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Evaluation the Genetic Variability and Association Analysis of Soybean (*Glycine max* (l.) Merrill for Some Physiological Parameters

Monika Soni [a*], M. K. Shrivastava [a], Yogendra Singh [a], Stuti Sharma [a], Pawan K. Amrate [a] and Jhilick Banerjee [a]

[a] Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study was carried out to estimate the important genetic parameters, heritability, genetic advance correlation, and path coefficient analysis in fifty advanced breeding lines of soybean. Randomized Block design (RBD) with three replications was used to design this experiment at the Department of Plant Breeding and Genetics, JNKVV, Jabalpur in 2020. Genotypes were evaluated for eight traits based on important physiological growth parameters such as leaf area index 1 (30 DAS), leaf area index 2 (45 DAS) leaf area index 3 (60 DAS), leaf area duration 1, (30-45 DAS), leaf area duration 2 (45-60 DAS), seed filling duration, harvest index, seed yield per plant. All statistical analysis was done in CRAN R package. ANOVA revealed a sufficient amount of variability was found among soybean genotypes for all traits assessed, which gives an opportunity to plant breeders for the enhancement of these traits. The value of the phenotypic coefficient of variation (PCV) is greater than the genotypic coefficient of variation (GCV). The high GCV and PCV were observed for leaf Area Index 1, leaf Area Index 3, leaf Area Duration 2, seed filling duration, harvest index and seed yield. High heritability (0.8) coupled with high genetic advance as percentage mean (66.4) were recorded for leaf area index 1 (30 DAS). It indicates that the trait is governed by additive gene action and directional selection for this trait would be more effective for desired genetic improvement. Correlation coefficient study indicated that Leaf area index 1, leaf area duration1 and

**Corresponding author: E-mail: monikasoni4456@gmail.com;*

harvest index showed a significant positive correlation with seed yield. Greater LAI of soybean genotypes would be enabled greater radiation absorption during the seed filling period. Harvest index showed a significant positive direct effect along with a positive correlation with seed yield, which can be considered as suitable selection criteria for the development of high-yielding soybean genotypes.

Keywords: Genetic variability; phenotypic variance; yield; leaf area index; leaf area duration; correlation; path coefficient.

1. INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is one of the most important oilseed crops in the world in terms of production and trade. It has been a dominant oilseed source since the 1960s. Soybean is an essential source of protein, oil, and micronutrients in human and animal feed worldwide. It contains 40–42% high-quality protein and 18–22% oil [1]. It is a rich source of lysine (6.4%) and other essential amino acids, vitamins, and minerals [1]. It is not only to supply food for humans and animals but also at the same time to serve as a means for improving the soil through their ability to fix atmospheric nitrogen. Due to the versatile nature of this crop, its contribution to the industrial, agricultural, and medicinal sectors is significantly increasing. As per AMIS, FAO estimates, among the major soybean growing countries, India ranks fourth in area and fifth in production. In India, the cultivation of soybean was undertaken in an area of 12.06 million hectares with a production of 13.58 million tons and productivity of 1126 kg/ha [2]. Among the states, Madhya Pradesh is known as the “Soya State” of India, comprising 55% of the total national area of soybean cultivation. Apart from Madhya Pradesh, Maharashtra (46.01 lakh ha.) and Rajasthan (10.62 lakh ha) are major soybean-growing states in India.

The Leaf Area Index (LAI) is an important indicator of radiation, precipitation interception, energy conversion, and water balance in plants. It is a reliable parameter for plant growth. Several studies in agronomy and horticulture measure the results of interventions such as fertilizers and irrigation in terms of leaf area index. The assumption made is that the leaf area is functional and thus maintaining some rate of canopy photosynthesis [3]. greater LAI augments the number of layers that light must pass through, increasing the likelihood of solar radiation trapped by the leaves [4]. The relationship between leaf area index and yield is not simple and will vary with the kinds of crops and life-stages of a plant. Accurately simulating the leaf area index is necessary for the accurate simulation of biomass accumulation and transpiration. The opposite is also true, partitioning to the leaves to form a new leaf area is influenced by biomass accumulation [5-8]. A typical leaf area index pattern begins with a lag increase early in the crop season followed by a rapid increase of leaf area index until a maximum value is reached and after that, a sharp decline of leaf area index [9] Therefore, the leaf area index could be measured in different phases of the plant cycle to accurately calculate the optimum yield of most seed crops, individual seed weight is commonly analyzed as the product of the individual seed growth rate by seed filling duration. In legume seeds, the active filling period begins when the pod wall has approximately reached its final size. Seed filling duration varies with changes in environmental conditions [10]. Leaf area duration is the ability of the plant to maintain the green leaves over a unit area of land throughout its life and it expresses in days. Leaf area duration is important to some extent for pod and seed number per unit land area, but it is a major determinate of final seed size. Seed yield is the product of total dry matter and harvest index [11,12]. The seed filling duration of soybean is related to seed yield. Soybean yield significantly decreased when it was exposed to temperature stress, water stress, or the combination of both stresses together [10],[13],[14],[15]. Soybean growth and development are the results of a genetic potential interacting with the environment and minimizing these stresses will optimize seed yield [15].

