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Evaluation of growing degree days (GDD) values of timely and late sowing dates in different varieties of rice

AP Deshmukh, SB Kharbade and R Balasubramanian

Abstract
An agro-meteorological investigation was undertaken on "Crop weather pest relationship and validation of DSSAT model for rice varieties under different transplanting dates'' during *kharif*, 2016 and 2017 at Agricultural Research Station Farm, Vadgaon Maval, Dist. Pune, under Mahatma Phule Krishi Vidyapeeth, Rahuri, for the purpose to evaluate the heat efficiency of rice crop. An experiment was laid out in split plot design with three replications. The treatment comprised of four sowing dates *viz*., $S_{1:}$ 26th MW (25 June-1 July), $S_{2:}$ 28th MW (9 July-15 July), $S_{3:}$ 30 MW (23 July-29 July) and $S_{4:}$ 32nd MW (06 August -12 August) as main plot treatments and four varieties *viz.,* V_1: VDN-99-29 (*Phule samruddhi*), $V_{2:}$ VDN-3-51-18 (*Indrayani*), $V_{3:}$ IET-13549 (*Bhogavati*) and $V_{4:}$ RDN-99-1 (*Phule Radha*) as sub plot treatments.

Keywords: Growing degree day, rice, timely

Introduction

Rice (*Oryza sativa* L.) is a 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. India ranks first in area with about 44 m. ha under rice and second in production with 104.8 million tones with an average productivity of 2390 kg ha^{-1} (Rami *et al*., 2016) [4]. Rice provides 21 per cent of global human per capita energy and 15 per cent of per capita protein. Although rice protein ranks high in nutritional quality among cereals, protein content is modest. Rice also provides minerals, vitamins and fiber, although all constituents except carbohydrates are reduced by milling. Growing degree days (GDD) are the simple and accurate method to predict that when a particular plant stage will occur. Growing degree days (GDD), sometimes also called thermal days, are a unit of measure describing the amount of accumulated heat through the growing season. Growing degree days (GDD) are the simple and accurate method to predict that when a particular plant stage will occur. Each developmental stages of the crop have its own heat requirement. Crop development can be estimated by accumulated degree days throughout the season. Delayed sowing not only restricts the accumulation of heat units but also slows down the vegetative growth and leads to forced maturity due to onset of winter which leads to decrease in yield.

Material and Methods

The present experiments related investigation entitled, "Crop weather pest relationship and validation of DSSAT model for Rice varieties under different transplanting dates" were conducted at Agriculture Research Station Farm, Vadgaon Maval, Tal. Dist. (M.S.) during *kharif* seasons of 2016-17 and 2017-18, to identify optimum transplanting date for Rice, to develop crop weather relationships, to develop pest weather relations and to validate the DSSAT model.

Experimental Details

The experiment was conducted in a split -plot design with three replications and sixteen treatment combinations were formed considering different varieties and transplanting. The details are listed below.

1. Name of crop: Rice
2. Varieties: 1. VDN-99-29 (Phule Samrudhi)
   2. VDN-3-51-18 (Indrayani)
   3. IET-13549 (Bhogavati)
   4. RDN-99-1 (Phule Radha)
3. Number of treatment: 16 combinations
4. Number of replications: 3
5. Number of plots: 48
6. Experimental Design: Split plot Design
7. Plot size: a. Gross Plot: 4.80 m x 3.60 m
   b. Net Plot: 4.0 m x 3.0 m
8. Spacing: 20 cm x 15 cm
9. Seed rate: 20 kg ha^{-1}
10. Fertilizer dose: 175: 60: 60 NPK kg ha^{-1}
11. Seasons: I) *Kharif*, 2016
    II) *Kharif*, 2017
12. Place of research work: Agricultural Research Station Farm, Vadgaon Maval, Tal. Maval, Dist. Pune
13. Transplanting dates: S_1: 26th MW (25 June-1 July)
    S_2: 28th MW (16 July-15July)
    S_3: 30 MW (23 July-29July)

Accumulated growing degree days (GDD)

Growing degree days is a way of assigning a heat value to each day. The values are added together to give an estimate of the amount of seasonal growth of plants.

