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RESEARCH ARTICLE

Impact of sowing windows and varieties on canopy temperature (CT), stress degree days (SDD) in soybean

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SUMMARY

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. Experiment was carried out on Research Farm of Department of Agricultural Meteorology, Parbhani. The canopy temperature designates the plant water stress. If the canopy temperature of soybean crop is greater, then soil moisture stress occurred in the field. Canopy temperature is one of the most reliable indicators of the crop water stress due to its direct relation with the plant water status. The highest mean canopy temperature (32.0^0C) and (32.1^0C) were observed in D_4 (MW-30) date of sowing and genotype V_1 (MAUS-47), respectively whereas stage P_{10} (maturity stage) indicate the highest mean canopy temperature 32.4^0C. The lowest mean canopy temperature (30.9^0C) and (30.7^0C) recorded in D_1 (MW-27) date of sowing and genotype V_4 (MAUS-158), respectively. Whereas stage P_1 (emergence stage) indicated the lowest mean canopy temperature *i.e.* 30.30^0C. The variety growth character like emergence and final plant count, plant height, number of functional leaves, number of branches, number of pods, mean leaf area, leaf area index, dry matter, weight of pods per plant, weight of grain per plant, 1000 seed weight (test weight), grain yield, straw yield and biological yield was maximum observed in D_1 (MW-27) date of sowing and in cultivar V_4 (MAUS-158). Whereas, minimum observed in D_4 (MW-30) date of sowing and cultivar V_1 (MAUS-47).

Key Words : Sowing windows, Canopy temperature, Stress degree days, Soybean

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In Maharashtra mainly the cultivation of soybean is rainfed crop. It is the common experience of farmer and scientist that the rainfall at the maturity leads to the loss of seeds besides deterioration of seed quality. Thus, it is observed that harvesting period of soybean is coupled with post monsoon rains resulted in the loss of seeds and its quality. In the past years it was observed that germination of seeds was considerably reduced to 11 to 20 per cent (Anonymous, 2000). This has alarmed for finding proper time for sowing so as to skip the crops from rains at harvest. Performance of the crop has been reported to be highly governed by timely sowing and spatial arrangement (Sharma *et al.*, 1984). Delayed sowing of soybean not only resulted in yield reduction (Karmarkar and Bhatnagar, 1995) but also deteriorating the quality in respect to oil and protein content (Billare *et al.*, 2000). 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). In view of above, a field experiment was undertaken to find out the mean canopy temperature (^{0}C) and mean canopy air temperature difference (Tc-Ta) at different phenophases of soybean crop under varied weather conditions at Parbhani.

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MATERIAL AND METHODS

The present investigation was carried out by laying out experiment on soybean with objective to study the performance of soybean (*Glycine max* L.) genotypes under varied weather conditions at Parbhani, Maharashtra. The experiment was conducted during *Kharif* season of 2010-2011, on the Experimental Farm, Department of Agricultural Meteorology, College of Agriculture, Marathwada Krishi Vidyapeeth, Parbhani. The details of the materials used and methods adopted during the present investigation are narrated under following heads:

Experimental details:

Design	:	Split plot design
Number of treatment (combination)	:	24
Number of replication	:	Three
Gross plot size	:	5.4m x 3.6 m
Net plot size	:	4.5 m x 2.7 m
Season	:	*Kharif* 2010
Number of plots	:	72.

Treatment details:

Main treatment (*sowing dates 4*):

D_1	:	MW 27 (02 to 08 July)
D_2	:	MW-28 (09 to 15 July)
D_3	:	MW-29 (16 to 22 July)
D_4	:	MW-30 (23 to 29 July).

Sub treatment (Cultivar 6):

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 (check).

Yield of grains (kg/ha):

Biomass from each plot was threshed by beating with wooden sticks. Seeds were separated from bhusa by winnowing and seed yield was recorded in kg per net plot. From this, seed yield per hectare was calculated.

Measuring canopy temperatures:

To make temperature measurement, the instrument (AG-42) must be fully charged when it is held by grip, the instruments promptly "come to life" as evidenced by the aviation of digital display. Point the instrument at the object whose temperature is to be measured and the display will immediately indicate the temperature at the object. The temperature difference between the target and the ambient air, can be measured by pressing the trigger on the front of the hand grip. The instrument will immediately calculated and display the differential temperature. The telatemp model AG-42 has an acceptance angle of 4 and "Sees" a one foot spot at twenty foot distance.

