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To Study the Thermal Requirement of Soybean (*Glycine max*) Varieties under Varied Environment at Parbhani District, India

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A B S T R A C T

Soybean is an important pulse crop rich in food value. Maharashtra is accounting second place in production. The field experiment was conducted at Department of Agricultural Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani field entitled Study of Phenophagic thermal requirement of soybean (*Glycine max*) under varied environment at parbhani region. The experiment was laid in split plot design, gross plot size was 5.4 m x 3.6 m and 4.5 m x 2.7 m net plot size, replicated thrice in which four sowing dates were imposed as a main treatments and four varieties were tested as sub plot treatment. The crop was sown on 27 MW and MAUS-158 took maximum yield as compare to other treatments. The crop was sown on 27 MW took maximum growing degree days, photo thermal unit, helio-thermal unit to attend different phonological stages till maturity which reduced significantly with subsequent delay in sowing time. Among the varieties (MAUS-158) took highest calendar days growing degree days, photo thermal unit, helio-thermal unit to reach the maturity.

Introduction

Soybean is the third largest oil seed crop of India (Tiwari, 2003). Cultivation of soybean on large scale was started in selected state during the year 1971-1972 (Wasnik, 1986). Pulses and vegetable oils are the integral parts of Indian diet. The per capita availability of pulses and oils in India is 35 and 12 g/day as against recommended level of 85 and 45 g/day, respectively. The temperature is an important meteorological variables that affect plant growth and development (Londe and Woodward, 1988). Day light or bright sunshine hours play an important role in growth and development of soybean crop. Same varieties flower in less than 30 days after emergence if exposed to day light less than twelve hours (Beard and Knowles, 1973). Soybean is widely cultivated in tropical, subtropical and warm temperate regions of the world. Soybean grows well in warm and moist

climate. A temperature of 26 ^{0}C to 30 ^{0}C appears to be the optimum for most of the varieties. Soil temperature of 15.5 ^{0}C or above favour rapid germination and vigorous seedling growth. The minimum temperature for effective growth is about 10 ^{0}C. Days length is the key factor in most of the soybean varieties as they are short day plant and are sensitive to photoperiods. Most of the varieties will flower and mature quickly in grown under condition where the day length is less than 14 hrs provided that temperatures are also favorable. In view of above, a field experiment was undertaken to find out the growing degree days (GDD) photo thermal units (PTU) helio-thermal units (HTU) and Heat use efficiency at different phenophases of soybean crop in different sowing windows of soybean crop.

Materials and Methods

The field experiment was conducted at the department of agricultural meteorology, college of agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani field entitled study of thermal requirement of soybean (*Glycine max*) varieties under varied environment.

The experiment was laid in split plot design, gross plot size was 5.4 m x 3.6 m and 4.5 m x 2.7 m net plot size, replicated thrice in which four sowing dates were imposed as a main treatments and four varieties were tested as sub plot treatment. The entire recommended package of practices was adopted. The crop was harvested at physiological maturity stage.

Computation of agro-meteorological indices

Growing degree days (GDD)

Growing degree days defined as the total amount of heat required between the lower and upper thresholds, for an organisms to develop from one point to another in it's life cycle is calculated in units. The growing degree days (GDD) were worked out by considering the base temperature of 10 ^{0}C.

The total growing degree days (GDD) for different phenophases were calculated by using the following equation:

$$\text{Accumulated GDD} = \Delta \left[\frac{(Tmax + Tmin)/2}{ds}\right] - \frac{Tb}{dh}$$

Where,

GDD = Growing degree day

Tmax = Daily maximum temperature (°C)

Tmin = Daily minimum temperature (°C)

Tb = Base temperature (10°C)

Ds = Date of emergence

DH = Date of harvest.

Photo thermal units (PTU)

PTU = GDD × maximum sunshine hours (Rajput, 1980 and Pandey *et al.*, 2010).

Helio-thermal units (HTU)

The HTU may be defined as the accumulated product of GDD and bright sunshine hours between the developmental thresholds for each day.

The HTU is the product of GDD and the mean daily hours of bright sunshine. The sum of HTU for each phenophase was worked out by using the following equation:

HTU= (GDD × bright Sunshine hours.)

