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Research Article

THERMAL INDICES FOR SUITABLE SOWING WINDOW FOR *RABI* SORGHUM IN WESTERN MAHARASHTRA AGROCLIMATIC ZONE

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Abstract: Sorghum (*Sorghum bicolor* L. Moench) is one of the main staple foods for the world's poorest and most food insecure people across the semi-arid tropics and it is an important food crop in India. Optimum time of sowing is one of the important technologies that gives an opportunity for better utilization of natural resources by the crop. A field experiment was conducted for two consecutive years at the Department of Agricultural Meteorology Farm, College of Agriculture, Pune during *rabi* 2016 and 2017. The experiment was laid out in split -plot design with three replications with sixteen treatment combinations were formed considering different varieties and sowing windows. Main plot treatments were varieties which comprised of, Maldandi (M-35-1) Phule Vasudha, Phule Maulee and Phule Chitra. Sub plot treatments were sowing dates, which comprised of 35th MW (27 Aug-02 Sep), 37th MW (10 Sep-16 Sep), 39th MW (24 Sep- 30 Sep), 41st MW (08 Oct-14 Oct). Results showed that the higher GDD was observed under 35th MW sowing window in variety Phule Vasudha (1783.8 and 1871.6) during 2016-17 and 2017-18, respectively. Higher photo thermal units (PTU) observed under 35th MW sowing window in Phule Vasudha (21406.2 and 22454.9) during 2016-17 and 2017-18, respectively. Higher HTU (12322 and 122893) was observed under 35th MW sowing window (S3) in variety Phule Vasudha (V2) during 2016-17 and 2017-18, respectively. Variety Phule Maulee accumulated the lower HTU values (9196.4 and 7564.3) during 2016-17 and 22017-18, respectively. 35th MW sowing window has shown the higher accumulation of all the three thermal indices during both the years. Phule Vasudha has shown the highest accumulation of heat units in all the sowing windows during both the years.

Keywords: Thermal indices, Growing Degree days, Helio Thermal Units, Photo Thermal Units

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Introduction

Sorghum (*Sorghum bicolor* L. Moench) is one of the main staple foods for the world's poorest. India contributes about 16% of the world's sorghum production. The area under *rabi* sorghum in India during 2015-16 was 5.65 lakh hectare with production 4.41 Mt and productivity 780 kg ha-1. Sorghum grain has high nutritive value with 70-80% carbohydrate, 11-13% protein, 2-5% fat, 1-3% fibre, and 1-2% ash. Protein in sorghum is gluten free and thus, it is a speciality food for people who suffer from celiac disease, as well as diabetic patients [1]. Nutritional values of sorghum grains are very important in nutritional security in the poor countries.

In present times and in coming years, climate change and global warming are the concerning issues of the humanity. The rate of global warming is expected to continue increasing if no mitigation efforts taken place to reduce the carbon intensity of the world economy and the consequent emission of green-house gases [2]. Agricultural production, and thus global food security, is directly affected by global warming [3]. Increasing atmospheric greenhouse gas concentrations are expected to induce significant climate change over the next century and beyond, but the impacts on society remain highly uncertain [4]. Sorghum plays very pivotal role in the food and nutritional security of poor nations as well as developing countries. Sorghum is very versatile crop that can overcome the climate change impact on the food security. Optimum time of sowing is one of the important technologies that gives an opportunity for better utilization of natural resources by the crop. It helps in identification of critical phenological phases of crops for achieving optimum production with less cost of cultivation. This investigation discusses about the determination of Heat units for optimum sowing window as temperature is an important environmental factor that affects plant growth development and yield. Heat unit concept has been applied to correlate pheonological development in crops to predict sowing dates [5].

Material and methods

Location of the Experimental Site

The field experiment was conducted for two consecutive years at the Department of Agricultural Meteorology Farm, College of Agriculture, Pune during *rabi* 2016 and 2017. The geographical location of the site (Pune) was 18°32'N, latitude; 73°5'E, longitude and 559 m above mean sea level (MSL). The soil is medium black calcareous having depth of about 1m. The average annual rainfall of Pune is 675 mm.

Experimental Details

The experiment was conducted in split -plot design with three replications with sixteen treatment combinations were formed considering different varieties and sowing windows. Main plot treatments were varieties which comprised of, Maldandi (M-35-1) Phule Vasudha, Phule Maulee and Phule Chitra. Sub plot treatments were sowing dates, which comprised of 35th MW (27 Aug-02 Sep), 37th MW (10 Sep-16 Sep), 39th MW (24 Sep- 30 Sep), 41st MW (08 Oct-14 Oct).

