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Growth of soybean (*Glycine max* (L.) Merrill) influenced by canopy temperature and humidity under different sowing dates

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Abstract
The field experiment entitled “Growth of soybean (*Glycine max* (L.) Merrill) influenced by canopy temperature and humidity under different sowing dates” was conducted during *kharif* seasons of 2013 and 2014 at Department of Agricultural Meteorology Farm, Centre of Advanced Faculty Training in Agricultural Meteorology (CAFT), College of Agriculture, The canopy temperature (24.80^{0}C) was lower at (S_1-24th MW) as compared to delayed sowing (S_4-30th MW) (24.80^{0}C) and canopy humidity (93 and 89%), respectively. The canopy temperature (24.39^{0}C) was lower at protected condition (Lambda cyhalothrin 5EC @ 1.0 ml l^{-1}) as compared to unprotected condition. The canopy temperature (24.80^{0}C) was lower at (V_2-KDS-344) as compared to variety (V_1-JS-335), The canopy temperature (24.800C) was lower at (S_1-24th MW) as compared to delayed sowing (S_4-30th MW) (24.80^{0}C) and canopy humidity (93 and 89%), respectively. It was observed that mean canopy humidity (%) remained between 87% to 92% across the total growing period of the crop. Application of Lambda cyhalothrin 5EC @ 1.0 ml l^{-1} for two different varieties under four sowing windows produced significantly higher values of growth characters i.e. plant height (60.96), number of branches plant^{-1} (8.94), leaf are plant^{-1} (14.80dm^2), dry matter accumulation (18.04) resulting in significant increase in pod numbers and grain yield during both the year as compared to unprotected conditions and delayed sowing windows.

Keywords: Soybean, environmental factors, sowing windows, growth parameters

Introduction

Soybean is one of the most important leguminous crops belonging to family Leguminoseae. Soybean is native of Asia and the first known records however, indicate that soybean emerged as a domesticated crop around eleventh century BC in China, (Nagata, 1960) [11] and was introduced in India in 1870-80 (Andole, 1984) [2]. The soybean play an important role in Indian economy and also in human diet. Among oilseed crops, soybean is rich source of protein and oil producing crop and occupies an important place in international market. It is cultivated on large scale in many parts of the world particularly, USA, USSR, China, Japan etc. Imports of edible oil become a serious drain of the scarce foreign exchange resource. Soybean, "The miracle golden bean of 20th century" has revolutionized the agriculture as well as generated economy of many countries like China and Japan (Balasubharamanian, 1972) [3]. Soybean is easy for cultivation, requiring less N fertilizer, labour and having more benefit: cost ratio. Soybean builds up soil fertility by fixing large amount of atmospheric nitrogen through root nodules and also through leaf fall on the ground, at senescence. It also reduces soil erosion. It has relatively better suitability to most soils. All these qualities make it an ideal crop for inclusion in crop rotation and cropping system. High relative humidity can cause deterioration of seeds. One percent increase in moisture content can reduce the seed longevity to half. Long distance nutrients and minerals transport is also affected by relative humidity.

Temperature, defined as the energy state of an object is one of the principle controls over plant distribution and productivity. It has large effects on physiological activity at all spatial and temporal scales and has influence on time course of crop development. In soybean, the vegetative development is marked by the sequence of seedling emergence, cotyledons expansion, the appearance of first pair of opposite unifoliolate leaves and subsequent appearance of leaves that are alternate and trifoliate. After six or more trifoliate leaves have appeared, the floral initiation occurs. In the reproductive development, after pollination, pods begin to develop and reach an almost full width while the developing embryo is still very small. The seed filling begins and then seeds enter a period of rapid linear dry matter accumulation. Physiological maturity is reached when pods lose their green color and soybeans are harvested after drying in the pod to 15% (or less) moisture. The rate of development in each phase, or inversely its duration, is determined by genetic and environmental interactions among which, light, water and temperature. Temperature has effect on development, first as a general promoter of development through activation of enzymatic processes, and second as a modifier and a preconditioner of photo-periodism, The rise in temperature above the optimum with negative impacts on plants is known as heat stress and is among the most commonly encountered stress factors, acting either independently or in combination with drought stress. With the current trend in surface temperature due to global warming, more extreme episodes of heat stress are likely to occur, thereby causing adverse impacts on crop yield.

