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AGROMETEOROLOGICAL INDICES OF RICE CULTIVARS UNDER DIFFERENT ENVIRONMENT AT NAVSARI (GUJARAT), INDIA

B. M. Mote*, Neeraj Kumar and Y. G. Ban[1]

Agricultural Meteorological Cell, Department of Agriculutral Engineering, N.A.U., Navsari - 396 450 (Gujarat), India.
[1]Department of Genetic and Plant Breeding, N.A.U., Navsari - 396 450 (Gujarat), India.

Abstract

Field experiment was conducted during *kharif* season of 2012 at College Farm of N. M. College of Agriculture, Navsari Agricultural University, Navsari (Gujarat), India; to study the agrometeorological indices of rice cultivars. The treatment consisted of three cultivars *viz*., V_1 (Jaya), V_2 (Gurjari) and V_3 (GNR-2) with three dates of sowing *viz*., D_1 (12 July 2012), D_2 (27 July 2012) and D_3 (11 August 2012). The agrometeorological indices *viz*., photothermal units (PTU), heliothermal units (HTU), photothermal index (PTI), energy degree unit (EDU) were work out for different phonological stages of the rice cultivars under different environment. Results revealed that the first date of sowing in cv. Jaya from emergence to physiological maturity significantly higher value of total (PTU ^oC day hr), (HTU ^oC day hr), PTI(^oC day hr) and (EDU leangle day^{-1}) were observed *i.e.* 33311.3^oC day hr, 129990.7^oC day hr, 111.2^oC day hr and 95060868 leangle day^{-1} followed by second date of sowing 31244.6^oC day hr, 12138.6^oC day hr, 108.5^oC day hr and 86902882 leangle day^{-1} and third date of sowing 28814^oC day hr, 11784.8^oC day hr, 103.0^oC day hr and 80999804 leangle day^{-1}. Similar trend was observed in cv. Gurjari and cv. GNR-2. Progressive delay in sowing caused decrease PTU, HTU, PTI and EDU.

Key words : PTU, HTU, PTI, EDU, phenophases, rice cultivars, dates of sowing.

Introduction

Rice is the important crop in the world. It is the staple food for more than 65 per cent of the people and it provides employment and livelihood security to 70 per cent of Indian population. India grows rice in highly diverse conditions starting from below sea levels to hill as high as > 2000 meters (Rami *et al*., 2010). Weather variability is considered one of the major factors of inter-annual variability of crop growth and yield in all environments besides rainfall, temperature and bright sun shine hours also have been bearing on crop growth and development as well as yield response of different species to different environments, can be quite different. The heat unit concept assumes that a direct and linear relationship between growth and temperature is advantageous for the assessment of yield potential of a crop in different weather conditions (Kumar *et al*., 2014). Alteration of sowing dates a directly influences growth and development of crops. Crop growth refers to an increase in crop weight, height, volume or area over a certain time scale. Development refers to the timing or progress of the crop from one phasic stage of next (Gudadhe *et al*., 2013). Quantification of these effects may help in the choice of sowing time and match phenology of crop in specific environment to achieve higher heat and radiation use efficiency. The average temperature required throughout the life period of the rice crop ranges from 21^{0}C to 37^{0}C. At the time of tillering, the crop requires high temperature for growth. The temperature requirement in reproductive stage is in the range of 26.5^{0}C to 29.5^{0}C while at the time of ripening the temperature should be in between 20^{0}C to 25^{0}C (De Datta, 1981). The occurrence of different phenological events during a growing season of crop and the effect of temperature on plant growth can be explained using accrued heat units (Sunil and Sharma, 2005).

