Original Research Article

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 °C to 30 °C appears to be the optimum for most of the varieties. Soil temperature of 15.5 °C or above favour rapid germination and vigorous seedling growth. The minimum temperature for effective growth is about 10 °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 °C.

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

\[
\text{Accumulated GDD} = \Delta \left( \frac{T_{\text{max}} + T_{\text{min}}}{2} \right) - T_b
\]

Where,

- \(GDD\) = Growing degree day
- \(T_{\text{max}}\) = Daily maximum temperature (°C)
- \(T_{\text{min}}\) = Daily minimum temperature (°C)
- \(T_b\) = Base temperature (10°C)
- \(D_s\) = Date of emergence
- \(D_H\) = Date of harvest.

**Photo thermal units (PTU)**

\[
\text{PTU} = GDD \times \text{maximum sunshine hours}
\]

(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:

\[
\text{HTU} = (GDD \times \text{bright Sunshine hours})
\]
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 D2 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 D4. 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 (V2) 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 V2 (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.

Harvest index

The data regarding harvest index is presented in Table 16 indicated that the mean harvest index was 46.0%. The sowing date D4 (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 D2 (MW 27).The cultivar V2 (MAUS 158) recorded highest harvest index (i.e.47.8 per cent) and lowest harvest index was recorded by V3 (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 D1 (MW-26) 276.3 °C days and lowest D3 (MW-28) 248.4 °C days and D2 (MW-27) and D4 (MW-29) i.e.272.9 & 273.4 °C days respectively.

Whereas, D1 (MW-26) treatment indicated more heat load than other treatment of date of sowing i.e. 276.3 °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°C, 316.4°C, 249.7°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 (D1 to D4) ranged from 1617.8 to 1656.7°C days hours. The HTU were higher in fourth date of sowing i.e. 1656.7°C days hours and lowest HTU were in D3 (MW-28) i.e. 1446.4 °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 °C days hours to 1390.3 °C days hours. It may be due to same crop duration in above three variety. Whereas, the HTU were highest in V2 (MAUS-158) i.e. 1602.9°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).

| Treatment | Seed yield (Kg ha⁻¹) | Straw yield (Kg ha⁻¹) | Biological yield (Kg ha⁻¹) | Harvest index % |
|-----------|----------------------|----------------------|---------------------------|-----------------|
| Date of sowing |                     |                      |                           |                 |
| D1 (MW 26) | 1391.9               | 1626.6               | 3018.4                    | 46.1            |
| D2 (MW 27) | 1655.2               | 2174.3               | 3829.4                    | 43.4            |
| D3 (MW 28) | 1497.0               | 1728.4               | 3225.4                    | 46.9            |
| D4 (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   |                      |                      |                           |                 |
| V1 (MAUS 71)| 1440.3               | 1702.8               | 3143.1                    | 46.2            |
| V2 (MAUS 158)| 1683.8              | 1887.2               | 3571.0                    | 47.8            |
| V3 (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 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
Table 2 Growing Degree Day (GDD) at different phenophases of soybean crop under different treatments

| Treatment | Date of sowing | Phenophases of soybean | Total | Mean |
|-----------|----------------|------------------------|-------|------|
|           |                | P₁ | P₂ | P₃ | P₄ | P₅ | P₆ | P₇ | P₈ | P₉ | P₁₀ |       |
| D₁ (MW 26) |                | 130.2 | 410.6 | 222.4 | 295.2 | 182.3 | 168.1 | 476.6 | 423.3 | 244.4 | 209.7 | 2762.6 |
| D₂ (MW 27) |                | 144.0 | 342.8 | 235.2 | 269.7 | 174.8 | 271.8 | 408.1 | 412.6 | 262.4 | 208.0 | 2729.2 |
| D₃ (MW 28) |                | 154.0 | 419.7 | 217.1 | 161.5 | 174.2 | 172.0 | 441.6 | 247.5 | 254.4 | 241.5 | 2483.5 |
| D₄ (MW 29) |                | 155.9 | 392.7 | 180.3 | 326.5 | 147.5 | 176.8 | 445.7 | 459.5 | 266.6 | 183.1 | 2734.7 |

