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RESEARCH ARTICLE

Sowing windows influence on growing degree days (GDD) and heliothermal units (HTU) in soybean

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ABSTRACT : The GDD was higher in D_2 (MW-28) *i.e.* 164.2^{0}C followed by D_3 (MW-29) than rest of the treatments, whereas, the lowest GDD was recorded in D_4 (MW-30) *i.e.* 150.8^{0}C. Mean heat load was reported same in four varieties V_2 (MAUS-71), V_3 (MAUS-81), V_4 (MAUS-158) and V_6 (JS-9305) *i.e.* 160.9^{0}C, it may be due to same crop duration in these four varieties. Whereas, V_1 (MAUS-47) variety indicated less heat load than other varieties *i.e.* 147.3^{0}C, which may be due to small crop duration from emergence to maturity of such varieties. Helio thermal units directly or indirectly affected the grain yield of soybean by delaying flowering and pod formation. The requirement of HTU was higher (925.0) in D_2 (MW-28), whereas, HTU requirement was lower (825.8) in D_1 (MW-27) treatment. The mean helio thermal units was reported same in four varieties V_2 (MAUS-71), V_3 (MAUS-81), V_4 (MAUS-158) and V_6 (JS-93-05) *i.e.* 915.0^{0}C. It may be due to the same crop duration in above four varieties. Whereas, lowest heliothermal unit was recorded in V_1 (MAUS-47) *i.e.* 823.5^{0}C.

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Key Words :
Sowing windows, Growing degree day, Heliothermal soybean

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Soybean is the third largest oilseed crop of India. The temperature is an important meteorological variable that affects the 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 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 favours 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 if 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) helio-thermal units (HTU) at different phenophases of soybean crop in different sowing windows.

EXPERIMENTAL METHODOLOGY

The experiment was laid out in Split Plot Design with three replications and two factors *viz.*, date of sowing D_1 (MW-27), D_2 (MW-28), D_3 (MW-29) and D_4 (MW-30) and cultivars V_1 (MAUS-47), V_2 (MAUS-71), V_3 (MAUS-81), V_4 (MAUS-158), V_5 (JS-9305) and V_6 (JS-335) to find out the optimum

sowing time for soybean genotypes. 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 with gross plot size 5.4 m × 3.6 m and 4.5 m × 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.

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), it is calculated by using the following formula:

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

Harvest index :

It is the per cent of economical yield to the total biological yield. Harvest index reflects the proportion to assimilate distribution between economical and total biomass (Donald and Hamblin, 1976). It is computed by using the following formula :

$$\text{HI (\%)} = \frac{\text{Total grain yield / plot}}{\text{Total biological yield / plot}} \times 100$$

Computation of agrometeorological indices :

Growing degree days (GDD) :

Growing degree days is 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 its 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 :

$$\text{Accumulated GDD} = \sum_{Ds}^{Dh}\left(\frac{T_{max} + T_{min}}{2}\right) - Tb$$

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.

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 :

$$\text{Accumulated GDD} = \sum_{Ds}^{Dh}\left(\frac{T - Tb}{D}\right) - Tb$$

where,

HTU = Helio-thermal units
T = Mean daily temperature (^{0}C)
Tb = Base temperature
ds = Date of emergence
dh = Date of harvest
D = Hours of bright sunshine.

Statistical analysis :

The obtained data was analyzed by statistical significant at P<0.05 level, S.E. and C.D. at 5 per cent level by the procedure given by (Gomez and Gomez, 1984).

EXPERIMENTAL FINDINGS AND DISCUSSION

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

Mean leaf area per plant (dm^2) :

The data on mean leaf area (dm^2) 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^2) per plant were influenced significantly by different dates of sowing, at all stages of crop growth. Mean leaf area was observed significantly more in D_1 (MW-27) than other treatments (Table 2).

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_1 (MW-27) than other treatments.

Interaction (D × V) :

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 dates of sowing at all the stages of crop growth. Mean leaf area was significantly more in D_1 (MW-27) than other treatments.

Cultivars :

The mean leaf area index was influenced significantly by different cultivars at all stages of crop growth. V_4 (MAUS-158) produced more leaf area than other cultivars.

Harvest index :

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

Date of sowing :

Harvest index did not show much variation and ranged between 38.42 to 41.48 per cent. The sowing date D_1 (MW-27) recorded more harvest index *i.e.* 41.48 and it was followed by D_3 (MW-29), D_2 (MW-28) and D_4 (MW-30) *i.e.* 40.82, 39.11 and 38.62, respectively. Lowest harvest index *i.e.* 38.42 was recorded in D_4 (MW-30).

