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Effects of Varying Temperature and Photoperiod on Grain Yield and its Components in Soybean Genotypes Grown in Punjab, India

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Abstract Seventeen soybean (*Glycine max* (L.) Merrill) genotypes were grown under three different dates of sowing (March 1, June 7 and August 5) exposing vegetative and reproductive phases to different temperature and photoperiod regimes. Pooled analysis of variance over the three environments (sowing dates) revealed significant variance for genotype, sowing date and genotype × sowing date interaction for all the seven quantitative characters studied. Highest number of pods/plant and grain yield were obtained from June sowing whereas plant height, 100-seed weight, days to flowering and maturity were highest in March sowing. Relative ranking of different genotypes varied with sowing dates indicating the presence of genotype × environment interaction that could be exploited to get highest yielding genotypes under each sowing date. Study identified genotype, SL (E) 45 that can be grown during summer season (March-June) under Punjab conditions.

Keywords Sowing date, Soybean, Yield, Yield components, G × E interactions.

Introduction

Soybean (*Glycine max* (L.) Merrill) is a high value legume containing high protein (40–42%), good quality oil (18–20%) and appreciable amount of minerals and vitamins. Soybean yield is greatly influenced by the factors like temperature [1], moisture and photoperiod [2]. Variation of these environmental factors affecting growth and production are difficult to be controlled. But their manipulation through determination of suitable planting date could be helpful in achieving maximum potential of the plants. Moreover, a specific genotype does not always exhibit the same phenotypic characteristics under all environments. Different soybean genotypes show differential response to environmental conditions. Therefore, interaction between genotype and environment determines season or location where a genotype would be most suitable.

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Table 1. Mean squares for different characters in soybean over different sowing dates. *Significant at 0.05 probability level, **Significant at 0.01 probability level.

Source of variation	d.f.	Days to flowering	Days to maturity	Plant height (cm)	No. of pods/plant	100-seed weight (g)	Grain yield (g/plant)	Harvest index (%)
Replications (in env.)	6	2.05	4.71*	14.30*	62.70	1.27**	0.10	4.57
Sowing Dates (D)	2	3546.09**	26115.75**	24964.42**	5450.25**	110.71**	193.50**	22020.10**
Genotypes (G)	16	146.62**	165.84**	329.46**	252.79**	10.58**	10.24**	261.59**
Interaction (G×D)	32	29.89**	93.84**	140.93**	168.29**	3.20**	7.68**	279.16**
Error	96	2.32	1.41	4.97	28.67	0.29	0.13	8.02

The G × E interaction studies are needed to identify the stable varieties under varying environmental conditions [3]. Soybean is a short day plant and sensitive to photoperiod and temperature. Most of the genotypes of soybean recommended for north-west part of India flower around mid August and mature in end October irrespective of sowing date. The soybean genotypes used in the present study are less sensitive to photoperiod and temperature, can be grown from March through August. Thus, these genotypes can be used to study the effect of photoperiod and temperature on important agronomic characters. The present study, therefore, has been conducted to assess the effect of varying temperature and day length on grain yield and its components under three different environmental conditions characterized by different temperature and photoperiod regimes.

Materials and Methods

The present investigation was carried out at the Pulses Research area of the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana. Seventeen genotypes of soybean were grown under three different dates of sowing i.e. March 1 (D_1), June 7 (D_2) and August 5 (D_3). Each genotype was planted in four rows of 3 m length with row to row spacing of 22.5 cm and plant to plant spacing of 5 cm within the rows in a randomized complete block design with three replication in each of three sowing dates. Observations were recorded on ten randomly taken plants of each genotype and three dates of sowing. Seven quantitative characters viz. days to flowering, days to maturity, plant height, number of pods per plant, 100-seed weight, grain yield per plant and harvest index were measured. The analysis of variance (ANOVA) for each character over three sowing dates was performed using Microsoft Excel and CPCSI software.