***Author for correspondence:** Email: amarmote4141@gmail.com

Materials and Methods

The field experiment was conducted on College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari (Gujarat), India; during *Kharif* season of the year 2012. The Navsari Agricultural University campus is geographically located at 20° 57' N latitude and 72° 54' E longitude at an altitude of 10 m above the mean sea level. The different phonological stages like seedling emergence, tillering, panicle initiation, flowering,

grain filling and physiological maturity of rice cultivars were recorded by visiting the field frequently from sowing to harvesting. In the seed bed, emergence was recorded. After sowing, 5 plants were tagged with aluminium sheet in each plot to record the number of days required to attain various phenophases. The whole life cycle of the rice crop from sowing to maturity was divided into six distinct phenophases *viz*., emergence, tillering, panicle initiation, Anthesis, beginning of grain filling and physiological maturity. Data of weather parameters *viz.,* maximum temperature, minimum temperature and bright sunshine hours for the period of experimentation were recorded from agrometeorological observatory of Navsari Agricultural University which is near to experimental site. The agrometeorological indices like helio thermal unit (HTU), Photo thermal index (PTI), photo thermal unit (PTI) and energy degree unit (EDU) for completion of each phenophases and heat use efficiency were calculated by using following formulas:

$$\text{Growing Degree Days (GDD)} = \sum_{i-1}^{n} \frac{(\text{T max} + \text{T min})}{2} - \text{Tc}$$

Where, T max and T min are the maximum and minimum temperature of the day and Tc is the minimum threshold temperature of the crop, also called as base temperature or minimum threshold temperature. The base temperature of rice crop of 10°C was used for computation of GDD on daily basis (Thomas, 1957).

$$\text{Photothermal Unit (PTU)} = \sum_{i=1}^{n} \text{GDD} \times \text{N}$$

$$\text{Heliothermal Unit (HTU)} = \sum_{i=1}^{n} \text{GDD} \times \text{n}$$

$$\text{Phenothermal index (PTI)} = \frac{\text{GDD between two phenological stages}}{\text{No. of days taken between two phenophases}}$$

Where, N = Maximum possible sunshine hours, N = Actual sunshine hours, GDD = Growing degree days (°C day).

$$EDU = \sum_{s}^{h} GDD * E$$

Where, E = daily accumulation of solar radiation in Langley per day.

Solar radiation

Solar radiation at the surface can be estimated by using the following formula:

$$RS = Ra\ [a+b\ (n/N)]$$

Where, R = Solar radiation at surface.

Ra = Radiation at the top of the atmosphere.

a & b = Constant, a = 0.42 and b = 0.30

n = Actual bright sunshine duration.

N = Maximum possible sunshine duration.

$$\text{Heat use efficiency (HUE)} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Accumulated heat units (}^{0}\text{C day)}}$$

Results and Discussion

Photothermal units (ºC day hr)

The PTU for different phenophases is presented in (table 1) revealed that From sowing to emergence stage in cv. Jaya total PTU values for first, second and third date of sowing were 1612.8, 1013.0 and 1205.7 respectively. Similarly in cv. Gurjari were 1353.0, 772.7, 711.8 and cv. GNR-2 1612.8, 1265.8 and 1446.7 respectively. From emergence to tillering stage it is observed that in cv. Jaya value of PTU for first, second and third date of sowing were 9272.4, 9156.4 and 8989.8 in cv. Gurjari for first, second and third date of sowing were 8539.9, 8928.6 and 8634.8 and cv. GNR-2 were 8788.4, 8903.6 and 8541.0 respectively. Tillering to panicle initiation the higher value of PTU were recorded in first date of sowing followed by second and third in all genotypes. From panicle initiation to anthesis, also similar trend was observed. From anthesis to beginning of grain filling in cv. Jaya maximum total PTU values at third date of sowing 1568.3 but in cv. Gurjari and cv. Jay for same stage total PTU values for first, second and third date of sowing were 1498.0, 1227.3, 1223.0 and1262.1, 1452.9 and 1080.4 respectively. From beginning of grain filling to physiological maturity highest total PTU values observed at first of sowing.

Heliothermal units (ºC day hr)

Table 2 showed that higher values of HTU in cv. Jaya were found at first date of sowing (12990.7ºC day hr) followed by second and third date of sowing (12138.6ºC day hr) and (11784.8ºC day hr), respectively. Similar trend was also observed in cv. Gurjari and cv. GNR-2. Results showed that total HTU was decreased with delay of sowing.