RESULTS 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 was influenced significantly by different date of sowing, at all stages of crop growth. Mean leaf area was observed significantly more in D_1 (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_1 (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.

Dry matter per plant (*g/plant*):

The data on mean dry matter per plant (g/plant) as influenced by different treatments at 15 days of interval are presented in Table 2. It was observed that mean dry matter per plant (g/plant) was increased continuously up to 75 DAS of crop but later it was decreased.

Date of sowing:

The data presented in Table 2 indicate that the production was influenced significantly by different date of sowing at all stages of crop growth. Dry matter was observed significantly more in D_1 (MW-27) than the other date of sowing.

Cultivars:

The mean dry matter production was influenced significantly by different cultivars at all stages of crop growth. The cultivar V_4 (MAUS-158) produced higher dry matters than other cultivars.

Interaction (DxV):

The interaction effect between date of sowing and

Table 1 : Mean leaf area (dm^2) per plant of soybean as influenced by different treatments

Treatments	Days after sowing				
	30	45	60	75	At harvest
Date of sowing					
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. $\pm$	0.05	0.03	0.07	0.04	0.11
C.D. at 5%	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. $\pm$	0.07	0.06	0.10	0.14	0.12
C.D. at 5%	0.20	0.19	0.29	0.40	0.36
Interaction (D x V)					
S.E. $\pm$	0.15	0.13	0.21	0.28	0.24
C.D. at 5%	NS	NS	NS	NS	NS
G. mean	11.15	15.01	22.08	29.63	19.83

NS=Non-significant

Table 2 : Mean dry matter (g/plant) as influenced by different treatments at various growth stages of soybean

Treatments	Days after sowing				
	30	45	60	75	At harvest
Date of sowing					
D_1 (MW-27)	7.66	13.15	18.90	27.14	21.71
D_2 (MW-28)	6.93	12.21	17.15	26.56	20.12
D_3 (MW-29)	7.56	12.88	17.69	27.11	20.40
D_4 (MW-30)	5.71	11.30	16.60	25.50	18.89
S.E. $\pm$	0.06	0.04	0.07	0.08	0.10
C.D. at 5%	0.17	0.13	0.21	0.23	0.30
Cultivars					
V_1 (MAUS-47)	5.41	10.04	15.48	24.49	18.41
V_2 (MAUS-71)	7.80	13.51	18.62	27.91	21.38
V_3 (MAUS-81)	6.72	12.10	17.31	25.93	19.98
V_4 (MAUS-158)	8.54	14.05	19.21	28.86	22.19
V_5 (JS-93-05)	6.15	11.61	16.59	25.17	19.08
V_6 (JS-335)	7.16	13.08	18.15	27.10	20.64
S.E. $\pm$	0.08	0.08	0.06	0.11	0.08
C.D. at 5%	0.24	0.23	0.18	0.33	0.24
Interaction (D x V)					
S.E. $\pm$	0.17	0.16	0.13	0.22	0.17
C.D. at 5%	NS	NS	NS	NS	NS
G. mean	6.96	12.39	17.56	26.57	20.28

NS=Non-significant

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 3.

Date of sowing:

The data on mean leaf area index (LAI) per plant was influenced significantly by different date of sowing at all stages of crop growth. Mean leaf area was significantly more in D_1 (MW-27) than other treatments.

Table 3 : Mean leaf area index (LAI) as influenced by different treatments

Treatments	Days after sowing				
	30	45	60	75	At harvest
Date of sowing					
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
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
G. mean	0.49	0.66	0.97	1.31	0.89

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)
Date of sowing			
D_1 (MW-27)	2876	4057	6933
D_2 (MW-28)	2035	3167	5202
D_3 (MW-29)	2304	3342	5648
D_4 (MW-30)	1780	2853	4632
S.E. $\pm$	31.50	7.22	32.51
C.D. at 5%	94.12	20.10	96.98
Cultivar			
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. $\pm$	42.30	9.18	44.20
C.D. at 5%	126.42	27.51	131.95
Interaction (D x V)			
S.E. $\pm$	84.60	18.16	88.47
C.D. at 5%	NS	NS	NS
G. mean	2249	3355	5604

NS= Non-significant

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.