Material and Methods

The experiment was conducted in a split- split -plot design with sixteen treatment combinations replicated thrice were formed considering different protection, varieties and sowing windows with 45cm x 5cm spacing, Two treatments protected (Lambda cyhalothrin 5EC @ 1.0 ml l^{-1}) (P_1) and unprotected (P_2) with two varieties JS-335 (V_1), KDS-344 (V_2) and four sowing windows (S_1)- 24th MW, (S_2) -26th MW,(S_3)-28th MW,(S_4)-30th MW. Observations were recorded on five randomly selected plant-5 s at weekly intervals starting with 14 days after sowing (DAS) till harvesting. The data of the treatments were recorded at 14 DAS intervals. While recording the data, it was noted that the observations on canopy temperature and humidity should be recorded early in the morning and in afternoon because of minimum and maximum values. Weekly Meteorological data during crop was collected from Agro meteorological observatory of India Meteorological Department located at College of Agriculture Pune. The canopy temperature was measured by infrared thermometer and Vaisala sensor. It detects minute difference between crop canopy and surrounding air temperature. The easy handling during operation and speed of measurement are the advantage over more laborious methods such as direct thermocouple placement on leaves. Thus the use of infrared thermometer as research tool to measure crop or plant temperature remotely was becoming increasingly popular. Telatemp (model AG-42) was used for measurement of canopy temperature and canopy-air temperature differential in this experiment. The canopy humidity was measured by Vaisala sensor.

Result and Discussion

Canopy temperature (^{0}C): The canopy temperature (^{0}C) experienced by the crop across the total growing period during 2013 and 2014. During 2013, it was observed that mean canopy temperature (^{0}C) showed increased slightly from 14 DAS (18.7^{0}C) to 42 DAS (21.7^{0}C). Then it was approximately same from 42 DAS (21.7^{0}C) to 56 DAS (20.4^{0}C). The highest canopy temperature (^{0}C) was faced at the time of maturity period during both the years of experimentation.

During the year 2013, canopy temperature (°C) (18.4 ^{0}C to 18.5 ^{0}C) experienced by the crop during 28 DAS showed increased in unprotected condition as compared to protected condition (Lambda cyhalothrin 5EC @1.0 ml l^{-1}). From 28 DAS to 84 DAS the canopy temperature (^{0}C) experienced by the crop showed more or less similar, it was increased from 28 DAS (18.4^{0}C) to harvest (23.4^{0}C) in protected condition and (18.5^{0}C) to (24.0^{0}C) under unprotected condition. During the year 2014, it was increased from 28 DAS (19.1 ^{0}C) to harvest (25.1^{0}C) in protected condition and (19.6^{0}C) to (25.8^{0}C) under unprotected condition. The unprotected plot showed the highest canopy temperature (^{0}C) as compared to protected plot. It might be due to the heavy and continuous rains and low temperature did not allow the defoliators population to grow. Hence due to very low population of the pest the correlation with most of the weather parameters was found non-significant. This slight variation in appearance of tobacco caterpillar may be due to agro-climatic variation or crop age. These results are in conformity with the findings of Kumawat and Kumar (2007) [10].

Among the varieties the canopy temperature (^{0}C) remained more or less similar over total growing period of the crop during both the years of 2013 and 2014.During 2013, the variety JS-355 recorded the highest canopy temperature from 28 DAS (19.1^{0}C) to harvest (24.5^{0}C) as compared to variety KDS-344 at 28 DAS (18.2^{0}C) to harvest (24.0^{0}C). During 2014, the variety JS-355 recorded the highest canopy temperature from 28 DAS (19.4^{0}C) to harvest (25.6^{0}C) as compared to variety KDS-344 at 28 DAS (19.3^{0}C) to harvest (25.5^{0}C).These results are in conformity with the findings of Singh (2008), Kathmale *et al*. (2013) [7].

During the year 2013, canopy temperature (18.3 ^{0}C to 19.1^{0}C) at 28 DAS and (24.1^{0}C to 24.1^{0}C) at harvest experienced by the crop showed increased with later sowings (S_1-24th MW to S_4-30thMW) during 2014 also recorded the similar results that canopy temperature increased from emergence to harvesting with delayed in sowing windows (S_1-24th MW to S_4-30thMW) at 28 DAS (18.9^{0}C to 20.4^{0}C) and at harvest (25.4^{0}C to 25.5^{0}C). It might be due to lower temperature during the flowering period increased the productivity of soybean. The fact is that the positive correlation of seed yield with these agro-meteorology indices could not necessarily be taken to mean the thermal regime with higher prevailing temperatures which contribute the positive correlation with the seed yield of soybean. These results are in conformity with the findings of Kumar *et al.* (2008) [9], Kumar *et al.* (2012) [8], Gudadhe *et al.* (2013) [6], Singh (2013) [12].