The knowledge of certain genetic parameters is essential for proper understanding and their manipulation in any crop improvement programme which provides precise information for selection of particular traits. Genetic parameters like genotypic (GCV) and phenotypic (PCV) coefficient of variation, heritability, genetic advance and path coefficient analysis are very useful biometrical tools for measuring variability present in genotypes. Seed yield is the result of the expression and association of several plant growth components. path analysis can reveal whether this association is direct from a particular trait or indirect through any other component traits [16]. Understanding the correlation between grain yield and other characteristics is helpful in the selection of suitable plant types. Correlation and path coefficient analysis can be used as an important tool to bring information about appropriate cause and effects relationship between yield and some yield components [17],[18]. considering all these important traits investigations were undertaken to reveal the genetic association of physiological growth parameters and seed yield in advanced breeding lines of soybean.

2. MATERIALS AND METHODS

The experimental material consists of fifty advanced breeding lines of soybean which developed at JNKVV, Jabalpur. The experiment was carried out in Kharif 2020-21 with Randomized Block Design at Seed Breeding Farm, Jawaharlal Nehru Krishi Vishwavidyalaya. Three lines were sown for each of breeding material with 45 x 7 cm row to row and plant to plant distance. The soil of the experimental area was medium deep black with good drainage. The soil has neutral pH (7.5) and mainly constitute by (25.3) sand, silt (18.9) and clay (55.8). It has high cation exchange capacity (30.24Cmol kg^{-1}), low in salt content (EC - 21dSm-^{1}) and also low in organic carbon (0.52g kg^{-1}). The crop was raised with the following recommended packages and practices of soybean cultivation The experimental site is lies between 22°49' and 20°80' North latitude and 78°21' and 80°58' East longitude at an altitude of 411.78 meters above the mean sea level. The five plants were harvested and threshed separately from each entry and the seed yield of the individual plant was weighed in grams. The various growth observations were recorded at an interval of 30 DAS to harvest. Leaf area index and leaf area duration were calculated according to the formula given by [19].Leaf area index and leaf area duration were calculated according to the formula given by [19]. Three soybean plants were uprooted at 30, 60, 90 DAS and at harvest the observations were recorded timely based on collected data, various growth functions were calculated. All statistical analysis was done in the CRAN R package.

The leaf area index (LAI) was calculated from the data of leaf area per plant at 30, 60 and 90 days respectively. According to the formula given by Watson [19].

LAI = Total Leaf Area /total ground area

The leaf area duration (LAD) was calculated by the formula given by [19]. It can be calculated at any or all development stages, but in the context of yield, the relevant measurement would be at intervals from R1 to R7 (beginning flower to physiological maturity where 50% of pods are yellow) [3].

LAD = LA2+ LA1 (t2 - t1)/2

Where LA1 and LA2 represent the leaf area at two successive time intervals (t1 and t2).

The seed filling duration was calculated as the time from anthesis to physiological maturity. It is different from the total reproductive period measured from flowering to R8 (days to maturity) or the total seed filling period measured from R5 to R8 [20].

The Harvest index was worked out from the following formula:

HI = Seed yield /biological yield X 100

3. RESULTS AND DISCUSSION

Analysis of variance revealed that the mean sum of squares of various traits Viz. leaf area index, leaf area duration, grain filling duration, harvest index and seed yield per plant are significant and indicated a sufficient amount of variability (Table 1). ANOVA indicated that mean sum of squares due to replications were significant at P=0.001 for Leaf area index 1, Leaf area index 2, leaf area duration 1, Leaf area duration 2, and seed yield per plant significant at P=0.05. On the other hand, mean sum of squares due to genotype was significant at P=0.001 for leaf area index 1, leaf area index 2, leaf area index 3, leaf area duration 1, leaf area duration 2, grain filling duration, harvest index, seed yield per plant.