GDD = Σ [(Tx + Tn) / 2 – Base temperature]

Tx=Daily maximum temperature Tn=Daily minimum temperature Base temperature is the lowest temperature where metabolic processes result in a net substance gain in aboveground biomass. n= actual sunshine hour.

Grain Yield / Economic yield Economic yield is the grain yield of the crop and it was recorded from each plot after harvesting.

Biological yield Biological yield refers to the total yield of the plant material. Each plant from all subplots was uprooted from the ground level at the time of maturity and the weight of the whole plant before thrashing was recorded as biological yield.

Result and Discussion

Accumulated growing degree days (GDD) Prevailing weather and climatic conditions greatly influence the agricultural productivity of the crop. Crop yield of a particular area depends on its climatic conditions, temperature, sunshine hours, light intensity and radiation. Rice development depends on temperature and light and it requires a specific amount of heat to switch over from one growth stage in their lifecycle to another, such as from seeding to the harvest stage. Temperature plays a very important role for the biological processes and hence the growth and development of plants. Various forms of temperature summations, commonly referred to as thermal units or growing degree days, have been utilized in numerous studies to predict phenological events for different crops. Growing degree days are used to find out the suitability of a particular region for the production of a particular crop, determine the growth stages of crops, predict the best timing for application of fertilizer, herbicide and plant growth regulators, estimate heat stress accumulation on crops, predict physiological maturity and harvesting dates. Growing degree days (GDD) was calculated for different varities at maturity stage under early and late sowing dates.

Growing Degree Days (GDD)

Heat unit requirement or GDD has been used for characterizing the thermal response in rice crop and other crops. Bright sunshine hours, maximum and minimum temperatures during the growth period were recorded from meteorological observatory. Growing degree days (GDD) were computed by taking a base temperature as 4.5 ^{0}C.

It was evident from the (Table 1 and 2) that accumulated growing degree days (GDD) for different genotypes under different thermal environments varied considerably from transplanting to maturity. Different rice varieties responded differently in terms of accumulated GDD at the time of maturity. Higher GDD was observed under 28th MW in varieties VDN-99-29 (2511.7 and 2457.6) and VDN-3-51-18 (2440.8 and 2382.7) during 2016 and 2017, respectively.

Lowest GDD was noticed under 32nd MW in case of RDN-99-1 (1637.4 and 1675.85) during 2016 and 2017, respectively. In general, the GDD values decreased when the transplanting was delayed this might be due to early maturity of crops under delayed transplanted condition because of higher temperature.

These results are in agreement with Praveen and Sanjeevan (2013) [3], Chen *et al.* (2016) [2] and Modarresi *et al.* (2015) [6] who reported that heat unit requirement decreased with delay in transplanting time.

Grain Yield

Effect of transplanting times

The grain yield of rice was influenced significantly due to extend transplanting times. The grain yield was maximum at 28th MW transplanting time (53.5 and 57.8 q/ha) and was on par with 26th MW transplanting time (49.9 and 54.5 q/ha). This was followed by 30 MW transplanting time (44.8 and 48.2 q ha^{-1}), 32 MW transplanting time (33.0 and 36.0 q ha^{-1}) during 2016 and 2017, respectively (Table 3).

Effect of varieties

The grain yield of rice was influenced significantly due to rice varieties. The grain yield was significantly higher in VDN-99-29 (V_1) (54.7 and 58.9 q ha^{-1}) and significantly superior over rest of the rice varieties. This was followed by VDN-3-51-18 (V_2) (49.0 and 53.6 q ha^{-1}), IET13549 (V_3) (41.1 and 44.7 q ha^{-1}). A variety RDN-99-1 recorded significantly lower grain yield (36.4 and 39.2 q ha^{-1}) during 2016 and 2017, respectively. The differences in grain yield of rice varieties might be due to inherent genetical potential of rice variety. Similar results were reported by Belhekar and Kashid 2009) [1], Shinde (2014) and Pandi (2014).