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 (2876 kg/ha) and was 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 two weeks dry spell resulted in low

Table 5 : Mean soil moisture (%) at different growth stages of soybean crop as affected by different treatments

Treatments	Days after sowing					
	15	30	45	60	75	At harvest
Date of sowing						
D_1 (MW-27)	32.55	33.37	37.96	35.15	32.25	31.51
D_2 (MW-28)	26.86	31.60	34.10	30.18	27.47	23.42
D_3 (MW-29)	30.32	32.45	35.92	33.97	30.18	27.47
D_4 (MW-30)	28.13	31.20	32.80	28.34	25.90	22.42
S.E. $\pm$	0.81	0.03	0.018	0.04	0.01	0.03
C.D. at 5%	2.41	0.10	0.05	0.12	0.03	0.08
Cultivars						
V_1 (MAUS-47)	27.42	31.95	34.27	30.90	29.05	25.72
V_2 (MAUS-71)	29.95	32.16	35.78	32.38	29.45	26.10
V_3 (MAUS-81)	29.80	32.15	34.80	32.06	29.20	25.95
V_4 (MAUS-158)	30.05	32.20	35.79	32.48	29.54	26.35
V_5 (JS-93-05)	29.72	32.14	34.68	31.83	29.16	25.81
V_6 (JS-335)	29.85	32.15	35.76	32.29	29.32	26.08
S.E. $\pm$	0.02	0.03	0.03	0.04	0.03	0.03
C.D. at 5%	0.05	0.10	0.10	0.12	0.09	0.08
G. mean	29.41	32.12	35.34	31.99	29.28	26.00

Table 6 : Mean canopy temperature (^{0}C) at different phenophases of soybean crop

Treatments	Phenophases										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)	29.9	30.2	30.4	30.5	30.6	31.2	31.3	31.4	31.8	31.4	30.9
D_2 (MW-28)	30.5	30.7	31.1	31.2	31.4	31.7	32.0	32.1	32.7	32.8	31.6
D_3 (MW-29)	30.2	30.6	30.8	30.9	31.3	31.4	31.5	31.9	32.1	32.2	31.3
D_4 (MW-30)	30.8	31.0	31.4	31.5	32.1	32.3	32.4	32.4	33.0	33.2	32.0
Cultivars											
V_1 (MAUS-47)	31.1	31.3	31.6	31.8	31.9	32.4	32.4	32.7	33.0	33.1	32.10
V_2 (MAUS-71)	29.9	30.2	30.4	30.5	31.0	31.3	31.4	31.5	32.1	32.2	31.1
V_3 (MAUS-81)	30.5	30.8	31.2	31.3	31.7	31.9	32.1	32.2	32.5	32.6	31.7
V_4 (MAUS-158)	29.6	29.9	30.3	30.1	30.8	30.7	30.9	31.2	31.7	32.0	30.7
V_5 (JS-93-05)	30.8	31.1	31.4	31.6	31.6	32.1	32.3	32.4	32.8	33.0	31.9
V_6 (JS-335)	30.2	30.5	30.7	30.6	31.3	31.6	31.7	31.9	32.2	32.3	31.3
Mean	30.3	30.6	30.9	31.0	31.4	31.6	31.8	31.9	32.4	32.4	31.4

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 and P_{10} – Dough stage to maturity

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 4.

Soil moisture studies:

The data on soil moisture at different sowing dates of soybean crop from sowing to maturity are presented in Table 5. The data on soil moisture revealed that the soil moisture in D_1 (MW-27) sowing dates treatment was on an average more than rest of the treatments, while in D_2 (MW-28) and D_4 (MW-30) sowing date treatment the soil moisture stress at early growth stages was noticed, due to, that yield of soybean crop was affected. The differences in soil moisture of the genotypes were significant at all stages. The soil moisture content showed consistent increasing from 15 DAS to 45 DAS and then continuously decreased up to harvest of crop. At 45 DAS the mean soil moisture was 35.34 per cent while at harvest the mean soil moisture was 26.00 per cent.

Canopy temperature (^0C):

Canopy temperature for soybean crop under different sowing dates and varieties from sowing to maturity are presented in Table 6.

Canopy temperature (^0C) *at different phenophases*:

Data from Table 6 indicated that significant differences in canopy temperature at each phenophases of different date of sowing and different cultivars. The canopy temperature were higher under stressed conditions as compared to unstressed conditions throughout the crop growth period. As per the date of sowing and different cultivars the highest mean canopy temperature (32.0^0C) and (32.1^0C) were observed in D_4 date of sowing and V_1 (MAUS-47) genotype, respectively. Whereas stage P_{10} (maturity stage) indicate the highest mean canopy temperature *i.e.* 32.4^0C.