Table 1. Analysis of variance for eight growth parameters of 50 Soybean genotypes

Source of variation	df	LAI 1	LAI 2	LAI 3	LAD 1	LAD 2	SFD	HI	SYPP
Replications	2	2.8***	2.8*	0.2	484.7*	346.6*	4.3	57.6	1.3*
Treatments	49	2.5***	2.3***	1.9***	897.5***	804.2***	45.7***	349.9***	23.6***
Error	98	0.2	0.7	0.1	153.3	83.6	2.4	20.2	0.4

, **, * significant difference at p=0.05, p=0.001, p=0.001, ANOVA: Analysis of variance DF: Degree of freedom, LAI: leaf area index, LAD: leaf area duration, HI: Harvest index, SYPP: seed yield per plant*

Genotypic variance, phenotypic variance, genotypic coefficient of variation, phenotypic coefficient of variation, heritability (broad sense), genetic advance and genetic advance expressed as a percent of the mean for eight characters are presented in Table 2.

3.1 Leaf area Index 1

The range for leaf area index 1 was 0.3 to 5.4 with a 2.4 mean value (Table 2). The magnitude of genotypic coefficient of variance (36.6 %) while a phenotypic coefficient of variance (41.6%). The heritability in the broad sense (0.8 %), genetic advance (1.6) and genetic advance mean percent value was 66.4 %.

3.2 Leaf Area Index 2

The range for leaf area index 2 was 0.8 to 9.6 with the mean value 3.2 (Table 2). The magnitude of genotypic coefficient of variance (23.3 %) while the phenotypic coefficient of variance (34.3 %). The heritability in the broad sense (0.5 %), genetic advance (1.1) and genetic advance mean percent value was 32.6 %.

3. Leaf area Index 3

The range for leaf area index 3 was 0.8 to 6.3 and mean value was 3.0 (Table 2). The magnitude of genotypic coefficient of variance (26.3 %) while the phenotypic coefficient of variance (29.5 %). The heritability in a broad sense (0.8 %), genetic advance (1.4) and genetic advance mean percent value was 48.1 %. Similar results were also reported by Shruthi et al. [21]. These results are similar to the observations found in the present investigation. Likewise, Ralebhat et al. [9] obtained similar conclusions regarding leaf area index.

3.4 Leaf area Duration 1

The range for leaf area duration 1 was 65.8 to 158.7 with the mean value 29.2 (Table 2). The magnitude of genotypic coefficient of variance (23.9 %) while the phenotypic coefficient of variance (30.4 %). The heritability in a broad sense (0.6 %), genetic advance (1.4) and genetic advance mean percent value was 48.1 %.

3.5 Leaf area Duration 2

The range for leaf area duration 2 was 68.5 to 128.5 and the mean value was 28.6 (Table 2). The magnitude of genotypic coefficient of variance (22.6 %) while the phenotypic coefficient of variance (26.3 %). The heritability in a broad sense (0.7 %) and genetic advance (27.5) with genetic advance mean percent value was 40.1 %.

3.6 Seed Filling Duration

The range for seed filling duration was 56.6 to 70.0 with the mean value was 48.0 (Table 2). The magnitude of genotypic coefficient of variance (6.7 %) while the phenotypic coefficient of variance (7.2 %). The heritability in a broad sense (0.9 %) and genetic advance (7.3) with genetic advance mean percent value was 12.8 %.

3.7 Harvest Index

The range for the Harvest index was 42.8 to 78.8. The mean value for grain filling duration was 16.6 (Table 2). The magnitude of genotypic coefficient of variance (24.5 %) while phenotypic coefficient of variance (26.6 %). The heritability in a broad sense (0.8 %) and genetic advance (19.9) with genetic advance mean percent value was 46.3 %.