Canopy humidity RH (%): During 2013 and 2014, canopy humidity (%) did not show marked variation and remained more or less similar at the observed growth period of the crop. The highest value of canopy humidity (%) was observed in protected condition (Lambda cyhalothrin 5EC @1.0 ml l^{-1}) as compared to unprotected condition. These results are in conformity with the findings of Kumawat and Kumar (2007) [10].

Among the varieties, canopy humidity (%) did not show marked variation and remain more or less similar across the total growing period during both the years of 2013 and 2014.The variety KDS-344 recorded the highest canopy humidity (%) as compared to variety JS-335 during both the years of experimentation. These results are in conformity with the findings of Singh (2008), Kathmale *et al.* (2013) [7].

During the year 2013, at 28 DAS the canopy humidity was more for S_1 (24th MW) and decreased from later sowing windows. It was decreased from (91% to 86 %) at 28 DAS to (92 % to 88 %) at harvest from (S_1-24th MW to S_4-30thMW). During the year 2014, the canopy humidity (%) showed decreasing trend from (S_1-24th MW to S_4-30thMW)at 28 DAS (94% to 84 %) and at harvest (95 % to 90 %) averaged across the total growing period, canopy humidity (%) showed decreasing trend from (S_1-24th MW,S_2-26th MW,S_3-28th -MW to S_4-30thMW)sowing times. The favorable impact of climatic conditions on seed yield might be ascribed the lower evaporative demand and there by more vegetative growth and consequently more seed yield. The higher relative humidity during the flowering phase might have to help in proper seed setting by overcoming the pollen desiccation and thereby in good seed yields. It is very clear that sowing windows and genotypes received more or less similar canopy humidity (%) during the growth phases of soybean crop during the experimentation. Lower amount of canopy humidity (%) recorded at top as well as bottom in evening. These results are in conformity with the findings of Kumar *et al.* (2008) [9], Kumar *et al.* (2012) [8], Gudadhe *et al.* (2013) [6], Singh (2013) [12].

Growth characters

All growth characters were significantly influenced due to different protection treatments, varieties and sowing windows during both the years of experimentation i.e. 2013 and 2014., plant height (60.96), number of branches plant^{-1} (8.94), leaf area plant^{-1}(14.80dm^2), dry matter accumulation (18.04) in protected treatment (Lambda cyhalothrin 5EC@ 1.0 ml l^{-1}) were significantly superior than unprotected treatment during both the years. plant height (63.10), number of branches plant^{-1}(9.16), leaf area plant^{-1}(14.28dm^2), dry matter accumulation (17.62) in variety (V_2-KDS-344) were significantly superior than variety (V_1-JS-335). The S_1 -(24th MW) sowing window recorded higher values of, plant height (62.64), number of branches plant^{-1}(9.11), leaf area plant^{-1} (14.49dm^2), dry matter accumulation (17.23) over rest of the sowing windows and it was statistically at par with S_2-(26th MW).Statistically the lowest values of above parameters were recorded at S_4-(30th MW) during both the years.

It could be observed that at all the stages of growth protection treatment (P_1) (Lambda cyhalothrin 5EC @ 1.0 ml l^{-1}) recorded significantly higher plant height (58.79 and 63.13 cm) as compared to unprotected treatment (P_2) (56.05 and 58.68 cm) during both the years of 2013 and 2014, respectively. These results are in accordance with the findings of Kumawat and Kumar (2007) [10] and also found that at all the stages of growth, variety KDS-344 (V_2) recorded significantly higher plant height (61.20 and 65.0cm) as compared to variety JS-335 (V_1) (53.63 and 56.81cm) during both the years. The maximum plant height (60.93 and 64.35 cm) was recorded with 24th MW (S_1) sowing and it was at par with 26th MW i.e. (S_2) These results are in conformity with the findings of Ahmed *et al*. (2010) [1], Bhatia *et al*. (1999) [4], Singh (2013) [12].