Growing Degree Days (GDD)

The growing degree days (GDD) were calculated during the crop period and attempted to relate the same with crop duration as well as grain yield.

Table-1 Accumulated GDD in Sorghum during 2016-17 and 2017-18

Treatment		S_1-35th MW		S_2-37th MW		S_3-39th MW		S_4-41st MW	
	Growth stage	16-17	17-18	16-17	17-18	16-17	17-18	16-17	17-18
Maldandi	S-PI	599.15	670.35	562.8	742.6	499.05	499.05	419.55	419.55
	S -FL	1175.0	1248.7	1070.2	1150.8	966.25	966.25	777.95	777.95
	S-PM	1697.4	1717.8	1621.8	1776	1411.6	1411.6	1223.3	1223.3
Phule vasudha	S-PI	566.2	568.8	562.8	821.2	523.05	523.05	463.25	463.25
	S -FL	1175.0	1133.8	1093.2	1150.8	966.25	966.25	838.65	838.65
	S-PM	1783.8	1871.6	1610.1	1862.8	1528.1	1528.1	1339.8	1339.8
Phule maulee	S-PI	486.55	517.2	453.1	669.4	441.95	441.95	373.65	373.65
	S -FL	990.25	1089.2	907.35	960.7	826.4	826.4	705.2	705.2
	S-PM	1514.7	1619.3	1389.9	1553.2	1260.9	1260.9	1101.1	1101.1
Phule chitra	S-PI	486.55	517.2	484.65	727.4	486.1	486.1	397.15	397.15
	S -FL	990.25	1113.1	992.95	1053.5	893.5	893.5	716.7	716.7
	S-PM	1514.7	1649.8	1437.6	1652.9	1334.1	1334.1	1166.9	1166.9

Note: S-PI: sowing to Panicle initiation, S-FL:sowing to 50% flowering and S-PM:sowing to physiological maturity

Table-2 Accumulated PTU in Sorghum during 2016-17 and 2017-18

Treatment		S_1-35th MW		S_2-37th MW		S_3-39th MW		S_4-41st MW	
	Growth stage	16-17	17-18	16-17	17-18	16-17	17-18	16-17	17-18
Maldandi	S-PI	7189.8	8044.2	6753.6	8911.2	5988.6	6690	5034.6	5208
	S -FL	14100.6	14984.4	12842.4	13810.2	11595	12306	9335.4	9920.4
	S-PM	20613.6	20369.4	19462.2	21312	16939.8	19234.2	14680.2	15093.6
Phule vasudha	S-PI	6794.4	6825.6	6753.6	9854.4	6276.6	7633.2	5559	5665.2
	S -FL	14100.6	13605.6	13118.4	13810.2	11595	14132.4	10063.8	10852.8
	S-PM	21406.2	22459.2	19321.8	22354.2	18337.2	20238	16077.6	16685.4
Phule maulee	S-PI	5838.6	6206.4	5437.2	8032.8	5303.4	5993.4	4483.8	4642.2
	S -FL	11883	13070.4	10888.2	11528.4	9916.8	10749.6	8462.4	8756.4
	S-PM	18176.4	19432.2	16679.4	18638.4	15131.4	16046.4	13213.8	13349.4
Phule chitra	S-PI	5838.6	6206.4	5815.8	8728.8	5833.2	6507.6	4765.8	4936.2
	S -FL	11883	13357.2	11915.4	12642	10722	11848.2	8600.4	9287.4
	S-PM	18176.4	19798.2	17251.8	19834.8	16009.2	17613.6	14002.8	14197.8

Note: S-PI: sowing to Panicle initiation, S-FL:sowing to 50% flowering and S-PM:sowing to physiological maturity