The canopy temperature designates the plant water stress. If the canopy temperature of soybean crop is greater, then soil moisture stress occurred in the field. Canopy temperature is one of the most reliable indicators of the crop water stress due to its direct relation with the plant water status. As per the date of sowing and variety the mean lowest canopy temperature (30.9^0C) and (30.7^0C) recorded in D_1 date of sowing and genotype V_4 (MAUS-158), respectively. Whereas P_1 (emergence stage) indicated the lowest mean canopy temperature *i.e.* 30.3^0C. The data presented in Table 6 revealed that the average canopy temperature ranged from 30.3^0C to 32.4^0C in P_1 to P_{10} stage (emergence to maturity). The canopy temperature was less than air temperature because of occurrence of rainfall in all stages except only P_{10} stage (maturity stage). While in maturity stage canopy temperature is more than air temperature so there was moisture stress observed. Similar results were reported by Singh and Kanemasu (1983), Idso (1982) and Zhang Wen-Zhang *et al.* (2007).

Canopy-air temperature (*Tc-Ta*) *difference during phenophases*:

The data pertaining to canopy-air temperature differential (Tc-Ta) during crop growth period in all date of sowing and

Table 7 : Mean canopy air temperature difference (Tc-Ta) at different phenophases of soybean crop

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)	-3.3	-3.1	-2.8	-1.7	-1.3	-1.1	-1.2	-1.2	-0.8	-0.4	-1.7
D_2 (MW-28)	-2.8	-2.7	-1.2	-1.1	-0.5	-0.8	-1.0	-1.1	-0.5	0.2	-1.2
D_3 (MW-29)	-3.0	-2.9	-2.2	-1.5	-0.7	-1.0	-1.1	-1.2	-0.6	0.1	-1.4
D_4 (MW-30)	-2.6	-2.5	-1.0	-0.9	-0.5	-0.5	-0.8	-1.0	-0.2	0.4	-1.0
Cultivars											
V_1 (MAUS-47)	-2.2	-2.1	-1.0	-0.6	-0.3	-0.4	-0.5	-0.7	-0.1	0.5	-0.7
V_2 (MAUS-71)	-3.4	-3.2	-2.3	-1.7	-1.0	-1.1	-1.4	-1.4	-0.9	-0.2	-1.7
V_3 (MAUS-81)	-2.7	-2.6	-1.5	-1.1	-0.6	-0.8	-0.9	-1.0	-0.5	0.30	-1.2
V_4 (MAUS-158)	-3.9	-3.7	-2.8	-2.1	-1.3	-1.2	-1.6	-1.7	-1.0	-0.4	-2.0
V_5 (JS-93-05)	-2.5	-2.4	-1.2	-0.9	-0.4	-0.6	-0.6	-0.7	-0.2	0.4	-0.9
V_6 (JS-335)	-3.0	-2.8	-2.0	-1.5	-0.8	-1.0	-1.1	-1.2	-0.7	-0.1	-1.4
Mean	-2.9	-2.8	-1.8	-1.3	-0.7	-0.8	-1.0	-1.1	-0.5	0.1	-1.30

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 and P_{10} – Dough stage to maturity

different cultivars are presented in Table 7. The Tc-Ta values were recorded in similar fashion as that of canopy temperature in all date of sowing and genotypes. The average Tc-Ta values ranged from -2.9^{0}C to 0.1^{0}C in P_1 to P_{10} stage.

In maturity stage (P_{10}) there were significant differences observed in all date of sowing and genotypes. The P_{10} stage showed higher positive (Tc - Ta) (0.1^{0}C) difference, which showed the soil moisture stress in P_{10} stage. While in other stages, rainfall was occurred, so that Tc-Ta were negative which showed no any moisture stress in remaining stage except P_{10} stage (maturity stage). The highest (Tc-Ta) difference were observed in P_{10} stage in all date of sowing and genotypes. Whereas, the lowest (Tc - Ta) difference were observed in P_1 (emergence stage) in all date of sowing and genotypes. The similar results were reported by Ajayi and Pandey *et al.* (1983) and Idso (1982).

Conclusion:

It was found that the highest canopy temperature was observed in D_4 (MW-30) *i.e.* 32.0^{0}C and cultivar V_1 (MAUS-47) *i.e.* 32.1^{0}C due to bright sunshine and clear weather. Lowest canopy temperature were recorded in D_1 (MW-27) *i.e.* 30.9^{0}C and cultivar V_4 (MAUS-158) *i.e.* 30.7^{0}C. So, no any moisture stress was observed in all phenophases stage except P_{10} (maturity stage). In P_{10} stage canopy temperature was more than air temperature so moisture stress was observed there.

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