Results and Discussion

Post harvest studies

Seed yield and straw yield (kg/ha)

The data regarding grain yield and seed yield are presented in Table 1. The data on grain yield and straw yield indicated that the crop sown in D_2 MW-27 recorded higher grain yield (1655.2 Kg ha^{-1}) and (i.e. 2174.3 Kg ha^{-1}) found significantly superior over other treatments whereas the lowest yield was recorded in treatment D_4 Over all this year the crop recorded highest yield due to ample soil moisture during crop growing period. Similar result found that Anil Nath A *et al*., (2014). Statistical analysis of soybean cultivars showed significant result. During this year, variety MAUS-158 (V_2) produced higher seed yield and straw yield (1683.8 kg/ha) (1887.2 Kg ha^{-1}) and found significantly superior over the remaining treatments. It may be due to suitable weather conditions for the cultivar V_2 (MAUS 158). Similar result found by Chavan *et al*., (2018). The interaction effect between date of sowing and different cultivars was found to be non significant at all stages.

Biological yield (Kg ha^{-1})

The data regarding biological yield was significantly influenced by different treatments are presented in Table 1.The data presented in Table 1. indicated that crop sowed in D_2 (MW 27) recorded highest biological yield (i.e. 3829.4 Kg ha^{-1}) and found that the significantly superior over other sowing dates D_1 (MW 26), D_3 (MW 28) and D_4 (MW 29). Similar result were reported by Anil Nath *et al*., (2014).Statistical analysis of soybean cultivars showed significant results and presented in Table 1. Among the varietal treatments, cultivars V_2 (MAUS 158) produced higher biological yield (i.e. 3571.0 kg ha^{-1}) and found that the non-significantly superior over V_3 (MAUS 162) i.e. (2884.1 Kg ha^{-1}). Similar result was reported by Chavan *et al*., (2018) The interaction effect between date of sowing and varieties was found to be non-significant.

Harvest index

The data regarding harvest index is presented in Table 16 indicated that the mean harvest index was 46.0%. The sowing date D_4 (MW 29) recorded highest harvest index i.e.47.6 per cent and lowest harvest index i.e. 43.4 per cent was recorded in D_2 (MW 27).The cultivar V_2 (MAUS 158) recorded highest harvest index (i.e.47.8 per cent) and lowest harvest index was recorded by V_3 (MAUS162) (i.e. 44.0 per cent). Similar result was reported by Chavan K.K *et al*., (2018). The interaction effect between date of sowing and varieties was found to be non-significant.

Agro-meteorological indices

Growing degree days (GDD)

Growing degree days (GDD) for soybean crop under different sowing dates from sowing to maturity are presented in Table1. The data presented in Table1 revealed that the highest mean GDD was reported during D_1 (MW-26) 276.3 ^{0}C days and lowest D_3 (MW-28) 248.4 ^{0}C days and D_2 (MW-27) and to D_4 (MW-29) i.e.272.9 & 273.4 ^{0}C days respectively.

Whereas, D_1 (MW-26) treatment indicated more heat load than other treatment of date of sowing i.e. 276.3 ^{0}C days. It may be due to maximum air temperature observed at the time of sowing (MW-26). It is cleared that when the temperature of air was maximum then it will definitely affect GDD of soybean crop.

The data presented in Table 1 revealed that the mean GDD requirement of three varieties i,e. V1 (MAUS-71), V2 (MAUS-158), V3

(MAUS-162) i.e. 237.2^{0}C, 316.4 ^{0}C, 249.7 ^{0}C respectively. It may be occurs due to small crop duration, from emergence to maturity of such varieties. These results are in confirmatory with the work done by Chavan *et al.,* (2018) and Singh *et al.,* (2007).

Helio thermal units (HTU)

The data presented in Table 2. Helio-thermal units for each phenophase were different required by different dates of sowing. The mean helio-thermal units were observed, in date of sowing (D_1 to D_4) ranged from 1617.8 to 1656.7^{0}C days hours. The HTU were higher in fourth date of sowing i.e. 1656.7^{0}C days hours and lowest HTU were in D_3 (MW-28) i.e. 1446.4 ^{0}C days hours than rest of the treatments due to variation of temperature, bright sunshine and dry spell occurred during the crop growing season. The helio thermal units directly or indirectly affect the grain yield of soybean by delaying flowering, pod formation. Higher HTU are not conducive for better yield of soybean. The requirement of mean helio-thermal units of different variety during crop life cycle was ranged from 1362.8 ^{0}C days hours to 1390.3 ^{0}C days hours. It may be due to same crop duration in above three variety. Whereas, the HTU were highest in V_2 (MAUS-158) i.e. 1602.9^{0}C days hours than rest of the treatments due to variation of temperature, growing period, bright sunshine and dry spell occurred during the crop growing season. These results are in confirmatory with the work done by Chavan *et al.,* (2018) and Singh *et al.,* (2007).