Table-3 Accumulated HTU in Sorghum during 2016-17 and 2017-18

Treatment		S_1-35th MW		S_2-37th MW		S_3-39th MW		S_4-41st MW	
	Growth stage	16-17	17-18	16-17	17-18	16-17	17-18	16-17	17-18
Maldandi	S-PI	2551.5	3632.5	2409.8	4052.1	3571.3	3446.6	3434	2689.2
	S -FL	7259.7	7655.3	6792.7	7199.2	7617.8	6832.6	6459	5355.7
	S-PM	11782	10862	11298	11608	11272	11104	10167	8554.3
Phule vasudha	S-PI	2291.5	3227	2409.7	4711.1	3796.9	4147.7	3826	3042.6
	S -FL	7259.7	7000.9	6981.3	7199.2	7617.8	7971.6	6863	5962.1
	S-PM	12322	12283	11187	12000	12307	1183	11241	9544
Phule maulee	S-PI	1846.7	2860.6	1666.9	3409.9	3068.8	2959	3017.9	2284
	S -FL	5765.7	6612.9	5429.4	5933.7	6375.5	6069.6	5828.2	4880.7
	S-PM	10104	10225.7	11675	10005	10142	9199.0	9196.4	7564.3
Phule chitra	S-PI	1846.7	2860.6	1889.4	3962.4	3448.2	3317.4	3231.9	2489.8
	S -FL	5765.0	6829.1	6089.8	6414.8	6955.0	6540.6	5911.0	5182.0
	S-PM	10104	10477	9873.0	10755	10596	10156.2	9799.7	8055.9

Note: S-PI: sowing to Panicle initiation, S-FL:sowing to 50% flowering and S-PM:sowing to physiological maturity

The GDD were calculated using the following formula.

$$GDD=\sum_{i=1}^{n}\frac{Tmax\text{-}Tmin}{2}\text{-}Tbase$$

Where $\sum_{i=1}^{n}$ =Period in days from sowing date till the last date of harvesting

T_{max} = maximum temperature in °C

T_{min} = minimum temperature in °C

T_{base} = minimum threshold temperature or base temperature (°C)

The base temperature for sorghum crop is 10°C.

Photo-Thermal Units (PTU)

Photo-thermal units were determined by GDD multiplying with maximum possible sunshine hours (N).

Heliothermal units = GDD x N

Helio Thermal Units (HTU)

Heliothermal units for various growth stages is calculated by the formula given by Ritchie and Nesmith, (1991).

HTU = GDD x Bright sunshine hours

Results and Discussion

Growing Degree Day (GDD)

Bright sunshine hours, maximum and minimum temperatures during the growth period were recorded from meteorological observatory. GDD were calculated from them. It was evident from the data [Table-1] that accumulated growing degree days (GDD) varied considerably from sowing to maturity. Different sorghum varieties responded differently in terms of accumulated GDD at the time of maturity. Higher GDD was observed under 35th MW sowing window in variety Phule Vasudha (1783.8 and 1871.6) during 2016-17 and 2017-18, respectively. Lower GDD was noticed under 41st MW sowing window in case of Phule Maulee (1101.1 and 1101.1) during 2016-17 and 2017-18, respectively. In general, the GDD values decreased when the sowing was delayed. This might be due to early maturity of crops under delayed sown condition because of higher temperature. With delayed date of sowing, accumulated GDD reduced significantly in sorghum. This was due to increase in the temperature during delayed plantings which leads to early maturity of the crop. The similar results were reported by [6,7].

Photo Thermal Unit (PTU)

Different sorghum varieties responded differently in terms of accumulated PTU at the time of maturity. Photo thermal unit (PTU) for different genotypes varied considerably at maturity [Table-2]. Higher photo thermal units (PTU) observed under 35th MW sowing window in Phule Vasudha (21406.2 and 22454.9) during 2016-17 and 2017-18, respectively. Lower GDD was noticed under 41st MW in case of Phule Maulee (13213.8 and 13349.4) during 2016-17 and 2017-18, respectively. With delayed sowing window, accumulated PTU reduced significantly in sorghum. This was due to increase in the temperature during delayed plantings which accelerated the growth of the crop. The similar results were reported by [6,7].

Helio Thermal Unit (HTU)

Different sorghum varieties responded differently in terms of accumulated HTU at the time of maturity. The highest HTU was observed in 35th MW sowing window (S3) in all the varieties. Heliotermal unit (HTU) for different genotypes varied considerably at maturity period [Table-3]. Higher HTU (12322 and 122893) was observed under 35th MW sowing window (S3) in variety Phule Vasudha (V2) during 2016-17 and 2017-18, respectively. Variety Phule Maulee accumulated the lower HTU values (9196.4 and 7564.3) during 2016-17 and 22017-18, respectively. With delayed sowing window, accumulated HTU reduced significantly in sorghum. This was due to increase in the temperature during delayed plantings which accelerated the growth of the crop. The similar results were reported by [6,7].

Conclusion

35th MW sowing window has shown the higher accumulation of all the three thermal indices during both the years. Phule Vasudha has shown the highest accumulation of heat units in all the sowing windows during both the years.

Application of research: This investigation discusses about the determination of Heat units for optimum sowing window

Research Category: Agricultural Meteorology

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