

# Growing degree days (GDD), heliothermal units (HTU) as influenced by sowing periods and varieties in soybean

■ S.R. PATIL, M.G. JADHAV AND J.D. JADHAV

## SUMMARY

The field experiment was conducted at the department field to assess the crop weather relationship in different cultivars of soybean. 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 six varieties were tested as sub plot treatment. The GDD was higher in D<sub>2</sub> (MW-28) *i.e.* 164.20C followed by D<sub>3</sub> (MW-29) than rest of the treatments, whereas the lowest GDD was recorded in D<sub>4</sub> (MW-30) *i.e.* 150.80C. Mean heat load was reported same in four varieties V<sub>2</sub> (MAUS-71), V<sub>3</sub> (MAUS-81), V<sub>4</sub> (MAUS-158) and V<sub>6</sub> (JS-9305) *i.e.* 160.90C, it may be due to same crop duration in above four varieties. Whereas, V<sub>1</sub> (MAUS-47) variety indicated less heat load than other variety *i.e.* 147.30C it may be due to small crop duration from emergence to maturity of such variety. Helio thermal units directly or indirectly affect the grain yield of soybean by delaying flowering and pod formation. The requirement of HTU was higher (925.0) in D<sub>2</sub> (MW-28), whereas HTU requirement was lower (825.8) in D<sub>1</sub> (MW-27) treatment. The mean helio thermal units was reported same in four varieties V<sub>2</sub> (MAUS-71), V<sub>3</sub> (MAUS-81), V<sub>4</sub> (MAUS-158) and V<sub>6</sub> (JS-9305) *i.e.* 915.0°C. It may be due to the same crop duration in above four varieties. Whereas, lowest helio thermal unit was recorded in V<sub>1</sub> (MAUS-47) *i.e.* 823.5°C.

**Key Words :** Growing degree days, Heliothermal units, Periods, Varieties

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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 favourable.

In view of above, a field experiment was undertaken to find out the growing degree days (GDD) and helio-thermal units (HTU) at different phenophases of soybean crop in different sowing windows of soybean crop.

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## MATERIAL AND METHODS

The field experiment was conducted at the department field to assess the crop weather relationship in different cultivars of soybean. 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 six varieties were tested as sub plot treatment. The entire recommended package of practices were adopted. The crop was harvested at physiological maturity stage.

### Leaf area index (LAI) :

Leaf area index is the measure of crop growth per unit area since the crop yield is to be assessed per unit of ground area instead of per plant. Therefore, the leaf area existing on one plant was considered as leaf produced on unit ground area (actual area of plant). This was proposed by Watson (1952). The measured is known as leaf area index (LAI) and it was calculated by using following formula:

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Ground area per plant (cm}^2\text{)}}$$

### 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).

It was computed by using following formula:

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

### 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:

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

where,

GDD	=	Growing degree day
T <sub>max</sub>	=	Daily maximum temperature (°C)
T <sub>min</sub>	=	Daily minimum temperature (°C)
T <sub>b</sub>	=	Base temperature (10 °C)
D <sub>s</sub>	=	Date of emergence
D <sub>h</sub>	=	Date of harvest.

#### 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:

$$\text{Accumulated HTU} = d \left[ \frac{(T - T_b) D}{D_s} \right] - T_b$$

where,

HTU	=	Helio-thermal units
T	=	Mean daily temperature (°C)
T <sub>b</sub>	=	Base temperature
d <sub>s</sub>	=	Date of emergence
d <sub>h</sub>	=	Date of harvest
D	=	Hours of bright sunshine.

## RESULTS AND DISCUSSION

The data collected during the investigation have been analyzed by using appropriate statistical methods.

#### Mean leaf area per plant (dm<sup>2</sup>) :

The data on mean leaf area (dm<sup>2</sup>) per plant as influenced by different treatments at 15 days interval are presented in Table 1 .

#### Date of sowing:

The data on mean leaf area (dm<sup>2</sup>) per plant were influenced significantly by different date of sowing, at all stages of crop growth. Mean leaf area was observed significantly more in D<sub>1</sub> (MW-27) than other treatments.