Phenothermal index (ºC days hr)

The maximum value of PTI observed from sowing to emergence as compare to other phonological stage in all sowing dates and genotypes except cv. GNR-2. It was fairly noticeable from data for higher values of PTI

Table 1 : PTU (°C days Hr) required for attainment of phenophases of rice cultivars under variable weather conditions.

Cultivars	Transplanting dates	Sowing to emergence	Emergence to tillering	Tillering to panicle initiation	Panicle initiation to anthesis	Anthesis to beginning of grain filling	Beginning of grain filling to phy. maturity	Total
Jaya	12/07/2012	1612.8 (6)	9272.4 (37)	8110.9 (36)	7213.7 (33)	1058.0 (5)	6043.3 (30)	33311.3
	27/07/2012	1013.0 (4)	9156.4 (38)	7398.0 (34)	7176.8 (34)	1489.3 (6)	5011.1 (27)	31244.8
	11/08/2012	1205.7 (5)	8989.8 (39)	7228.2 (33)	7181.9 (35)	1568.3 (9)	2639.9 (16)	28814
Gurjari	12/07/2012	1353.0 (5)	8539.9 (34)	10843.1 (47)	7787.2 (37)	1498.0 (7)	4512.9 (24)	34534.4
	27/07/2012	772.7 (3)	8928.6 (37)	9098.5 (41)	7862.6 (38)	1227.3 (6)	4393.1 (25)	32283.0
	11/08/2012	711.8 (3)	8634.8 (37)	8077.0 (38)	8421.5 (41)	1223.0 (7)	3368.1 (23)	30436.5
GNR-2	12/07/2012	1612.8 (6)	8788.4 (21)	9499.0 (42)	7552.1 (37)	1262.1 (6)	4857.1 (24)	33571.7
	27/07/2012	1265.8 (5)	8903.6 (37)	8217.6 (38)	7846.6 (37)	1452.9 (7)	4464.0 (26)	32150.6
	11/08/2012	1446.7 (6)	8541.0 (37)	7051.5 (33)	7381.4 (36)	1080.4 (6)	2903.1 (17)	28404.4

Figure in parenthesis shows number of days taken for attainment of phenophase.

Table 2 : HTU (°C days Hr) required for attainment of phenophases of rice cultivars under variable weather conditions.

Cultivars	Transplanting dates	Sowing to emergence	Emergence to tillering	Tillering to panicle initiation	Panicle initiation to anthesis	Anthesis to beginning of grain filling	Beginning of grain filling to phy. maturity	Total
Jaya	12/07/2012	1133.8 (6)	3118.8 (37)	1375.8 (36)	2601.1 (33)	575.0 (5)	4185.9 (30)	12990.7
	27/07/2012	640.1 (4)	1376.9 (38)	1859.5 (34)	3481.9 (34)	1011.3 (6)	3768.6 (27)	12138.6
	11/08/2012	314.0 (5)	1158.3 (39)	2236.1 (33)	4845.7 (35)	1118.9 (9)	2111.5 (16)	11784.8
Gurjari	12/07/2012	976.6 (5)	3237.1 (34)	1890.6 (47)	328.7 (37)	4224.7 (7)	3321.5 (24)	13979.3
	27/07/2012	521.8 (3)	1444.5 (37)	2154.2 (41)	4510.8 (38)	948.2 (6)	3392.1 (25)	12971.8
	11/08/2012	83.7 (3)	1264.9 (37)	2359.9 (38)	5686.9 (41)	988.6 (7)	278.4 (23)	10662.6
GNR-2	12/07/2012	1133.8 (6)	3118.8 (21)	1720.3 (42)	2991.7 (37)	967.4 (6)	3488.2 (24)	13420.3
	27/07/2012	841.1 (5)	1175.8 (37)	2015.9 (38)	4336.9 (37)	1086.6 (7)	3406.5 (26)	12863.1
	11/08/2012	434.8 (6)	1014.1 (37)	2096.5 (33)	4847.1 (36)	716 (6)	2343.0 (17)	11451.7

Figure in parenthesis shows number of days taken for attainment of phenophase.

were recorded in first date of sowing followed by second and third dates (table 3).

