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Study the heat unit requirement of soybean (*Glycine max*) varieties under varied weather condition at Parbhani

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Abstract
The field experiment was conducted at department of agricultural meteorology, college of agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani field entitled Performance of soybean (*Glycine max*) varieties under varied weather condition. 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 took maximum calendar days, 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. The grain yield recorded in 27 MW were significantly highest to rest of sowing dates. The significant reduction in grain yield of timely sown varieties was recorded when sowing was delayed sowing dates. Among the varieties highest grain yield of 2611 kg ha^{-1} was recorded in varieties MAUS-158, which was significantly superior over MAUS-71, MAUS-81 and JS-335. Among the varieties (MAUS-158) took highest calendar days growing degree days, photo thermal unit, helio-thermal unit to reach the maturity. The variety (MAUS-158) recorded the highest grain yield at 27 MW sowing as compared to all other sowing dates.

Keywords: Grain yield, growing degree day, photo-thermal units, helio thermal units, rainfall, temperature

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) [7]. 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) [4]. 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) [1]. 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 favourable. 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.

Material and Methods
The field experiment was conducted at the department of agricultural meteorology, college of agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani field entitled Performance of soybean (*Glycine max*) varieties under varied weather condition.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 were adopted. The crop was harvested at physiological maturity stage.

Harvest index

It is the per cent of economical yield to the total biological yield. Harvest index reflects the proportion of assimilate distribution between economical and total biomass (Donald and Hamblin, 1976) [2].

It was computed by using following formula:

$$HI = \frac{\text{Total grain yield}}{\text{Total biological yield}}$$

Heat use efficiency (HUE) [(kg/ha) / ºC day]

$$HUE = \frac{\text{Total grain yield (kg/ha)}}{\text{Accumulated GDD (ºC days)}}$$

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:

$$\text{Accumulated GDD} = \sum_{ds}^{dh} [(T_{max} + T_{min})/2] - Tb$$

Where,

GDD = Growing degree day

Tmax = Daily maximum temperature (^{0}C)

Tmin = Daily minimum temperature (^{0}C)

Tb = Base temperature (10 ^{0}C)

Ds = Date of emergence

DH = Date of harvest.

Photo thermal units (PTU)

PTU = GDD × maximum sunshine hours (Rajput, 1980; Pandey *et al*. 2010) [10, 9]

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

Harvest index

The data on harvest index are presented in Table 1 indicated that the mean harvest index was 53.7.

Date of sowing

Harvest index did not show much variation and ranged between 52.9 to 54.3 per cent. The sowing date D_4 (MW-30) recorded more harvest index *i.e*. 54.3 and it was followed by D_2 (MW-28), D_1 (MW-27) and D_3 (MW-29) *i.e.* 53.9, 53.4 and 52.9, respectively.

Cultivars

The cultivar V_1 (MAUS-158) recorded more harvest index and ranked first in all genotypes *i.e.* 56.3 and it was followed by V_2 (MAUS-71), V_4 (JS-335) and V_3 (MAUS-81). The lowest harvest index was recorded in V_3 (MAUS-81) *i.e*. 51.8.

Post-harvest studies

Grain yield and straw yield (kg/ha)

The data regarding grain yield are presented in Table 1.

Date of sowing

The data on grain yield and straw yield indicated that the crop sown in D_1 MW-27 (02-08 July) recorded higher grain yield (3021 kg/ ha) and (2939 kg/ ha) found significantly superior over other treatments whereas the lowest yield was recorded in treatment D4 (23-29 July). Over all this year the crop recorded highest yield due to ample soil moisture during crop growing period. Similar result found that Patil *et al.* (2014).

Cultivars

Statistical analysis of soybean cultivars showed significant result. During this year, variety MAUS-158 (V_1) produced higher grain yield (2611 kg/ha) and found significantly superior over the remaining treatments. Whereas, the variety V_3 (MAUS-81) produced lowest grain yield (2242 kg/ha). Similar result found that Patil *et al.* (2014).

Interaction

The interaction effect between date of sowing and different cultivars was found to be non-significant at all stages and the results to that effect are presented in Table 1.

Heat use efficiency

Data in Table 1 show that the highest HUE in D_1 (27 MW) sown crop could be ascribed by proportionate increasing dry matter per each heat unit absorbed. The lower HUE in delayed sowing can be expected due to accumulation of comparable GDD to that of early sowing at later crop growth stages and variety MAUS-158 was more HUE over the rest of varieties.