Effect of interaction

The grain yield (q ha^{-1}) of rice was significantly influenced by interaction between varieties and transplanting times during 2016 and 2017. Transplanting at 28th MW transplanting time (S_2) recorded maximum grain yield (68.3 and 73.0 q ha^{-1}) in variety VDN-99-29 (V_1). This was followed by variety VDN-3-51-18 (V_2) (59.1 and 64.5 q ha^{-1}), IET13549 (V_2) (59.1 and 64.5 q ha^{-1}) and RDN-99-1 (V_3) (48.0 and 52.4 q ha^{-1}) during 2016 and 2017, respectively. Lower precipitation particularly during panicle emergence and grain filling stages interfered with normal development of grain caused shriveling of grains. Thus, reduction in grain yield was caused due to smaller size of grains. This results showed that delay in transplanting of rice varieties could not able to assimilate the more biomass resulted in reduced grain yield of rice. Similar results were reported by Manjappa and Kumar (2002) [5] and Mukesh *et al.* (2013) [7].

Straw Yield

Data with respect to mean straw yield of rice as influenced by different treatments are presented in Table 4.13. The mean straw yield of rice was 50.0 and 54.2 q/ha during 2016 and 2017, respectively.

Effect of transplanting times

The straw yield of rice was influenced significantly due to extend transplanting times. The straw yield was maximum at 28th MW transplanting time (75.4 and 80.6 q/ha) and was at par with transplanting time at 26th MW (65.1 and 71.1 q/ha). This was followed by 30 th MW transplanting time (63.0 and 67.4 q/ha) and 32ndMW transplanting time (38.3 and 40.9 q ha^{-1}) during 2016 and 2017, respectively. The reduction in straw yield caused due to transplanting times was because of difference in rainfall and temperature. A transplanting time of 28th MW was favorable to high straw production because the post anthesis period coincided with optimum precipitation and temperature. However, later transplanting 32nd MW were unfavorable to straw yield since low precipitation during early transplanting might have adversely affected the emergence and ultimately tillers per running meter. In later transplanting (32nd MW), the period between anthesis and leaf senescence was curtailed by the onset of relatively higher temperature. These results are in agreement with the findings of Giri and Kumar (2001), Manjappa and Kumar (2002) [5], Gill *et al.* (2009) and Kerketta *et al.* (2010).

Effect of varieties

The straw yield of rice was influenced significantly due to rice varieties. The straw yield was significantly higher in VDN-99-29(V_1)(60.42 and 65.00 q/ha) and significantly superior over rest of the rice varieties. This was followed by VDN-3-51-18 (V_2) (54.08 and 59.19 q/ha), IET13549 (V_3) (45.32 and 49.35 q/ha). The variety RDN-99-1 recorded significantly lower straw yield (40.16 and 43.26 q/ha) during 2016 and 2017, respectively. The differences in straw yield of rice varieties might be due to inherent genetical potential of rice variety. Similar results were reported by Belhekar and Kashid (2009) [1], Shinde (2014) and Pandi (2014).

Effect of interaction

The straw yield (q ha^{-1}) was significantly influenced by interaction between varieties and transplanting times during 2016 and 2017. Transplanting at 28th MW transplanting time (S_2) recorded maximum straw yield (75.04 and 80.6 q/ha) in variety VDN-99-29 (V_1). This was followed by variety VDN-3-51-18(V_2) (65.2 and 71.2 q ha^{-1}), IET13549 (V_3) (53.0 and 57.8 q ha^{-1}) and RDN-99-1(V_3) (42.5 and 45.5 q ha^{-1}) during 2016 and 2017, respectively.