#### Cultivars:

The mean leaf area was influenced significantly by different cultivars at all stages of crop growth. Mean leaf area was observed significantly more in D<sub>1</sub> (MW-27) than other treatments.

#### Interaction (DxV):

The interaction effect between date of sowing and different cultivars was found to be non significant at all stages.

### Growth analysis:

#### Mean leaf area index :

The data on mean leaf area index (LAI) per plant as influenced by different treatment at 15 at days interval are presented in Table 2.

#### Date of sowing:

The data on mean leaf area index (LAI) per plant were influenced significantly by different date of sowing at all stages of crop growth. Mean leaf area was significantly more in D<sub>1</sub>

(MW-27) than other treatments.

**Cultivars:**

The mean leaf area index was influenced significantly by different cultivars at all stages of crop growth, V<sub>4</sub> (MAUS-158) produced more leaf area than other cultivars.

**Harvest index:**

The data on harvest index are presented in Table 3 indicated that the mean harvest index was 40.06.

**Date of sowing:**

Harvest index did not show much variation and ranged

**Table 1 : Mean leaf area (dm<sup>2</sup>) per plant of soybean as influenced by different treatments**

Treatments	Days after sowing				
	30	45	60	75	At harvest
<b>Date of sowing</b>					
D <sub>1</sub> (MW-27)	12.15	16.72	23.24	32.45	20.84
D <sub>2</sub> (MW-28)	10.84	14.22	21.66	28.58	19.30
D <sub>3</sub> (MW-29)	11.62	15.71	22.40	30.27	19.98
D <sub>4</sub> (MW-30)	9.85	13.42	21.02	27.33	19.21
S.E. ±	0.05	0.03	0.07	0.04	0.11
C.D. at 5%	0.16	0.09	0.19	0.12	0.33
<b>Cultivars</b>					
V <sub>1</sub> (MAUS-47)	9.10	12.94	18.15	26.37	17.55
V <sub>2</sub> (MAUS-71)	12.22	16.10	24.30	31.42	21.27
V <sub>3</sub> (MAUS-81)	11.16	14.81	21.13	29.30	19.25
V <sub>4</sub> (MAUS-158)	12.64	16.80	25.30	32.13	21.91
V <sub>5</sub> (JS-93-05)	9.89	13.95	20.18	28.05	18.56
V <sub>6</sub> (JS-335)	11.83	15.50	23.51	30.53	20.44
S.E. ±	0.07	0.06	0.10	0.14	0.12
C.D. at 5%	0.20	0.19	0.29	0.40	0.36
<b>Interaction (D x V)</b>					
S.E. ±	0.15	0.13	0.21	0.28	0.24
C.D. at 5%	NS	NS	NS	NS	NS
<b>G. mean</b>	11.15	15.01	22.08	29.63	19.83

NS= Non-significant

**Table 2 : Mean leaf area index (LAI) as influenced by different treatments**

Treatments	Days after sowing				
	30	45	60	75	At harvest
<b>Date of sowing</b>					
D <sub>1</sub> (MW-27)	0.54	0.74	1.03	1.44	0.92
D <sub>2</sub> (MW-28)	0.48	0.63	0.96	1.27	0.85
D <sub>3</sub> (MW-29)	0.51	0.69	0.99	1.34	0.88
D <sub>4</sub> (MW-30)	0.43	0.59	0.93	1.21	0.85
<b>Cultivars</b>					
V <sub>1</sub> (MAUS-47)	0.40	0.59	0.80	1.17	0.78
V <sub>2</sub> (MAUS-71)	0.54	0.71	1.08	1.39	0.94
V <sub>3</sub> (MAUS-81)	0.49	0.65	0.93	1.30	0.85
V <sub>4</sub> (MAUS-158)	0.56	0.74	1.12	1.42	0.97
V <sub>5</sub> (JS-93-05)	0.43	0.62	0.89	1.24	0.82
V <sub>6</sub> (JS-335)	0.52	0.68	1.04	1.35	0.90
<b>G. mean</b>	0.49	0.66	0.97	1.31	0.89