Results and Discussion

Result of analysis of variance for each date of sowing revealed significant genotypic mean squares for all the characters (data not shown). Pooled analysis of variance over the three environments (sowing dates) is shown in Table 1. The variance due to genotypes and sowing dates were highly significant for all the characters studied. Similar trend was observed for genotype × sowing date interaction for all the characters. This highly significant variance for interaction between genotypes and sowing dates suggested that genotypes respond differently in direction and magnitude. Both genotypes and environment were more or less equally responsible for the variance observed while sowing dates increased the difference among genotypes. G × E interactions were also earlier observed for yield and its components viz., pod number per plant, plant height, seed yield per plant and 1000-seed weight [4, 5].

The results of the analysis of variance showed a significant effect of sowing date on mean days to flowering (Table 2) suggesting strong influence of photothermal conditions in determining days to flow-

Table 2. Mean performance of different genotypes of soybean sown at three different sowing dates (D_1, D_2, D_3) for days to flowering, days to maturity, plant height and No. of pods per plant.

Sl. No.	Genotypes	Days to flowering D_1	D_2	D_3	Days to maturity D_1	D_2	D_3	Plant hright (cm) D_1	D_2	D_3	No. of pods/plant D_1	D_2	D_3
1	MACS 330	56.0	43.6	31.0	122.0	106.0	82.0	70.0	30.6	20.0	28.6	43.0	11.3
2	SL (E) 1	42.0	48.0	31.0	146.0	114.0	84.0	64.6	39.6	39.3	42.0	51.0	16.6
3	SL (E) 14	43.0	36.6	31.0	146.0	106.0	82.0	92.0	39.0	29.6	36.0	47.3	15.0
4	SL (E) 14A	46.0	36.0	31.0	122.0	106.0	83.0	65.6	35.6	23.3	46.6	30.6	17.0
5	SL (E) 18	49.0	42.3	32.0	122.0	106.0	83.0	89.0	40.0	27.3	37.3	43.3	37.3
6	SL (E) 20	46.0	40.0	32.0	122.0	106.0	82.0	68.0	38.0	26.3	35.3	34.0	26.0
7	SL (E) 21	58.0	47.6	37.0	122.0	108.0	82.0	60.0	33.0	20.6	40.6	29.6	25.3
8	SL (E) 27	60.0	47.6	36.0	122.0	106.0	83.0	61.3	31.6	20.0	28.3	39.3	15.3
9	SL (E) 28	46.0	36.6	32.0	122.0	108.0	82.0	44.6	37.0	25.3	24.6	27.3	15.0
10	SL (E) 32	45.0	36.6	34.0	122.0	106.0	82.0	56.0	34.3	22.6	16.3	41.0	12.6
11	SL (E) 38	48.0	46.3	36.0	122.0	106.0	82.0	56.0	31.6	22.6	36.6	56.0	19.6
12	SL (E) 39	57.0	47.6	36.0	122.0	106.0	82.0	73.3	34.6	26.3	36.3	26.0	25.3
13	SL (E) 40	60.0	49.0	36.0	122.0	106.0	82.0	61.3	37.6	22.0	33.6	37.3	19.0
14	SL (E) 41	45.0	39.0	34.0	146.0	114.0	84.0	75.3	53.3	24.6	43.3	39.0	17.3
15	SL (E) 42	46.0	47.6	33.0	146.0	108.0	82.0	74.0	41.0	34.3	31.3	51.0	29.6
16	SL (E) 44	46.0	36.6	32.0	122.0	106.0	83.0	70.6	29.6	22.0	38.6	40.6	11.6
17	SL (E) 45	56.0	45.0	31.0	122.0	106.0	82.0	66.0	25.3	16.0	20.3	30.0	13.0
	Mean	49.9	42.2	33.3	127.6	107.4	82.4	67.5	36.0	24.8	33.9	39.2	19.2
	CD	2.7	2.8	1.9	0.10	3.02	1.62	3.9	3.3	3.8	5.5	13.5	5.0
	Range	42.0-60.0	36.0-49.0	31.0-37.0	122.0-146.0	106.0-114.0	82.0-84.0	44.6-92.0	25.3-53.3	16.0-39.3	16.3-46.6	26.0-56.0	11.3-37.3