Table.1 Mean seed yield (Kg ha^{-1}), straw yield (Kg ha^{-1}) and biological yield (Kg ha^{-1}), harvest index (%) of soybean as influenced by different treatments

Treatment	Seed yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Biological yield (Kg ha^{-1})	Harvest index %
Date of sowing				
D_1 (MW 26)	1391.9	1626.6	3018.4	46.1
D_2 (MW 27)	1655.2	2174.3	3829.4	43.4
D_3 (MW 28)	1497.0	1728.4	3225.4	46.9
D_4 (MW 29)	1287.6	1436.7	2724.3	47.6
S.E. ±	46.5	57.9	62.3	1.38
C.D. at 5 %	182.7	227.4	244.8	5.42
Cultivar				
V_1 (MAUS 71)	1440.3	1702.8	3143.1	46.2
V_2 (MAUS 158)	1683.8	1887.2	3571.0	47.8
V_3 (MAUS 162)	1249.7	1634.5	2884.1	44.0
S.E. ±	18.3	27.6	27.2	0.5
C.D. at 5 %	54.3	82.1	80.8	1.73
Interaction(D×V)				
S.E. ±	73.1	110.5	10.8.8	2.32
C.D. at 5 %	NS	NS	NS	NS
G. Mean	1457.9	1741.5	3199.3	46

Table.2 Growing Degree Day (GDD) at different phenophases of soybean crop under different treatments

Treatment	Phenophases of soybean										Total	Mean
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}		
Date of sowing												
D_1 (MW 26)	130.2	410.6	222.4	295.2	182.3	168.1	476.6	423.3	244..4	209.7	**2762.6**	**276.3**
D_2 (MW 27)	144.0	342.8	235.2	269.7	174.8	271.8	408.1	412.6	262.4	208.0	**2729.2**	**272.9**
D_3 (MW 28)	154.0	419.7	217.1	161.5	174.2	172.0	441.6	247.5	254.4	241.5	**2483.5**	**248.4**
D_4 (MW 29)	155.9	392.7	180.3	326.5	147.5	176.8	445.7	459.5	266.6	183.1	**2734.7**	**273.5**
Cultivars												
V_1 (MAUS-71)	155.5	337.5	232.4	263.6	180.6	202.3	302.9	334.1	226.9	176.1	**2371.8**	**237.2**
V_2 (MAUS-158)	187.4	448.7	232.8	307.1	187.2	225.6	624.9	391.8	298.3	260.2	**3163.9**	**316.4**
V_3 (MAUS-162)	135.2	388.2	176.2	218.9	141.4	163.6	401.2	431.3	245.6	195.3	**2746.5**	**249.7**
Mean	**146.0**	**391.4**	**213.8**	**263.2**	**169.7**	**197.2**	**443.0**	**385.7**	**256.9**	**210.6**	**2713.2**	**267.7**

P_1- Sowing to emergence
P_2- Emergence to seedling
P_3-Seedling to branching
P_4-Branching to flowering
P_5-Flowering to pod formation
P_6-Pod formation to grain formation
P_7-seed formation to pod development
P_8-Pod development to pod containing full grain size
P_9-Pod containing full grain size to dough stage
P_{10}-Dough stage to maturity

Table.3 Helio thermal unit (HTU) at different phenophases of soybean crop under different treatments

Treatment	Phenophases of soybean										Total	Mean
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}		
Date of sowing												
D_1 (MW 26)	491.7	996.3	780.0	832.3	1187.1	808.0	3728.9	3294.5	2205.0	1854.3	**16178.0**	**1617.8**
D_2 (MW 27)	501.1	920.1	1211.9	618.5	598.0	1697.4	2810.4	3419.7	2332.2	1654.8	**15764.1**	**1576.4**
D_3 (MW 28)	551.6	1122.9	999.4	508.8	701.5	1136.7	3351.8	1777.5	2197.5	2116.6	**14464.3**	**1446.4**
D_4 (MW 29)	449.9	1511.8	356.3	1149.9	1049.5	1036.0	3192.7	3858.4	2336.9	1622.5	**16563.9**	**1656.3**
Cultivars												
V_1 (MAUS-71)	291.7	853.3	1211.2	552.7	995.1	1271.8	2236.1	2604.8	2019.2	1592.4	**13628.3**	**1362.8**
V_2 (MAUS-158)	453.2	1216.6	639.5	1032.9	1136.1	1457.5	2006.6	3491.9	2660.7	1934.1	**16029.0**	**1602.9**
V_3 (MAUS-162)	300.8	968.5	660.0	696.6	720.8	979.3	2677.7	3165.9	2123.7	1609.7	**13903.0**	**1390.3**
Mean	**434.3**	**1084.2**	**836.9**	**770.3**	**912.6**	**1198.1**	**2857.7**	**3087.5**	**2267.9**	**1769.2**	**15218.7**	**1521.8**