**Table 3 : Harvest index of soybean as influenced by different treatments**

Treatments	Harvest index
<b>Date of sowing</b>	
D <sub>1</sub> (MW-27)	41.48
D <sub>2</sub> (MW-28)	39.11
D <sub>3</sub> (MW-29)	40.82
D <sub>4</sub> (MW-30)	38.62
<b>Cultivars</b>	
V <sub>1</sub> (MAUS-47)	38.94
V <sub>2</sub> (MAUS-71)	40.64
V <sub>3</sub> (MAUS-81)	39.65
V <sub>4</sub> (MAUS-158)	41.09
V <sub>5</sub> (JS-93-05)	39.11
V <sub>6</sub> (JS-335)	40.95
G. mean	40.06

between 38.62 to 41.48 per cent. The sowing date D<sub>1</sub> (MW-27) recorded more harvest index *i.e.* 41.48 and it was followed by D<sub>3</sub> (MW-29), D<sub>2</sub> (MW-28) and D<sub>4</sub> (MW-30) *i.e.* 40.82, 39.11 and 38.62, respectively. Lowest harvest index *i.e.* 38.62, was recorded in D<sub>4</sub> (MW-30).

**Cultivars:**

The cultivar V<sub>4</sub> (MAUS-158) recorded more harvest index

and ranked first in all genotypes *i.e.* 41.09 and it was followed by V<sub>2</sub> (MAUS-71) and V<sub>6</sub> (MAUS-JS-335). The lowest harvest index was recorded in V<sub>1</sub> (MAUS-47) *i.e.* 38.94.

**Post harvest studies:****Grain yield (kg/ha):**

The data regarding grain yield are presented in Table 4.

**Date of sowing:**

The data on grain yield indicated that the crop sown in D<sub>1</sub> MW-27 (02-08 July) recorded higher grain yield (2876 kg/ha) and found significantly superior over other treatments whereas the lowest yield was recorded in treatment D<sub>4</sub> (23-29 July). The crop sown in second week of July recorded low seed yield due to two weeks, dry spell resulted in low germination of crop. Over all this year the crop recorded highest yield due to ample soil moisture during crop growing period.

**Cultivars:**

Statistical analysis of soybean cultivars showed significant result. During this year, variety MAUS-158 (V<sub>4</sub>) produced higher grain yield (2578 kg/ha) and found significantly superior over remaining treatments. Whereas, the variety V<sub>1</sub> (MAUS-47) produced lowest grain yield (1870 kg/ha).

**Table 4 : Mean grain yield (kg/ha), straw yield (kg/ha) and biological yield (kg/ha) as influenced by different treatments**

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
<b>Date of sowing</b>			
D <sub>1</sub> (MW-27)	2876	4057	6933
D <sub>2</sub> (MW-28)	2035	3167	5202
D <sub>3</sub> (MW-29)	2304	3342	5648
D <sub>4</sub> (MW-30)	1780	2853	4632
S.E. $\pm$	31.50	7.22	32.51
C.D. at 5%	94.12	20.10	96.98
<b>Cultivar</b>			
V <sub>1</sub> (MAUS-47)	1870	2934	4802
V <sub>2</sub> (MAUS-71)	2451	3579	6030
V <sub>3</sub> (MAUS-81)	2182	3320	5502
V <sub>4</sub> (MAUS-158)	2579	3697	6276
V <sub>5</sub> (JS-93-05)	2051	3191	5243
V <sub>6</sub> (JS-335)	2363	3406	5770
S.E. $\pm$	42.30	9.18	44.20
C.D. at 5%	126.42	27.51	131.95
<b>Interaction (D x V)</b>			
S.E. $\pm$	84.60	18.16	88.47
C.D. at 5%	NS	NS	NS
G. mean	2249	3355	5604

NS=Non-significant

**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 4.

**Straw yield (kg/ha):**

The data regarding straw yield are presented in Table 4.