ering of different genotypes. Mean value consistently decreased from March (D_2) (49.9 days) to June (D_2) (42.2 days) sowing and June (D_3) to August sowing (D_3) (33.3 days) for almost all the genotypes. Five genotypes MACS 330, SL (E) 1, SL (E) 14, SL (E) 14A and SL (E) 45 were earliest to flower (31.0 days) and SL (E) 21 flowered late by taking 37.0 days to flower under August sowing. The response of days to maturity to emvironmental change was similar to the response of days to flowering. The Table 2 showed that the mean number of days to maturity in D_1 sowing date was 127.6 with range of 122.0–146.0 days. In D_2, minimum number of days to maturity were 106.0 and maximum days to maturity were 114.0 with mean of 107.4 days. In D_3 sowing date, minimum number of days to maturity were 82.0 and maximum number of days taken to maturity were 84.0 with overall mean value of 82.4 days.

Likewise, highly significant variance observed for plant height attribued to genotypes, sowing dates and the interaction between genotypes and sowing dates. Effect of different sowing dates on plant height is evident from the fact that mean plant height was maximum for March sowing and decreased as sowing was delayed and this decrease in plant height was consistent for all the genotypes. It could be due to fact that in early planting, plants remained in vegetative phase for longer period leading to more plant height whereas low temperature and photoperiod as in August (D_3) sowing forced the plants to flower quickly leading to reduced plant height.

Similarly, for number of pods per plant, the genotypes showed significant variance suggesting genetic differences between genotypes for this trait in all the three sowing dates. Variance due to interaction between genotypes and sowing dates was also significant. The mean pod number slightly increased from D_1 (33.9) to D_2 (39.2) and then decreased in D_3 (19.2). Thus, the delay in planting cause reduction in number of pod per plant because of decrease in growing period specially decrease in vegetative phase of growth. The result is in accordance with findings of Batwal et al. [6]. Pedersen and Lauer [7] and Kantolic and Slafer [8].

Table 3. Mean performance of different genotypes of soybean sown at three different sowing dates (D_1, D_2, D_3) for 100-seed weight, grain yield and harvest index. *CD–Critical Difference.

Sl. No.	Genotypes	100-seed weight (g) D_1	D_2	D_3	Grain yield (g/plant) D_1	D_2	D_3	Harvest index (%) D_1	D_2	D_3
1	MACS 330	11.6	8.0	10.0	6.5	9.3	3.9	13.4	38.8	75.0
2	SL (E) 1	10.6	8.6	9.5	6.2	10.0	3.0	5.0	53.7	40.3
3	SL (E) 14	9.1	6.0	8.3	4.7	7.8	1.8	6.2	50.7	37.4
4	SL (E) 14A	10.1	6.5	9.5	7.0	6.0	2.6	8.4	39.2	32.7
5	SL (E) 18	9.6	7.1	9.5	6.0	9.1	5.3	13.6	53.1	39.5
6	SL (E) 20	9.6	6.1	7.6	4.3	6.2	3.2	13.1	39.3	44.9
7	SL (E) 21	8.8	5.3	8.0	4.6	5.5	3.7	14.9	35.5	38.5
8	SL (E) 27	10.0	5.1	9.1	3.3	3.1	3.1	14.5	42.7	51.5
9	SL (E) 28	9.0	8.5	10.6	4.2	7.2	3.6	9.0	46.9	51.6
10	SL (E) 32	10.0	7.8	8.1	3.4	7.1	2.4	5.4	48.1	78.3
11	SL (E) 38	9.1	6.0	8.5	4.4	6.5	1.5	9.1	43.8	46.0
12	SL (E) 39	10.3	5.5	8.5	5.5	4.9	2.1	9.6	41.4	45.4
13	SL (E) 40	9.5	8.6	8.5	6.0	2.6	2.7	17.6	36.5	42.2
14	SL (E) 41	9.0	7.8	9.8	3.7	11.6	2.9	6.7	44.2	49.3
15	SL (E) 42	6.0	4.1	5.6	7.4	7.8	2.7	19.7	33.6	33.6
16	SL (E) 44	9.0	7.5	7.6	4.4	6.3	2.5	8.5	52.4	60.1
17	SL (E) 45	13.0	7.3	7.6	8.8	5.5	3.7	13.8	47.5	76.6
	Mean	9.7	6.8	8.6	5.4	6.8	3.0	11.1	43.9	49.6
	*CD	0.9	0.7	0.9	0.3	0.6	0.7	1.5	2.5	7.6
	Range	6.0-13.0	4.1-8.6	5.6-10.6	3.3-8.8	2.6-11.6	1.5-5.3	5.0-19.7	33.6-53.7	32.7-78.3

