panicle initiation, 50 per cent flowering, and physiological maturity (Fig.1, 2, 3 and 4). The GDD accumulated by the rice genotypes sown on 23rd June and 7th July were lower by 9.6% and 2.1% respectively than 9th June sowing. Accumulation of GDD used to estimate the expected time of flowering. The deficit GDD at the time of flowering leads to early flowering. The excess GDD accumulation at flowering causes delayed flowering. In rice where the temperature drops from 24°C to 21°C a sharp decrease in days to flowering occur. A temperature drop by 1°C leads to 13 days delay in heading. When the temperature increases above 24°C, days to flowering decrease to 91 days at 27°C and to 86 days at 30°C. Temperature rises of 1°C above 24°C shorten the number of days to flowering by less than 2 days (Parthasarathi *et al*., 2013).

The rice genotypes sown on 9th June accumulated more GDD as compared to late sowing 7th July particularly in the case of CB-05-022 and the difference between maximum and minimum value was 343°C day was observed at physiological maturity. This describes clearly the effect of temperature on phenological stage is more important. These results indicated that, the variation in temperature prevailed under different dates of sowing. Both the maximum and minimum temperature varied widely in three sowing dates of investigation. This led to the variation in GDD requirement in different sowing windows. The difference in GDD values obtained in different sowing windows might be attributed to the difference in the minimum and maximum temperature observed during cropping period. Every crop needs a specific amount of GDD to enter its reproductive phase from vegetative phase. On the other hand in case of CO 51 the difference between the GDD accumulated was smaller among the dates of sowing and it was recorded as 167°C day. Early sowing 9th June crop resulted in absorbing sufficient GDD in relatively more time because of the long duration for each growth phases. While in 7th July sown crop experienced higher temperature during later growth stages in less time. These results were also confirmed by Pandey *et al*., (2010) who reported the lower GDD consumption under delayed sowing. The genotype CB-05-022 took longer time to attain the various phenological phases and utilized sufficient GDD led to provide higher grain yield and biomass. Present results were matched with the findings of Alam *et al*. (2004).

Conclusion

Based on the above findings, it is concluded that, rice genotypes sown on 9th June provided the best results of phenological heat unit and yield traits with efficient utilization of optimum natural resources, which could mitigate the detrimental effects of temperature fluctuations. Genotypes with longer crop duration *viz.,* CB-05-022, CB-06-123, IET 20924 and IET 23275 are suitable for optimum yield under changing climatic condition. Additionally, these long duration genotypes accumulate higher photothermal indices for their growth and development leads to accumulate more biomass and yield.

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