**Date of sowing:**

The data presented in Table 4 indicated that the crop sown in D<sub>1</sub> MW-27 (02-08 July) recorded higher straw yield (4057 kg/ha) and found significantly superior over other treatments, whereas lowest straw yield was recorded in

treatment D<sub>4</sub> MW-30 (23-29 July) *i.e.* 2853 kg/ha.

**Cultivars:**

Statistical analysis of soybean cultivars showed significant result. During this year variety MAUS-158 (V<sub>4</sub>) produced higher straw yield (3697 kg/ha) and found significantly superior over remaining treatments. Whereas, the variety MAUS-47 (V<sub>1</sub>) produced lowest straw yield *i.e.* (2934 kg/ha).

**Interaction:**

The interaction effects between date of sowing and different cultivar were found statistically non-significant.

**Table 5 : Growing degree day (GDD) at different phenophases of soybean crop under different treatments**

Treatments	Growth stages										Mean
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>	P <sub>6</sub>	P <sub>7</sub>	P <sub>8</sub>	P <sub>9</sub>	P <sub>10</sub>	
D <sub>1</sub> (MW-27)	99.1	357.2	82.4	59.2	80.1	87.4	265.2	178.1	167.3	187.2	156.3
D <sub>2</sub> (MW-28)	178.5	303.5	82.8	52.3	67.7	131.0	262.0	187.0	145.9	231.3	164.2
D <sub>3</sub> (MW-29)	123.1	357.3	96.4	81.9	62.1	123.3	252.1	183.8	131.3	179.5	159.1
D <sub>4</sub> (MW-30)	94.3	364.9	82.5	69.5	63.0	120.9	259.7	162.7	128.0	162.8	150.8
<b>Cultivars</b>											
V <sub>1</sub> (MAUS-47)	123.7	297.7	72.6	68.1	57.1	100.4	258.0	168.4	150.0	176.6	147.3
V <sub>2</sub> (MAUS-71)	123.7	361.9	89.8	65.0	72.1	119.4	260.7	182.2	137.5	196.2	160.9
V <sub>3</sub> (MAUS-81)	123.7	361.9	89.8	65.0	72.1	119.4	260.7	182.2	137.5	196.2	160.9
V <sub>4</sub> (MAUS-158)	123.7	361.9	89.8	65.0	72.1	119.4	260.7	182.2	137.5	196.2	160.9
V <sub>5</sub> (JS-93-05)	123.7	329.2	84.2	66.2	63.4	111.6	257.6	170.2	158.8	179.9	154.5
V <sub>6</sub> (JS-335)	123.7	361.9	89.8	65.0	72.1	119.4	260.7	182.2	137.5	196.2	160.9
Mean	123.7	345.7	86.0	65.7	68.2	115.6	259.7	177.9	143.1	190.2	157.6

P<sub>1</sub> – Sowing to emergence, P<sub>2</sub> – Emergence to seedling, P<sub>3</sub> – Seedling to branching, P<sub>4</sub> – Branching to flowering, P<sub>5</sub> – Flowering to pod formation, P<sub>6</sub> – Pod formation to grain formation, P<sub>7</sub> – Grain formation to pod development, P<sub>8</sub> – Pod development to pod containing full size and P<sub>9</sub> – Pod containing full size to dough stage