Table 1: Cumulative growing degree days (heat unit) at critical growth stage as influenced by different treatments during 2017

Sowing windows ↓	Variety→	V_1: Phule Samruddhi	V_2: Indrayani	V_3: Bhogavati	V_4: Phule Radha
S_1:26th MW	SO-EM	359.52	359.52	359.52	359.52
	EM-TI	641.8	641.8	641.8	641.8
	TI-PI	948.75	993.75	974.75	947.75
	PI-AN	1438.8	1644.15	1370.75	1264.95
	AN-GF	1545.1	1535.1	1754.4	1527.4
	GF-PM	1856.1	1874.6	1834.5	1831.2
	Total	2259.75	2205.2	2077.5	1985.65
S_2:28th MW	SO-EM	393.25	393.25	393.25	393.25
	EM-TI	619.1	619.1	619.1	619.1
	TI-PI	982.64	1012.64	951.64	931.64
	PI-AN	1620.3	1717.55	1395.6	1376.9
	AN-GF	1898.7	1541.0	1537.8	1563.7
	GF-PM	1967.4	1885.2	1864.1	1965.6
	Total	2457.6	2382.7	2253.8	2204.3
S_3:30th MW	SO-EM	395.45	395.45	395.45	395.45
	EM-TI	650.6	650.6	650.6	650.6
	TI-PI	952.2	979.2	931.2	967.2
	PI-AN	1327.95	1525.65	1203.55	1267.65
	AN-GF	1513.5	1502.4	1502.4	1587.3
	GF-PM	1637.4	1827.3	1614.7	1613.2
	Total	2070.15	2031.2	1829.75	1793.6
S_4:32nd MW	SO-EM	371.5	371.5	371.5	371.5
	EM-TI	587.35	587.35	587.35	587.35
	TI-PI	827.14	843.14	823.14	813.14
	PI-AN	1238.45	1313.3	1091.1	1055.25
	AN-GF	1490.2	1490.0	1489.4	1456.1
	GF-PM	1587.5	1665.7	1623.4	1564.3
	Total	1826.2	1784.65	1743.7	1675.85

Table 2: Cumulative growing degree days (heat unit) at critical growth stage as influenced by different treatments during 2017

Sowing windows ↓	Variety→	V_1: Phule Samruddhi	V_2: Indrayani	V_3: Bhogavati	V_4: Phule Radha
S_1:26th MW	SO-EM	359.52	359.52	359.52	359.52
	EM-TI	641.8	641.8	641.8	641.8
	TI-PI	948.75	993.75	974.75	947.75
	PI-AN	1438.8	1644.15	1370.75	1264.95
	AN-GF	1545.1	1535.1	1754.4	1527.4
	GF-PM	1856.1	1874.6	1834.5	1831.2
	Total	2259.75	2205.2	2077.5	1985.65
S_2:28th MW	SO-EM	393.25	393.25	393.25	393.25
	EM-TI	619.1	619.1	619.1	619.1
	TI-PI	982.64	1012.64	951.64	931.64
	PI-AN	1620.3	1717.55	1395.6	1376.9
	AN-GF	1898.7	1541.0	1537.8	1563.7
	GF-PM	1967.4	1885.2	1864.1	1965.6
	Total	2457.6	2382.7	2253.8	2204.3
S_3:30th MW	SO-EM	395.45	395.45	395.45	395.45
	EM-TI	650.6	650.6	650.6	650.6
	TI-PI	952.2	979.2	931.2	967.2
	PI-AN	1327.95	1525.65	1203.55	1267.65
	AN-GF	1513.5	1502.4	1502.4	1587.3
	GF-PM	1637.4	1827.3	1614.7	1613.2
	Total	2070.15	2031.2	1829.75	1793.6
S_4:32nd MW	SO-EM	371.5	371.5	371.5	371.5
	EM-TI	587.35	587.35	587.35	587.35
	TI-PI	827.14	843.14	823.14	813.14
	PI-AN	1238.45	1313.3	1091.1	1055.25
	AN-GF	1490.2	1490.0	1489.4	1456.1
	GF-PM	1587.5	1665.7	1623.4	1564.3
	Total	1826.2	1784.65	1743.7	1675.85

Table 3: Grain and straw yields (q/ha) in rice as influenced by different treatments (2016 and 2017)