Table 1: Mean grain yield (kg/ha), straw yield (kg/ha), biological yield (kg/ha), Harvest index and HUE as influenced by different treatments

Treatment	Seed yield kg ha^{-1}	Straw yield kg ha^{-1}	Biological yield kg ha^{-1}	Harvest index %	Heat use efficiency
Date of sowing					
D_1 (MW 27)	3021	2639	5660	53.4	1.78
D_2 (MW 28)	2515	2146	4660	53.9	1.53
D_3 (MW 29)	2441	2162	4603	52.9	1.51
D_4 (MW 30)	1741	1462	3203	54.3	1.12
S.E. ±	56.19	96.06	94.00	1.39	.....
C.D. at 5%	166.70	51.41	278.90	NS	
Cultivar					
V_1 (MAUS 158)	2611	2033	4644	56.3	1.59
V_2 (MAUS 71)	2454	2135	4589	53.5	1.52

V_3 (MAUS 81)	2242	2090	4332	51.8	1.39
V_4 (JS-335)	2412	2150	4562	52.9	1.46
S.E. ±	59.09	51.40	83.56	0.86	.....
C.D. at 5%	175.33	NS	NS	2.57	
Interaction(D×V)					
SE. ±	118.18	102.81	167.12	1.7	.....
CD. at 5%	NS	NS	NS	NS	
GM	2430	2102	4532	53.7	

Effect of Rainfall and temperature

Rainfall and Temperatures during vegetative and reproductive stage are presented in (Table 2). Data shows that soybean crop sown under different sowing dates had exposed to various thermal regimes during vegetative and reproductive phase of the crop. It was noted that 27 MW sown crop experienced higher total rainfall and mean minimum temperature during vegetative phase. However, during reproductive phase, later sowing dates that is, 27 MW experienced higher total rainfall, minimum and mean temperatures as compared to late sowing dates but maximum temperature was more in later sowing dates.

Table 2: Rainfall (mm) and Temperatures (°C) during vegetative and reproductive phase of soybean.

Sowing dates	Vegetative stage				Reproductive stage			
	Rainfall (mm)	T_{max} (^{0}C)	T_{min} (^{0}C)	T_{mean} ^{0}C)	Rainfall (mm)	T_{max} (^{0}C)	T_{min} (^{0}C)	T_{mean} (^{0}C)
D_1 (27 MW)	412.2	30.5	22.8	26.7	560.0	30.9	21.3	26.2
D_2 (28 MW)	309.5	30.8	22.1	26.5	572.6	31.2	20.8	26.0
D_3 (29 MW)	219.7	31.7	22.0	26.8	547.0	31.1	20.2	25.7
D_4 (30 MW)	268.5	31.3	22.2	26.8	475.5	31.0	19.1	25.1

Agro-meteorological indices

The data recorded on these aspects were not subjected to 'F' test of variances and results are interpreted on the basis of values.

Growing degree days (GDD)

Growing degree days (GDD) for soybean crop under different sowing dates from sowing to maturity are presented in Table 3. The data presented in Table 3 revealed that the highest mean heat load was reported during D_1 (MW-27) 169.5 ^{o}C days and lowest D_4 (MW-28) 156.0 ^{o}C days and D_2 (MW-28) and to D_3 (MW-29) i.e. 163.9 & 161.3 ^{o}C days respectively. It may be due to dry spell occurred during crop life cycle. Whereas, D_1 (MW-27) treatment indicated more heat load than other treatment of date of sowing i.e. 169.5 ^{0}C days. It may be due to maximum air temperature observed at the time of sowing (MW-27). 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 3 revealed that the mean heat requirement of variety during crop life cycle ranged from 164.7 ^{0}C to 161.5 ^{0}C. The mean heat load reported was 4 varieties V_1 (MAUS-158), V_2 (MAUS-71), V_3 (MAUS-81) and V_4 (JS-335) i.e. 164.7 ^{0}C, 161.5 ^{0}C, 161.5 ^{0}C and 163.3 ^{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 Kumar *et al*. (2008) [3], Singh *et al*. (2007) [6] and Neog *et al*. (2008) [5].

Table 3: Phenophase wise (GDD) required for different dates of sowing and varieties of soybean.

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 27)	66.7	249.4	117.8	156.9	87.7	113.2	283.1	285.6	187.9	146.9	1695.1	169.5
D_2 (MW 28)	79.2	241.6	92.2	184.4	81.2	119.9	260.1	299.9	159.9	121.0	1639.2	163.9
D_3 (MW 29)	87.2	242.4	120.0	165.2	103.6	97.1	221.7	266.6	177.3	132.5	1613.3	161.3
D_4 (MW 30)	103.9	209.2	99.2	205.1	80.1	94.5	249.6	276.5	147.4	94.6	1559.6	156.0
Cultivars												
V_1 (MAUS-158)	64.6	242.3	113.1	161.5	80.8	113.1	274.6	290.7	193.8	145.4	1647.3	164.7
V_2 (MAUS-71)	80.8	226.1	96.9	177.7	80.8	113.1	258.4	306.9	177.7	129.2	1615.0	161.5
V_3 (MAUS-81)	80.8	242.3	113.1	161.5	96.9	96.9	226.1	274.6	177.7	145.4	1615.0	161.5
V4 (JS-335)	96.9	226.1	96.9	193.8	80.8	113.1	258.4	274.6	161.5	113.1	1654.0	163.3
Mean	82.5	234.9	106.1	175.8	86.5	107.6	254.0	284.4	172.9	128.5	1654.0	163.3

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-Grain formation to pod development, P_8-Pod development to pod containing full size P_9-Pod containing full size to dough stage P_{10}-Dough stage to maturity

Helio thermal units (HTU)

The data presented in Table 4. 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 816.1 to 954.4 ^{o}C days hours. The HTU were higher in fourth date of sowing i.e. 954.4 ^{o}C days hours and lowest HTU were in D_1 (MW-27) i.e. 816.1 ^{o}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 932.3 ^{0}C days hours to 969.5 ^{0}C days hours. It may be due to same crop duration in above four variety. Whereas, the HTU were lowest in V_4 (JS-335) i.e. 932.3 ^{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 Kumar *et al*. (2008) [3], Patil *et al*. (2017), Singh *et al*. (2007) [6] and Neog *et al*. (2008) [5].