Statistically the highest mean maximum number of branches plant^{-1} registered under protected condition (Lambda cyhalothrin 5EC @ 1.0 ml l^{-1}) was 8.52 and 9.37 as compared unprotected condition 8.10 and 9.13 at 70 DAS during both the years of 2013 and 2014, respectively. at all the stages of growth, variety KDS-344 (V_2) recorded significantly higher number of branches plant^{-1} (8.64 and 9.69) as compared to variety JS-335 (V_1) (7.98 and 8.81) during both the years. These results are in conformity with the findings of Billore *et al*. (2000) [5] and Kathmale *et al*. (2013) [7]. Statistically the highest number of branches plant^{-1} (8.68 and 9.55) were recorded with 24th MW (S_1) sowing and at par with 26th MW i.e. (S_2) date of sowing from 56 and 70 DAS. The highest mean maximum leaf area plant^{-1}registered under protected condition (Lambda cyhalothrin 5EC @ 1.0 ml l^{-1}) was 14.21 and 15.39 dm^2 as compared unprotected condition (11.12 and 12.09 dm^2) at 70 DAS during both the years These results are in accordance with the findings of Kumawat and Kumar (2007) [10]. It could be observed that at all the stages of growth, variety KDS-344 (V_2) recorded significantly higher leaf area plant^{-1} (13.82 and 14.74 dm^2) as compared to variety JS-335 (V_1) (11.51 and 12.75 dm^2) at 70 days after sowing during both the years. Statistically the highest leaf area plant^{-1}(14.03 and 14.95 dm^2) was recorded with 24th MW (S_1) sowing and it was at par with 26th MW i.e. (S_2) date of sowing throughout the growth stages of the crop.

Table 1: Canopy temperature (°C) regime of soybean as influenced by different treatments (2013, 2014)

Treatment	Cumulative canopy temperature (°C)											
	28DAS		42 DAS		56 DAS		70 DAS		84DAS		At harvest	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
A) Protection (P)												
P_1: Protected	18.35	19.13	19.35	21.34	19.47	20.69	21.90	24.10	23.02	24.31	23.43	25.14
P_2: Unprotected	18.47	19.56	19.69	21.56	19.52	21.14	22.55	24.42	23.30	25.67	24.95	25.78
B) Varieties (V)												
V_1: JS-335	19.05	19.42	19.61	21.75	20.10	20.75	22.32	23.78	22.35	25.56	24.51	25.64
V_2: KDS-344	18.24	19.27	19.43	21.15	20.05	20.20	22.13	24.74	23.97	24.42	24.03	25.54
C) Sowing windows (S)												
S_1: 24 MW	18.30	18.91	19.41	21.85	19.52	20.70	21.85	24.32	22.90	25.13	24.10	25.42
S_2: 26 MW	18.72	19.23	19.75	21.35	19.60	20.51	21.92	24.13	23.19	24.71	24.17	25.66
S_3: 28 MW	19.10	20.30	20.31	22.30	20.35	21.36	22.53	23.91	23.09	24.82	24.39	25.81
S_4: 30 MW	19.13	20.35	20.72	22.13	20.61	21.10	22.60	24.69	24.13	25.31	24.10	25.48
General mean	18.67	19.52	19.78	21.68	19.90	20.81	22.23	24.26	23.24	24.99	24.21	25.56

Table 2: Canopy humidity (%) regime of soybean as influenced by different treatments (2013, 2014)

Treatment	Cumulative canopy humidity (%)											
	28DAS		42 DAS		56 DAS		70 DAS		84DAS		At harvest	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
A) Protection (P)												
P_1:Protected	89	91	92	91	87	92	89	92	90	91	92	94
P_2: Unprotected	87	87	88	89	85	90	85	88	89	89	88	92
B) Varieties (V)												
V_1: JS-335	86	84	86	87	84	88	86	87	87	90	89	90
V_2: KDS-344	90	92	94	93	88	94	88	93	92	89	93	95
C) Sowing windows (S)												
S_1: 24 MW	91	94	94	91	89	94	91	93	91	93	92	95
S_2: 26 MW	87	92	93	90	87	93	87	92	87	92	90	94

S_3: 28 MW	87	87	89	90	85	90	86	88	86	88	90	92
S_4: 30 MW	86	84	87	89	85	88	85	88	85	88	88	90
General mean	87	88	90	90	86	91	87	90	87	90	90	92

Table 3: Mean Plant height, Number of branches, Leaf area plant^{-1} and Total dry matter accumulation as influenced by different treatments, varieties and sowing windows.