	Treatment	Grain yield (q/ha)			Straw yield (q/ha)		
		2016	2017	Pooled	2016	2017	Pooled
A.	**Transplanting times(Main)**						
S_1:	26thMW (25 June-1 July)	49.9	54.5	52.2	65.1	71.1	68.1
S_2:	28thMW (09 July-15 July)	53.5	57.8	55.6	75.4	80.6	78.0
S_3:	30thMW (23 July-29 July)	44.8	48.2	46.5	63.0	67.4	65.2
S_4:	32ndMW (06 Aug-12 Aug)	33.0	36.0	34.5	38.3	40.9	39.6
	S.Em ±	1.14	1.24	1.19	1.36	1.48	1.42
	C.D. at 5%	3.96	4.29	4.12	4.72	5.11	4.91
B.	**Varieties (Sub plot):**						
V_1:	VDN-99-29 (Phule Samrudhi)	54.7	58.9	56.8	60.42	65.00	62.71
V_2:	VDN-3-51-18 (Indrayani)	49.0	53.6	51.3	54.08	59.19	56.64
V_3:	IET-13549 (Bhogavati)	41.1	44.7	42.9	45.32	49.35	47.33
V_3:	RDN-99-1 (Phule Radha)	36.4	39.2	37.8	40.16	43.26	41.71
	S.Em ±	0.98	1.06	1.02	1.10	1.19	1.14
	C.D at 5%	2.86	3.09	2.97	3.21	3.46	3.33
C.	**Interaction (A x B)**						
	Between levels of A						
	S.Em ±	2.29	2.48	2.38	2.73	2.95	2.84
	C.D. at 5%	7.91	8.58	8.24	9.44	10.21	9.83
	Between levels of B						
	S.Em ±	1.96	2.12	2.04	2.20	2.37	2.28
	C.D. at 5%	5.72	6.18	5.95	6.41	6.93	6.67
	General mean	45.3	49.1	47.2	50.0	54.2	52.1

Table 4: Grain and straw yields (q/ha) of rice as influenced by interaction between transplanting times andvarities (2016 and 2017)

Treatment	Grain yield (q/ha)											
	V_1			V_2			V_3			V_4		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
S_1	59.6	65.0	62.3	53.8	59.9	56.1	45.9	50.1	48.0	40.3	**43.2**	**41.8**
S_2	68.3	73.0	70.6	59.1	64.5	61.8	48.0	52.4	50.2	38.5	**41.2**	**39.9**
S_3	56.4	60.04	58.4	50.3	54.3	52.3	38.1	41.2	39.6	34.5	**37.0**	**35.7**
S_4	34.7	37.1	35.9	32.9	35.9	34.4	32.4	35.4	33.9	32.2	**35.5**	**33.8**
Mean	54.8	58.8	56.8	49.0	53.7	51.2	41.1	44.8	42.9	36.4	**39.2**	**37.8**

Treatment	Straw yield (q/ha)											
	V_1			V_2			V_3			V_4		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
S_1	65.1	71.1	68.1	58.7	65.4	62.1	50.1	54.6	52.3	44.1	47.1	45.6
S_2	75.4	80.6	78.0	65.2	71.2	68.2	53.0	57.8	55.4	42.5	45.5	44.0
S_3	63.0	67.4	65.2	56.0	60.6	58.3	42.5	45.9	44.2	38.5	41.2	39.8
S_4	38.3	40.9	39.6	36.3	39.6	38.0	35.8	39.0	37.4	35.6	39.2	37.4
Mean	60.5	65.0	62.7	54.1	59.2	56.7	45.4	49.3	47.3	40.2	43.3	41.7

Conclusion

Rice varieties grown under timely sowing conditions received longer photoperiod and accumulated higher number of GDD so they produce good biological yield as compared to normal and late sown rice varieties. also From this study, we concluded that varieties sown under early condition were given best results in term of yield parameters this is because early varieties accumulated more number of growing degree days as compared to normal and late sown varieties which is positively related to all yield attributes The information obtained in this study is extremely important for timely incorporation of various agricultural operations and prediction of best varieties suited for particular region.

Application of Research

In future farmers can use growing degree days values for prediction of best suitable varieties for particular regions and can utilize these values for appropriate management practices like fertilizer application and irrigation.

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