P_1- Sowing to emergence
P_2- Emergence to seedling
P_3-Seedling to branching
P_4-Branching to flowering
P_5-Flowering to pod formation
P_6-Pod formation to grain formation
P_7-seed formation to pod development
P_8-Pod development to pod containing full grain size
P_9-Pod containing full grain size to dough stage
P_{10}-Dough stage to maturity

Table.4 Photo thermal unit (PTU) at different phenophases of soybean crop under different treatments

Treatment	Phenophases of soybean										Mean
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	
Date of sowing											
D_1 (MW 26)	6294.3	12752.1	11983.5	10653.9	15195.0	10342.1	40472.4	42828.1	28664.6	24106.3	**20329.2**
D_2 (MW 27)	6413.5	15377.8	15511.7	17917.2	17654.3	12726.3	46535.4	44456.1	30318.3	21512.9	**22842.4**
D_3 (MW 28)	6660.1	14373.5	12792.3	13953.0	18978.8	14549.7	43573.9	43107.1	28567.8	27516.0	**22407.2**
D_4 (MW 29)	6478.3	19351.0	14561.2	14718.8	13433.1	13261.0	41505.1	50159.5	30379.8	21092.1	**22494.0**
Cultivar											
V_1 (MAUS-71)	3733.5	10922.0	15503.3	15794.6	12737.9	16278.6	29069.3	39862.1	26249.8	20701.4	**19085.3**
V_2 (MAUS-158)	5801.0	15572.3	18185.6	13220.7	14542.1	18655.6	39087.6	45394.2	24589.4	29043.4	**22409.2**
V_3 (MAUS-162)	3850.2	12396.6	18447.7	18916.8	16666.0	18975.1	34809.8	41156.8	27608.7	20925.7	**21375.4**
Mean	**5604.4**	**14392.2**	**15283.6**	**15025.0**	**15601.0**	**14969.8**	**39293.3**	**43852.0**	**28054.1**	**23556.8**	**21563.2**

P_1- Sowing to emergence
P_2- Emergence to seedling
P_3-Seedling to branching
P_4-Branching to flowering
P_5-Flowering to pod formation
P_6-Pod formation to grain formation
P_7-seed formation to pod development
P_8-Pod development to pod containing full grain size
P_9-Pod containing full grain size to dough stage
P_{10}-Dough stage to maturity

Photo-thermal unit (PTU)

The variation in PTU in different treatments at earing and maturity has been presented in (Table 3). The varieties sown on 27 MW required maximum PTU till maturity which was superior over 26 MW, 28 MW and 29 MW sown crop at all stages. MAUS-158 requires maximum PTU at all stage which was significantly superior over rest of varieties. The higher PTU value in early sown crop may be due to fact that crop took longer duration to reach Phonological stages. These results are in confirmatory with the work done by Chavan *et al.,* (2018).

It is cleared that, when the temperature of air was maximum then it will definitely affect GDD of soybean crop. The total GDD was higher in D_1 (MW-26) *i.e*. 276.3 ^{0}C days than rest of the treatments, whereas the lowest total GDD was recorded in D_3 (MW-28) *i.e.* 284.4^{0}C days. Varieties V_2 (MAUS-158) was highest mean GDD over the rest of varieties. Helio thermal units directly or indirectly affect the grain yield of soybean by delaying flowering and pod formation.

The requirement of HTU was higher (1656.7) in D_4 (MW-29), whereas HTU requirement was lower (1446.4) in D_3 (MW-28) treatment. The mean helio thermal units was reported in three varieties MAUS-158 variety was more HTU over the rest of treatment.

The total PTU was higher in D_2 (MW-27) than rest of the treatments, whereas while varieties V_2 (MAUS-158) was highest PTU over the rest of varieties.

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