**Table 6 : Helio-thermal units (HTU) at different phenophases of soybean crop under different treatments**

Treatments	Growth stages										Mean
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>	P <sub>6</sub>	P <sub>7</sub>	P <sub>8</sub>	P <sub>9</sub>	P <sub>10</sub>	
D <sub>1</sub> (MW-27)	422.4	1364.5	349.1	186.8	428.1	529.4	1297.8	884.2	1158.1	1637.9	825.8
D <sub>2</sub> (MW-28)	931.0	805.9	437.4	357.6	294.7	705.6	1273.1	1275.9	1313.6	1854.8	925.0
D <sub>3</sub> (MW-29)	497.0	1439.4	431.5	424.6	303.4	477.7	1597.5	1554.4	1172.7	1278.2	917.6
D <sub>4</sub> (MW-30)	234.1	1708.9	464.8	284.7	353.6	509.8	1862.7	1444.1	1131.1	1064.3	905.8
<b>Cultivars</b>											
V <sub>1</sub> (MAUS-47)	521.1	1163.5	291.3	364.4	245.6	454.0	1370.3	1056.3	1251.8	1517.0	823.5
V <sub>2</sub> (MAUS-71)	521.1	1402.4	429.9	311.5	356.2	595.2	1570.6	1357.6	1148.0	1457.3	915.0
V <sub>3</sub> (MAUS-81)	521.1	1402.4	429.9	311.5	356.2	595.2	1570.6	1357.6	1148.0	1457.3	915.0
V <sub>4</sub> (MAUS-158)	521.1	1402.4	429.9	311.5	356.2	595.2	1570.6	1357.6	1148.0	1457.3	915.0
V <sub>5</sub> (JS-93-05)	521.1	1204.9	513.1	270.5	399.5	499.0	1393.7	1251.1	1318.7	1406.6	877.8
V <sub>6</sub> (JS-335)	521.1	1402.4	429.9	311.5	356.2	595.2	1570.6	1357.6	1148.0	1457.3	915.0
Mean	521.1	1329.7	420.7	313.4	344.9	555.6	150.7	1289.6	1193.8	1458.8	893.5

P<sub>1</sub> – Sowing to emergence, P<sub>2</sub> – Emergence to seedling, P<sub>3</sub> – Seedling to branching, P<sub>4</sub> – Branching to flowering, P<sub>5</sub> – Flowering to pod formation, P<sub>6</sub> – Pod formation to grain formation, P<sub>7</sub> – Grain formation to pod development, P<sub>8</sub> – Pod development to pod containing full size, P<sub>9</sub> – Pod containing full size to dough stage and P<sub>10</sub> – Dough stage to maturity

**Biological yield (kg/ha):**

The data regarding biological yield are presented in Table 4.

**Date of sowing:**

The data presented in Table 3 indicated that the crop sown in D<sub>1</sub>-MW-27 (02-08 July) recorded higher biological yield (6933 kg/ha) and found significantly superior over other treatments. Where, as the lowest biological yield was recorded in treatment D<sub>4</sub> (23-29 July) *i.e.* 4632 (kg/ha).

**Cultivars:**

Statistical analysis of soybean cultivars showed significant result. During this year, variety MAUS-158 (V<sub>4</sub>) produced higher biological yield (6276 kg/ha) and found significantly superior over remaining treatments.

**Interaction:**

The interaction effect were statistically non-significant and the result are presented in Table 4.

**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 5. The data presented in Table 5 revealed that the mean heat requirement during crop life cycle *i.e.* emergence to maturity stage (P<sub>1</sub> to P<sub>10</sub>) was 157.6°C. The mean heat load was reported during D<sub>1</sub> (MW-27) to D<sub>2</sub> (MW-28) *i.e.* 156.3 to 164.2°C and again decreased from D<sub>3</sub> (MW-29) and to D<sub>4</sub> (MW-30) *i.e.* 159.1 to 150.8°C. It may be due to dry spell occurred during crop life cycle. Whereas, D<sub>2</sub> (MW-28) treatment indicated more heat load than other treatment of date of sowing *i.e.* 164.2°C. It may be due to maximum air temperature observed at the time of sowing (MW-28). The lowest (150.8) heat unit required for attaining various phenophase in D<sub>4</sub> (MW-30) treatment due to effect of temperature and delayed sowing during the crop growing season. It is cleared that when the temperature of air was maximum then it will definitely affect GDD of soybean crop. The higher mean value *i.e.* 345.7°C was recorded in phenophases (P<sub>2</sub>) at date of sowing.

The data presented in Table 5 revealed that the mean heat requirement of variety during crop life cycle ranged from 147.3°C to 160.9°C. The mean heat load reported was same in 4 varieties V<sub>2</sub> (MAUS-71), V<sub>3</sub> (MAUS-81), V<sub>4</sub> (MAUS-158) and V<sub>6</sub> (JS-93-05) *i.e.* 160.9°C whereas, V<sub>1</sub> (MAUS-47), cultivar indicate less heat load than other cultivar *i.e.* 147.3°C. 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), Singh *et al.* (2007) and Neog *et al.* (2008).