Energy degree unit (Leangle day^{-1})

In cv. Jaya significantly higher value of total EDU was observed at first date of sowing (95060868 Leangle day^{-1}) followed by second date of sowing (86902882 Leangle day^{-1}) and third date of sowing (80999804 Leangle day^{-1}). Similar trend was observed in cv. Gurjari and cv. GNR-2. Table 4 showed that total EDU was decreased with delay in sowing.

Thermal use efficiences

Heat use efficiencies (kg ºC day^{-1})

The values in table 5 revealed that in cv. Jaya at first and second date of sowing showed the same heat use efficiencies (1.33 kg ºC day^{-1}), but in third date of sowing slightly higher heat use efficiencies observed *i.e.* (1.43 kg ºC day^{-1}). In cv. Gurjari higher heat use efficiency (1.41 kgºC day^{-1}) seen in second date of sowing followed by first date of sowing (1.37 kgºC day^{-1}) and third date of sowing (1.24 kgºC day^{-1}), respectively. In case of cv. GNR-2 maximum heat use efficiency recorded in first date of sowing.

Photothermal use efficiencies (kg ºC day^{-1} hr^{-1})

In cv. Jaya at first and second date of sowing same photothermal use efficiencies (0.10 kgºC day^{-1} hr^{-1}) and in third date of sowing slightly higher photothermal use efficiency (0.11 kg ºC day^{-1} hr^{-1}). In cv. Gurjari higher and same photothermal use efficiency recorded in first and second date of sowing (0.11 kg ºC day^{-1} hr^{-1}) followed by third date of sowing (0.10 kg ºC day^{-1} hr^{-1}), respectively. In case of cv. GNR-2 maximum photothermal use

Table 3 : PTI (°C days Hr) required for attainment of phenophases of rice cultivars under variable weather conditions.

Cultivars	Transplanting dates	Sowing to emergence	Emergence to tillering	Tillering to panicle initiation	Panicle initiation to anthesis	Anthesis to beginning of grain filling	Beginning of grain filling to phy. maturity	Total
Jaya	12/07/2012	20.6 (6)	19.0 (37)	17.8 (36)	17.5 (33)	18.4 (5)	17.7 (30)	111.2
	27/07/2012	19.1 (4)	18.4 (38)	17.6 (34)	17.9 (34)	18.7 (6)	16.6 (27)	108.5
	11/08/2012	18.3 (5)	18.0 (39)	17.4 (33)	18.5 (35)	15.6 (9)	15.1 (16)	103.0
Gurjari	12/07/2012	20.6 (5)	19.0 (34)	17.9 (47)	17.7 (37)	18.8 (7)	16.7 (24)	110.9
	27/07/2012	19.5 (3)	18.4 (37)	17.5 (41)	18.3 (38)	18.1 (6)	15.2 (25)	107.2
	11/08/2012	18.0 (3)	18.4 (37)	17.5 (38)	18.3 (41)	18.1 (7)	15.2 (23)	105.6
GNR-2	12/07/2012	20.6 (6)	19.0 (21)	17.9 (42)	17.6 (37)	18.4 (6)	17.2 (24)	110.9
	27/07/2012	19.1 (5)	18.4 (37)	17.5 (38)	18.2 (37)	18.4 (7)	15.4 (26)	107.1
	11/08/2012	18.3 (6)	18.0 (37)	18.0 (33)	18.4 (36)	16.1 (6)	15.4 (17)	104.3

Figure in parenthesis shows number of days taken for attainment of phenophase.

Table 4 : Energy degree unit (Langley per day^{-1}) during phenophases of rice cultivars under variable weather conditions.