Treatments	Plant height (cm) 84 DAS			Number of branches 84 DAS			Leaf area plant^{-1} 70 DAS			Total dry matter accumulation 70 DAS		
	2013	2014	Pooled	2014	2013	Pooled	2013	2014	Pooled	2014	2013	Pooled
A) Protection (P)												
P_1: Protected	58.79	63.13	60.96	8.52	9.37	8.94	14.21	15.39	14.80	16.82	19.26	18.04
P_2: Unprotected	56.05	58.68	57.36	8.10	9.13	8.61	11.12	12.09	11.61	12.75	15.54	14.15
S.E.m ±	0.27	0.68	0.63	0.07	0.02	0.06	0.34	0.20	0.34	0.07	0.00	0.06
C. D. at 5%	1.64	4.15	2.49	0.40	0.13	0.24	2.05	1.23	1.34	0.45	0.01	0.25
B) Varieties (V)												
V_1: JS-335	53.63	56.81	55.22	7.98	8.81	8.39	11.51	12.75	12.13	13.31	15.83	14.57
V_2: KDS-344	61.20	65.00	63.10	8.64	9.69	9.16	13.82	14.74	14.28	16.26	18.98	17.62
S.E.m ±	0.34	0.51	0.53	0.12	0.09	0.13	0.35	0.49	0.52	0.31	0.20	0.32
C. D. at 5%	1.32	2.00	1.72	0.47	0.35	0.42	1.37	1.91	1.69	1.23	0.78	1.05
C) Sowing windows (S)												
S_1: 24 MW	60.93	64.35	62.64	8.68	9.55	9.11	14.03	14.95	14.49	15.81	18.65	17.23
S_2: 26 MW	58.08	61.51	59.79	8.48	9.36	8.92	13.25	14.33	13.79	15.25	17.67	16.46
S_3: 28 MW	56.87	60.56	58.71	8.22	9.21	8.71	12.19	13.40	12.80	14.36	16.81	15.59
S_4: 30 MW	53.80	57.20	55.50	7.86	8.88	8.37	11.19	12.28	11.73	13.72	16.47	15.10
S.E.m ±	0.52	0.53	0.64	0.13	0.13	0.16	0.36	0.32	0.42	0.31	0.36	0.41
C. D. at 5%	1.51	1.55	1.83	0.37	0.39	0.45	1.05	0.93	1.18	0.90	1.04	1.16
Interactions												
P×V												
S.E.m 1 ±	0.47	0.72	0.75	0.17	0.13	0.18	0.49	0.69	0.73	0.44	0.28	0.45
C. D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1.61	0.96	1.61
S.E.m 2 ±	0.43	0.85	0.83	0.14	0.09	0.14	0.49	0.53	0.62	0.32	0.20	0.33
C. D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1.94	1.41	2.02
P×S												
S.E.m 1 ±	0.73	0.75	0.91	0.18	0.19	0.22	0.51	0.45	0.59	0.44	0.50	0.58
C.D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.44	0.50	0.58
S.E.m 2 ±	0.72	0.83	0.95	0.19	0.18	0.23	0.56	0.62	0.73	N.S.	N.S.	N.S.
C. D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.49	0.48	0.59
V×S												
S.E.m 1 ±	0.73	0.75	0.91	0.18	0.19	0.22	0.51	0.49	0.61	0.44	0.50	0.58
C. D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
S.E.m 2 ±	0.72	0.83	0.95	0.19	0.18	0.23	0.56	0.62	0.73	0.49	0.48	0.59
C. D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
P×V×S												
S.E.m 1 ±	1.03	1.06	1.28	0.25	0.26	0.31	0.72	0.64	0.83	0.62	0.71	0.82
C. D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
S.E.m 2 ±	1.01	1.17	1.34	0.27	0.26	0.32	0.79	0.88	1.03	0.62	0.71	0.82
C. D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
S.E.m 3 ±	1.53	2.14	2.28	0.41	0.37	0.48	1.31	1.31	1.60	0.69	0.68	0.84
C. D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
General mean	57.42	60.90	59.16	8.31	9.25	8.78	12.66	13.74	13.20	0.99	0.96	1.19

It might be due to lower temperature during the flowering period increased the development of soybean. The fact is that the positive correlation of growth with these agro-meteorology indices could not necessarily be taken to mean the thermal regime with higher prevailing temperatures which contribute the positive correlation with the seed yield of soybean. The favorable impact of climatic conditions on seed yield might be ascribed the lower evaporative demand and there by more vegetative growth and consequently more dry matter accumulation. The higher relative humidity during the flowering phase might have to help in proper seed setting by overcoming the pollen desiccation and thereby in good seed yields. It is very clear that sowing windows and genotypes received more or less similar canopy humidity (%) during the growth phases of soybean crop during the experimentation. Lower amount of canopy humidity (%) recorded at top as well as bottom in evening.

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