| Cultivars |                | P₁ | P₂ | P₃ | P₄ | P₅ | P₆ | P₇ | P₈ | P₉ | P₁₀ |       |
|-----------|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| V₁ (MAUS-71) |                | 155.5 | 337.5 | 232.4 | 263.6 | 180.6 | 202.3 | 302.9 | 334.1 | 226.9 | 176.1 | 2371.8 |
| V₂ (MAUS-158) |                | 187.4 | 448.7 | 232.8 | 307.1 | 187.2 | 225.6 | 624.9 | 391.8 | 298.3 | 260.2 | 3163.9 |
| V₃ (MAUS-162) |                | 135.2 | 388.2 | 176.2 | 218.9 | 141.4 | 163.6 | 401.2 | 431.3 | 245.6 | 195.3 | 2746.5 |
| Mean      |                | 146.0 | 391.4 | 213.8 | 263.2 | 169.7 | 197.2 | 443.0 | 385.7 | 256.9 | 210.6 | 2713.2 |

P₁- Sowing to emergence  
P₂- Emergence to seedling  
P₃- Seedling to branching  
P₄- Branching to flowering  
P₅- Flowering to pod formation  
P₆- Pod formation to grain formation  
P₇- Seed formation to pod development  
P₈- Pod development to pod containing full grain size  
P₉- Pod containing full grain size to dough stage  
P₁₀- 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 |
|---------------|------------------------|-------|------|
|               | P₁ | P₂  | P₃  | P₄  | P₅  | P₆  | P₇  | P₈  | P₉  | P₁₀ |       |
| **Date of sowing** |       |       |       |       |       |       |       |       |       |      |       |
| D₁ (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 |
| D₂ (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 |
| D₃ (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 |
| D₄ (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** |       |       |       |       |       |       |       |       |       |      |       |
| V₁ (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 |
| V₂ (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 |
| V₃ (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 |

P₁- Sowing to emergence  
P₂- Emergence to seedling  
P₃- Seedling to branching  
P₄- Branching to flowering  
P₅- Flowering to pod formation  
P₆- Pod formation to grain formation  
P₇- Seed formation to pod development  
P₈- Pod development to pod containing full grain size  
P₉- Pod containing full grain size to dough stage  
P₁₀- Dough stage to maturity

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

| Treatment   | Phenophases of soybean | Mean          |
|-------------|------------------------|---------------|
|             | P₁          | P₂         | P₃           | P₄           | P₅         | P₆         | P₇       | P₈       | P₉          | P₁₀         |
| Date of sowing |              |             |              |              |             |             |          |          |              |             |
| D₁ (MW 26)  | 6294.3      | 12752.1    | 11983.5      | 10653.9      | 15195.0    | 10342.1    | 40472.4  | 42828.1  | 28664.6     | 24106.3     | **20329.2** |
| D₂ (MW 27)  | 6413.5      | 15377.8    | 15511.7      | 17917.2      | 17654.3    | 12726.3    | 46535.4  | 44456.1  | 30318.3     | 21512.9     | **22842.4** |
| D₃ (MW 28)  | 6660.1      | 14373.5    | 12792.3      | 13953.0      | 18978.8    | 14549.7    | 43573.9  | 43107.1  | 28567.8     | 27516.0     | **22407.2** |
| D₄ (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    |             |             |              |              |             |             |          |          |              |             |             |
| V₁ (MAUS-71)| 3733.5      | 10922.0    | 15503.3      | 15794.6      | 12737.9    | 16278.6    | 29069.3  | 39862.1  | 26249.8     | 20701.4     | **19085.3** |
| V₂ (MAUS-158)| 5801.0    | 15572.3    | 18185.6      | 13220.7      | 14542.1    | 18655.6    | 39087.6  | 45394.2  | 24589.4     | 29043.4     | **22409.2** |
| V₃ (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** |

P₁: Sowing to emergence  
P₂: Emergence to seedling  
P₃: Seedling to branching  
P₄: Branching to flowering  
P₅: Flowering to pod formation  
P₆: Pod formation to grain formation  
P₇: Flowering to pod development  
P₈: Pod development to pod containing full grain size  
P₉: Pod containing full grain size to dough stage  
P₁₀: 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 D₁ (MW-26) i.e. 276.3 ⁰C days than rest of the treatments, whereas the lowest total GDD was recorded in D₃ (MW-28) i.e. 284.4⁰C days. Varieties V₂ (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 D₄ (MW-29), whereas HTU requirement was lower (1446.4) in D₃ (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 D₂ (MW-27) than rest of the treatments, whereas while varieties V₂ (MAUS-158) was highest PTU over the rest of varieties.

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