Table 4: Phenophase wise (HTU) required for different dates of sowing and varieties of soybean.

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 27)	73.3	947.7	529.9	549.2	587.3	758.4	1953.4	714.0	901.9	1145.8	8160.9	816.1
D_2 (MW 28)	411.8	869.6	276.5	1143.3	592.8	1006.7	1300.3	809.6	1135.3	1161.6	8707.4	870.7
D_3 (MW 29)	270.2	1017.9	683.7	1371.2	787.4	407.8	997.4	1172.8	1577.5	1205.8	9491.6	949.2
D_4 (MW 30)	508.9	941.2	822.9	1578.9	216.1	831.2	474.1	1907.5	1355.6	907.7	9544.1	954.4
Cultivars												
V_1 (MAUS-158)	372.9	1398.4	652.6	932.3	466.1	652.6	1584.8	1678.1	1118.7	839.0	9695.5	969.5
V_2 (MAUS-71)	466.1	1305.2	559.4	1025.5	466.1	652.6	1491.6	1771.3	1025.5	745.8	9509.0	950.9
V_3 (MAUS-81)	466.1	1398.4	652.6	932.3	559.4	559.4	1305.2	1584.8	1025.5	839.0	9322.6	932.3
V4 (JS-335)	559.4	1305.2	559.4	1118.7	466.1	652.6	1491.6	1584.8	932.3	652.6	9322.6	932.3
Mean	372.9	1398.4	652.6	932.3	466.1	652.6	1584.8	1678.1	1118.7	839.0	9695.5	969.5

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-Grain formation to pod development, P_8-Pod development to pod containing full size P_9-Pod containing full size to dough stage P_{10}-Dough stage to maturity

Effect on photo-thermal unit (PTU)

The variation in PTU in different treatments at earing and maturity has been presented in (Table 5). The varieties sown on 27 MW required maximum PTU till maturity which was superior over 28 MW, 29 MW and 30 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 Phenological stages.

Table 5: Phenophase wise (PTU) required for different dates of sowing and varieties of soybean.

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 27)	793.1	2967.9	1401.2	1867.1	999.2	1290.5	3085.8	3113.0	2048.1	1601.2	19167.2	1916.7
D_2 (MW 28)	942.5	2874.4	1096.6	2194.4	925.7	1366.3	2834.5	3268.4	1742.9	1318.9	18564.6	1856.5
D_3 (MW 29)	1037.1	2884.0	1427.4	1965.9	1181.0	1106.9	2416.0	2905.4	1932.0	1444.3	18300.0	1830.0
D_4 (MW 30)	1235.8	2488.9	1179.9	2440.1	912.6	1076.7	2720.1	3013.3	1606.1	1030.6	17704.1	1770.4
Cultivars												
V_1 (MAUS-158)	768.7	2882.8	1345.3	1921.9	920.6	1288.8	2992.6	3168.6	2112.4	1584.3	18985.9	1898.6
V_2 (MAUS-71)	960.9	2690.6	1153.1	2114.0	920.6	1288.8	2816.6	3344.7	1936.4	1408.3	18633.9	1863.4
V_3 (MAUS-81)	960.9	2882.8	1345.3	1921.9	1104.7	1104.7	2464.5	2992.6	1936.4	1584.3	18298.0	1829.8
V4 (JS-335)	1153.1	2690.6	1153.1	2306.2	920.6	1288.8	2816.6	2992.6	1760.4	1232.2	18314.1	1831.4
Mean	981.5	2795.2	1262.7	2091.4	985.6	1226.4	2768.3	3099.8	1884.3	1400.5	18496.0	1849.6

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-Grain formation to pod development, P_8-Pod development to pod containing full size P_9-Pod containing full size to dough stage P_{10}-Dough stage to maturity

Conclusion

The 27 MW recorded the highest grain yield, Straw yield and HUE which was statistically significant of rest of treatment. 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-27) *i.e*. 1695.1 ^{0}C days followed by D_2 (MW-28) than rest of the treatments, whereas the lowest total GDD was recorded in D_4 (MW-30) *i.e.* 1559.6 ^{0}C days. Varieties V_1 (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 (954.4) in D_4 (MW-30), whereas HTU requirement was lower (816.1) in D_1 (MW-27) treatment. The mean helio thermal units was reported in four varieties MAUS-158 variety was more HTU over the rest of treatment. The total PTU was higher in D_1 (MW-27) followed by D_2 (MW-28) than rest of the treatments, whereas while varieties V_1 (MAUS-158) was highest PTU over the rest of varieties.

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