3.8 Seed Yield per Plant

The range for seed yield per plant was 7.7 to 16.1 The mean value for grain filling duration was 3.6 (Table 2). The magnitude of genotypic coefficient of variance (36.1 %) while phenotypic coefficient of variance (37.1 %). The heritability in a broad sense (0.9 %) and genetic advance (5.6) with genetic advance mean percent value was 72.3 %. These findings were also recorded by Pandey et al. [22], Kumar et al. [23]. According to them, high heritability coupled with high genetic advance as percent of mean was observed by seed yield per plant and harvest index. Sonkamble et al. [24] were also found that the High values of GCV and PCV were observed for seed yield and harvest index. Also found that High heritability along with high genetic advance as percentage mean was observed for seed yield and harvest index.

3.9 Correlation Coefficient

Correlation between different traits is generally due to the presence of linkage disequilibrium, pleiotropic gene actions and epistatic effect of different genes. Falconer [25]. The environment also plays an important role in the correlation. Correlation analysis (Table 3) revealed that LAI 1 was highly significant positively associated with LAI 2, LAI 3, LAD1, LAD 2, and seed yield per plant. Wamanrao et al. [26] also found that leaf area index (LAI) was positively correlated with seed yield. An increase in yield was observed with the increase of LAI for experiments with a small yield gap were revealed by Tagliapietra [27].

The traits LAI 3, LAD1, LAD 2, and harvest index were also exhibited highly significant and positive correlation with LAI 2. LAI 3 showed a highly significant and positive association with LAD1, LAD 2, and harvest index. LAD1 revealed highly significant and positive associated with LAD 2, seed filling duration and harvest index, and seed yield per plant. Data regarding LAD indicated that there were significant differences among all genotypes at 30-60, 60-90, and 90 DAS-at harvests of crops. These findings are in agreement with the result of Xiaobing et al. [28], Tandale et al. [29]. They also show a positive correlation between leaf area duration and seed yield. Harvest index is the largest contributor to soybean yield improvements Ui et al. [30] and Ralebhat et al. [9]. LAD 2 was found a positive and significant correlation with harvest index. whereas harvest index showed a positive and highly significant correlation only with seed yield per plant. Similar findings were also observed by Ben Tshibuyi Kasu-Bandi et al. [31] between HI and seed yield per plant. It was revealed that LAI 1 (0.1958) and LAD 1 (0.1712) were found to be significantly and positively correlated with seed yield per plant.

3.10 Path Coefficient

Path coefficient analysis provides an effective way of finding out direct and indirect sources of correlations. Study revealed (Table 4) that LAD 1 recorded the highest positive direct effect on seed yield. LAI 3 also exhibited a maximum positive direct effect on seed yield. Trait Harvest Index exhibited a positive direct effect on seed yield and a strong association with seed yield (0.8197) indicated the true relationship therefore direct selection through this trait will be effective for yield improvement. Bhuva et al. [32] also found a similar association between harvest index and seed yield. However, LAI 1, LAI 2, LAD 2, SFD has a negative direct effect on seed yield. Since the direct effect was negative, the direct selection for this trait to improve yield will be undesirable. The indirect effect of these traits on seed yield was contributed via LAI 3, LAD 1, and harvest index.

In the current study, no obvious correlation was found between seed filling duration (SFD) and yield. And also, between SFD and leaf area duration (LAD) similar results were also found by Lopez et al. [4]. The lower residual effect (0.906) indicated that most of the variability in grain yield for the genotypes under the present study has been explained by the independent variables included in the analysis. Singh and Chaudhary [24].

In more recent studies, HI has been reported to be a significant contributor to yield improvement Lopez et al. [4]. The strong contribution to final GY from HI aligns with reports in wheat, where a significant positive correlation between photosynthesis traits, HI, and GY, is documented Carmo-Silva et al. [33].

The greater LAI of soybean genotypes during the seed filling period indicates a delay in the rate at which the leaves senesced resulting in a longer stay green period. Greater LAI of soybean genotypes would be enabled greater radiation absorption during the seed filling period especially when LAI values are below the critical value for 95% radiation interception approx. 3-4 LAI Lopez et al. [4]. Therefore, increase radiation interception by photo dynamically active leaves of the genotypes is postulated to have contributed to the greater continued dry matter accumulation. Hence, longer leaf area duration plays an important role in yield improvement. The effective filling period can also be based on growing degree days. A longer effective filling period will be associated with attainment of maximum seed yield Egli [20].