Cultivars :

The cultivar V_4 (MAUS-158) recorded more harvest index and ranked first in all genotypes *i.e.* 41.09 and it was followed by V_2 (MAUS-71) and V_6 (MAUS-JS-335). The lowest harvest index was recorded in V_1 (MAUS-47) *i.e.* 38.94 (Table 3).

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_1 MW-27 (02-08, July) recorded higher grain yield

Table 1 : Mean leaf area (dm^2) per plant

Treatments	Mean leaf area (dm^2) per plant				
	Days after sowing				
	30	45	60	75	At harvest
D_1 (MW-27)	12.15	16.72	23.24	32.45	20.84
D_2 (MW-28)	10.84	14.22	21.66	28.58	19.30
D_3 (MW-29)	11.62	15.71	22.40	30.27	19.98
D_4 (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. (P=0.05)	0.16	0.09	0.19	0.12	0.33
Cultivars					
V_1 (MAUS-47)	9.10	12.94	18.15	26.37	17.55
V_2 (MAUS-71)	12.22	16.10	24.30	31.42	21.27
V_3 (MAUS-81)	11.16	14.81	21.13	29.30	19.25
V_4 (MAUS-158)	12.64	16.80	25.30	32.13	21.91
V_5 (JS-93-05)	9.89	13.95	20.18	28.05	18.56
V_6 (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. (P=0.05)	0.20	0.19	0.29	0.40	0.36
Interaction					
S.E. ±	0.15	0.13	0.21	0.28	0.24
C.D. (P=0.05)	NS	NS	NS	NS	NS
G. Mean	11.15	15.01	22.08	29.63	19.83

NS = Non-significant

(2035 kg/ha) and found significantly superior over other treatments whereas, the lowest yield was recorded in treatment D_4 (23-29 July). The crop sown in second week of July recorded low seed yield due to, dry spell which 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_4) produced higher grain yield (2579 kg/ha) and was found significantly superior over remaining treatments. Whereas, the variety V_1 (MAUS-47) produced lowest grain yield (1870 kg/ha).

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 3.

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_3 (MV-29) recorded higher straw yield (3442 kg/ha) and found significantly superior over other treatments, whereas, lowest straw yield was recorded in

Table 2 : Mean leaf area index (LAI)

Treatments	Mean leaf area index (LAI)				
	Days after sowing				
	30	45	60	75	At harvest
D_1 (MW-27)	0.54	0.74	1.03	1.44	0.92
D_2 (MW-28)	0.48	0.63	0.96	1.27	0.85
D_3 (MW-29)	0.51	0.69	0.99	1.34	0.88
D_4 (MW-30)	0.43	0.59	0.93	1.21	0.85
S.E. ±	–	–	–	–	–
C.D. (P=0.05)	–	–	–	–	–
Cultivars					
V_1 (MAUS-47)	0.40	0.59	0.80	1.17	0.78
V_2 (MAUS-71)	0.54	0.71	1.08	1.39	0.94
V_3 (MAUS-81)	0.49	0.65	0.93	1.30	0.85
V_4 (MAUS-158)	0.56	0.74	1.12	1.42	0.97
V_5 (JS-93-05)	0.43	0.62	0.89	1.24	0.82
V_6 (JS-335)	0.52	0.68	1.04	1.35	0.90
S.E. ±	–	–	–	–	–
C.D. (P=0.05)	–	–	–	–	–
Interaction					
S.E. ±	–	–	–	–	–
C.D. (P=0.05)	–	–	–	–	–
G. Mean	6.96	12.39	17.56	26.57	20.28

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

Treatments	D_1 (MW-27)	D_2 (MW-28)	D_3 (MW-29)	D_4 (MW-30)	S.E. ±	C.D. (P=0.05)	Cultivars	V_1 (MAUS-47)	V_2 (MAUS-71)	V_3 (MAUS-81)	V_4 (MAUS-158)	V_5 (JS-93-05)	V_6 (JS-335)	S.E. ±	C.D. (P=0.05)	Interaction	S.E. ±	C.D. (P=0.05)	G. mean
Harvest index	41.48	39.11	40.82	38.62	–	–		38.94	40.64	39.65	41.09	39.11	40.95	–	–		–	–	40.06

treatment D_4 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_4) produced higher straw yield (3697 kg/ha) and was found significantly superior over remaining treatments. Whereas, the variety MAUS-47 (V_1) produced lowest straw yield *i.e.* (2934 kg/ha).