**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<sub>1</sub> to D<sub>4</sub>) ranged from 825.8 to 925.0. The HTU were higher in second date of sowing *i.e.* 925.0 D<sub>2</sub> (MW-28) and decreasing slowly up to delayed sowing *i.e.* 905.8 in D<sub>4</sub> (MW-30). The lowest HTU were in D<sub>1</sub> (MW-27) *i.e.* 825.8 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 823.5°C to 915.0°C. The mean HTU was reported same in 4 variety V<sub>2</sub> (MAUS-71), V<sub>3</sub> (MAUS-81), V<sub>4</sub> (MAUS-158) and V<sub>6</sub> (JS-93-05) *i.e.* 915.0°C. It may be due to same crop duration in above four variety. Whereas, the HTU were lowest in V<sub>1</sub> (MAUS-47) *i.e.* 823.5°C 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), Singh *et al.* (2007) and Neog *et al.* (2008).

**Conclusion:**

It is cleared that, when the temperature of air was maximum then it will definitely affect GDD of soybean crop. The GDD was higher in D<sub>2</sub> (MW-28) *i.e.* 164.2°C followed by D<sub>3</sub> (MW-29) than rest of the treatments, whereas the lowest GDD was recorded in T<sub>4</sub> (MW-30) *i.e.* 150.8°C. Mean heat load was reported same in four varieties V<sub>2</sub> (MAUS-71), V<sub>3</sub> (MAUS-81), V<sub>4</sub> (MAUS-158) and V<sub>6</sub> (JS-9305) *i.e.* 160.9°C, it may be due to same crop duration in above four varieties. Whereas, V<sub>1</sub> (MAUS-47) variety indicate less heat load than other variety *i.e.* 147.3°C it may be due to small crop duration from emergence to maturity of such variety.

Helio thermal units directly or indirectly affect the grain yield of soybean by delaying flowering and pod formation. The requirement of HTU was higher (925.0) in D<sub>2</sub> (MW-28), whereas HTU requirement was lower (825.8) in D<sub>1</sub> (MW-27) treatment. The mean helio thermal units was reported same in four varieties V<sub>2</sub> (MAUS-71), V<sub>3</sub> (MAUS-81), V<sub>4</sub> (MAUS-158) and V<sub>6</sub> (JS-9305) *i.e.* 915.0°C. It may be due to the same crop duration in above four varieties. Whereas, lowest helio thermal unit was recorded in V<sub>1</sub> (MAUS-47) *i.e.* 823.5°C.

**REFERENCES**

- Beard, B.H. and Knowles, P.F. (1973). Soybean Research in California, Calif, Agril. Exp. Sat. Bull., 862.
- Donald, C.M. and Hamblin (1976). The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv. Agron*, **28** : 361-405.
- Kumar, A., Pandey, V., Shekh, A.M. and Kumar, M. (2008). Growth and yield response of soybean (*Glycine max* L.) In relation to temperature, photoperiod and sunshine duration at Anand, Gujrat, India. *American - Eurasian J. Agron.*, **1** (2): 45-50.
- Londe, S.P. and Woodward, F.I. (1988). Plants and temperature symposis of the society for experimental biology, No. 42.
- Neog P., Bhuyan, J. and Baruah, N. (2008). Thermal indices in relation to crop phenology and yield of soybean [*Glycine max* (L.) Merrill]. *J. Agro-meteorology*, **2**: 388-392.
- Singh, A., Rao, V.U.M., Singh, Diwan, Singh and Rat, Singh (2007). Study on agro meteorological indices for soybean crop under different growing environment. *J. Agro-meteorology*, **9** (1) : 81-85.
- Wasnik, M.D. (1986). Prospects and problems of soybean development in India. Annual workshop of all Indian Co-ordinated Research Project on soybean. MACS Res., Institute, Pune pp. 22-25.
- Watson, D.J. (1952). The physiological basis of variation in yield. *Adv. Agron.*, **4** : 101-145.


  
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