Growing environment characterized by varying temperature and photoperiod had marked effect on 100-seed weight also. The table showed that mean 100-seed weight was highest in D_1 (9.7 g) sowing followed by D_3 (8.6 g) and D_2 (6.8 g) for all the genotypes except for SL (E) 28 and SL (E) 41 and SL (E) 40. The temperature at grain filling stage affected seed weight i.e. when the grain filling stage occurred at high temperature and photoperiod, as in case of D_1 (March) sowing, bold seeds were produced which is opposite to the report of Khalil et al. [9]. Results showed that the effect of sowing date on grain yield is substantial.Significane of genotype × sowing date interaction indicated differential response of genotypes to sowing dates for this character. In case of D_1 sowing date, highest grain yield was recorded by SL (E) 45 (8.8 g/plant) (Table 3). The lowest grain yield was recorded by SL (E) 27 (3.3 g/plant). The highest yielding genotypes viz. SL (E) 45 in March sowing took 122 days to mature, thus, this genotype can be successfully grown from March to June under Punjab conditions i.e. after harvest of potato. In second sowing date (D_2), genotype SL (E) 41 showed highest mean value i.e. 11.6 g per plant and lowest value (2.6 g/plant) was showed by SL (E) 40. In D_3 the genotype SL (E) 18 had highest grain yield with value of 5.3 g per plant and lowest value was recorded by SL (E) 38 (1.5 g/plant). Effect of sowing date was similar on grain yield as recorded for pods per plant i.e. it was highest in normal sowing date (D_2) followed by early sowing (D_1) and late sowing (D_3) sowing. Thus, grain yield was highest in the *kharif* season which confirms to the results of Oad et al. [10]. Kumar et al. [11], Bastidas et al. [12], Ngalamu et al. [13] and Yagoub and Hamed [14] also reported decrease in yield with late sowing. Reduction in canopy size and shortened vegetative growth period has been stated as one of the main reasons for reduced seed yield in case of late sowing [15]. In late sowing, there is shorter growing season and early onset of flowering and before plant produce optimum biomass it enters the reproductive phase, as a result, there is reproductive competition with the growing consumption of photosynthesis. Thus reduced plant height and number of pods per plant affects the final yield [16].

In the present findings, large variations for harvest index were observed within and between environments. It is evident from Table 3 that most of the genotypes had high harvest index in August sowing followed by second (June) and first sowing (March). The genotypes in D_1 sowing produced high biomass that could not be converted into high grain yield thus resulting in low values for harvest index.

The results of this study showed that sowing date had significant effect on seed yield and yield components. Special conditions of day, heat degree and other environmental factors in different sowing dates have impact on plant growth and development. The main sowing season (*kharif* seaon) had the highest grain yield followed by March sowing. But the genotype SL (E) 45 gave good yield in March sowing along with higher 100-seed weight and this genotype can be successfully cultivated in summer (March–June) in Punjab. Different cultivars behaved differently in different sowing dates suggesting the presence of G × E interaction for characters studied.

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