Interaction :

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

Biological yield (kg/ha) :

The data regarding biological yield are presented in

Table 4 : Mean grain yield (kg/ha), straw yield (kg/ha) and biological yield (kg/ha)

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
D_1 (MW-27)			
D_2 (MW-28)	2035	3167	5202
D_3 (MW-29)	2304	3342	5648
D_4 (MW-30)	1780	2853	4632
S.E. ±	31.50	7.22	32.51
C.D. (P=0.05)	94.12	20.10	96.98
Cultivars			
V_1 (MAUS-47)	1870	2934	4802
V_2 (MAUS-71)	2451	3579	6030
V_3 (MAUS-81)	2182	3320	5502
V_4 (MAUS-158)	2579	3697	6276
V_5 (JS-93-05)	2051	3191	5243
V_6 (JS-335)	2363	3406	5770
S.E. ±	42.30	9.18	44.20
C.D. (P=0.05)	126.42	27.51	131.95
Interaction			
S.E. ±	84.60	18.16	88.47
C.D. (P=0.05)	NS	NS	NS
G. Mean	2249	3355	5604

NS = Non-significant

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

Treatments	Growth stages										Mean
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	
D_1 (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_2 (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_3 (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_4 (MW-30)	94.3	364.9	82.5	69.5	63.0	120.9	259.7	162.7	128.0	162.8	150.8
Cultivars											
V_1 (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_2 (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_3 (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_4 (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_5 (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_6 (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_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

Table 4.

Date of sowing :

The data presented in Table 3 indicated that the crop sown in D_3 (MV-29) recorded higher biological yield (6933 kg/ha) and was found significantly superior over other treatments. Whereas, the lowest biological yield was recorded in treatment D_4 (23-29, July) *i.e.* 4632 (kg/ha).

Cultivars :

Statistical analysis of soybean cultivars showed significant result. During this year, variety MAUS-158 (V_4) produced higher biological yield (6276 kg/ha) and was 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_1 to P_{10}) was 157.6^0 C. The mean heat load was reported during D_1 (MW-27) to D_2 (MW-28) *i.e.* 156.3 to 164.2^0 C and again decreased from D_3 (MW-29) and to D_4 (MW-30) *i.e.* 159.1 to 150.8^0 C. It may be due to dry spell occurred during crop life cycle. Whereas, D_2 (MW-28) treatment indicated more heat load than other treatment of date of sowing *i.e.* 164.2^0 C. It may be due to maximum air temperature observed at the time of sowing (MW-28). The lowest (150.8^0 C) heat unit was required for attaining various phenophase in D_4 (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.* 345.7^0 C was recorded in phenophases (P_2) at date of sowing.

The data presented in Table 5 also revealed that the mean heat requirement of variety during crop life cycle ranged from 147.3^0 C to 160.9^0 C. The mean heat load reported was same in 4 varieties V_2 (MAUS-71), V_3 (MAUS-81), V_4 (MAUS-158) and V_6 (JS-93-05) *i.e.* 160.9^0 C whereas, V_1 (MAUS-47), cultivar indicated less heat load than other cultivar (147.3^0 C). It might be occured 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).

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

Treatments	Growth stages										Mean
	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	
D_1 (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_2 (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_3 (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_4 (MW-30)	234.1	1708.9	464.8	284.7	353.6	509.8	1862.7	1444.1	1131.1	1064.3	905.8
Cultivars											
V_1 (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_2 (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_3 (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_4 (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_5 (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_6 (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_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 are presented in Table 6. Helio-thermal units for each phenophase were differently required by different dates of sowing. The mean helio-thermal units were observed, in date of sowing (D_1 to D_4) ranging from 825.8 to 925.0. The HTU was higher in second date of sowing *i.e.* 925.0 in D_2 (MW-28) and decreased slowly up to delayed sowing *i.e.* 905.8 in D_4 (MW-30). The lowest HTU was in D_1 (MW-27) *i.e.* 825.8 than rest of the treatments due to variation of temperature, bright sunshine and dry spell which occurred during the crop growing season.

The helio thermal units directly or indirectly affected the grain yield of soybean by delaying flowering and pod formation. Higher HTU are not conducive for better yield of soybean.

The requirement of mean helio-thermal units of different varieties during crop life cycle ranged from 823.5^0 C to 915.0^0 C. The mean HTU was reported same in 4 variety V_2 (MAUS-71), V_3 (MAUS-81), V_4 (MAUS-158) and V_6 (JS-93-05) *i.e.* 915.0^0 C. It may be due to same crop duration in above four varieties. Whereas, the HTU was lowest in V_1 (MAUS-47) *i.e.* 823.5^0 C than rest of the treatments due to variation of temperature, growing period, bright sunshine and dry spell, which 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).

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