Cultivars	Transplanting dates	Sowing to emergence	Emergence to tillering	Tillering to panicle initiation	Panicle initiation to anthesis	Anthesis to beginning of grain filling	Beginning of grain filling to phy. maturity	Total
Jaya	12/07/2012	351097.7 (6)	5756829 (37)	2547501 (36)	4341321 (33)	136942.8 (5)	6239645 (30)	95060868
	27/07/2012	129392.9 (4)	2621202 (38)	3164232 (34)	5747077 (34)	341169.9 (6)	4996589 (27)	86902882
	11/08/2012	78192.8 (5)	2312074 (39)	3778902 (33)	8031421 (35)	491918.6 (9)	1680088 (16)	80999804
Gurjari	12/07/2012	252935.1 (5)	5495109 (34)	4603475 (47)	6256789 (37)	359748.5 (7)	4065940 (24)	107751757
	27/07/2012	79296.7 (3)	2680368 (37)	4520107 (41)	8123215 (38)	277354 (6)	4359899 (25)	98291053
	11/08/2012	12361.2 (3)	2379790 (37)	4461959 (38)	11353864 (41)	342655.9 (7)	2826874 (23)	97024586
GNR-2	12/07/2012	351097.7 (6)	5454139 (21)	3945651 (42)	5138675 (37)	279070.4 (6)	4407248 (24)	100540517
	27/07/2012	212758.2 (5)	2186461 (37)	3821607 (38)	7795410 (37)	371324.4 (7)	4373900 (26)	96637341
	11/08/2012	612963 (6)	22634870 (37)	16457985 (33)	17517623 (36)	441075.6 (6)	3390572 (17)	265687763

Figure in parenthesis shows number of days taken for attainment of phenophase.

efficiency recorded in first date of sowing (0.11 kg ºC day^{-1} hr^{-1}) followed by second and third date of sowing (0.10 kg ºC day^{-1} hr^{-1}). These finding lend supported to the report of Rani *et al*. (2012).

Heliothermal use efficiency (kg ºC day^{-1} hr^{-1})

First date of sowing and second date of sowing in cv. Jaya at showed same heliothermal use efficiencies (0.27 kg ºC day^{-1} hr^{-1}) while in third date of sowing observed photothermal use efficiency faintly higher (0.29 kg ºC day^{-1} hr^{-1}). In cv. Gurjari in third date of sowing observed higher heliothermal use efficiency recorded (0.29 kg ºC day^{-1} hr^{-1}) followed by second and first date of sowing. In case of cv. GNR-2 maximum heliothermal use efficiency was recorded in first date of sowing (0.27 kg ºC day^{-1} hr^{-1}) compare second and third date of sowing.

Table 5 : Heat use efficiencies of rice genotypes under variable weather conditions.

Cultivars	Transplanting dates	HUE Kg ^{0}C day^{-1}	PTUE Kg ^{0}C day^{-1} hr^{-1}	HTUE Kg ^{0}C day^{-1} hr^{-1}	EDUE Kg ^{0}C Lengley day^{-1} hr^{-1}
Jaya	12/07/2012	1.33	0.10	0.27	3.8
	27/07/2012	1.33	0.10	0.27	3.9
	11/08/2012	1.43	0.11	0.29	4.2
Gurjari	12/07/2012	1.37	0.11	0.27	3.6
	27/07/2012	1.41	0.11	0.28	3.8
	11/08/2012	1.24	0.10	0.29	3.2
GNR-2	12/07/2012	1.35	0.11	0.27	3.7
	27/07/2012	1.24	0.10	0.25	3.4
	11/08/2012	1.29	0.10	0.26	1.1

HUE- Heat use efficiency, PTUE- Photo thermal use efficiency, HTUE- Helio thermal use efficiency, EDUE- Energy degree unit use efficiency.

Energy degree use efficiency (kg ºC Lengley day^{-1})

Data tabulated in table 5 revealed that in cv. Jaya at third date of sowing showed higher Energy degree use efficiency (EDUE) (4.2 kg ºC Langley day^{-1}) followed by second and first date of sowing but in cv. Gurjari in second date of sowing observed higher EDUE (3.8 kg ºC kg ºC Langley day^{-1}) followed by first (3.6 kgºC Langley day^{-1}) and third date of sowing (3.2 kg ºC Langley day^{-1}) respectively. In case of cv. GNR-2 higher EDUE recorded in first date of sowing (3.7 kg ºC Langley day^{-1}) followed by second and third date of sowing (3.4 kg ºC Langley day^{-1}) and (1.1 kg ºC Langley day^{-1}), respectively. These finding are in supported to the report of Rani *et al.* (2012).

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