Table 2. Range, mean, genotypic and phenotypic coefficients of variation, heritability, and genetic advance for different growth parameters in Soybean

S. No.	Character	Mean	Range		PV	GV	PCV (%)	GCV (%)	h ² b	GA	GA % of the mean	S. Ed ±	CD	
			Min.	Max.									5%	1%
1	Leaf Area Index 1	2.4	0.3	5.4	1.0	0.8	41.6	36.6	0.8	1.6	66.4	0.3	0.8	1.0
2	Leaf Area Index 2	3.2	0.8	9.6	1.2	0.6	34.3	23.3	0.5	1.1	32.6	0.5	1.3	1.7
3	Leaf Area Index 3	3.0	0.8	6.3	0.8	0.6	29.5	26.3	0.8	1.4	48.1	0.2	0.6	0.9
4	Leaf Area Duration 1	29.2	65.8	158.7	401.4	248.1	30.4	23.9	0.6	25.5	38.8	7.1	20.1	26.6
5	Leaf Area Duration 2	28.6	68.5	128.5	323.8	240.2	26.3	22.6	0.7	27.5	40.1	5.3	14.8	19.6
6	Seed Filling Duration	48.0	56.6	70.0	16.8	14.5	7.2	6.7	0.9	7.3	12.8	0.9	2.5	3.3
7	Harvest Index	16.6	42.8	78.8	130.1	109.9	26.6	24.5	0.8	19.9	46.3	2.6	7.3	9.6
8	Seed Yield Per Plant	3.6	7.7	16.1	8.2	7.7	37.1	36.1	0.9	5.6	72.3	0.4	1.1	1.4

PV= Phenotypic variance, GV= genotypic variance, GCV= Genotypic Coefficient of Variation, PCV= Phenotypic Coefficient of Variation, h2(b)= Heritability (Broad Sense) GA = Genetic Advance, SE standard error, CD = critical difference

Table 3. Genotypic and Phenotypic correlation coefficient of eight physiological growth parameters in soybean

Character	Correlation	LAI 1	LAI 2	LAI 3	LAD1	LAD2	SFD	HI	SYPP
LAI 1	G	1**							
	P	1**							
LAI 2	G	0.5411**	1**						
	P	0.3459**	1**						
LAI 3	G	0.4338**	0.5564**	1**					
	P	0.3819**	0.3856**	1**					
LAD1	G	0.8023**	0.9362**	0.5823**	1**				
	P	0.622**	0.9453**	0.4558**	1**				
LAD2	G	0.5224**	0.7812**	0.9534**	0.7775**	1**			

Character	Correlation	LAI 1	LAI 2	LAI 3	LAD1	LAD2	SFD	HI	SYPP
	P	0.4372**	0.7409**	0.9054**	0.7668**	1**			
SFD	G	0.1721	0.1797	0.1177	0.2051	0.1537	1**		
	P	0.1158	0.1508	0.0759	0.1748*	0.1246	1**		
HI	G	0.1773	0.2622	0.2291	0.2585	0.2674	0.0966	1**	
	P	0.1565	0.1609*	0.1753*	0.1866*	0.2016*	0.0962	1**	
SYPP	G	0.2083	0.1201	0.1266	0.1694	0.1387	-0.023	0.8197**	1**
	P	0.1958*	0.1231	0.1121	0.1712*	0.1382	-0.013	0.7954**	1**

, **, * significant difference at P=0.05, P=0.001, P=0.001, LAI = Leaf Area Index, LAD = Leaf Area Duration, SFD = Seed Filling Duration, HI= Harvest Index, SYPP = Seed Yield Per Plant, G= Genotypic correlation, P= Phenotypic correlation*

Table 4. Direct and indirect effect of eight physiological growth parameters on seed yield in soybean

	LAI 1	LAI 2	LAI 3	LAD1	LAD2	SFD	HI	Correlation with Seed yield
LAI 1	-1.2839	-0.54157	1.4355	2.82392	-2.35684	-0.02121	0.15245	0.2083
LAI 2	-0.69475	-1.00082	1.84146	3.29538	-3.52446	-0.02215	0.22541	0.1201
LAI 3	-0.5569	-0.55688	3.30942	2.04963	-4.3012	-0.0145	0.197	0.1266
LAD 1	-1.03002	-0.93697	1.92704	3.51995	-3.50754	-0.02528	0.22223	0.1694
LAD 2	-0.67072	-0.78186	3.15517	2.73666	-4.51148	-0.01894	0.22986	0.1387
SFD	-0.22101	-0.17987	0.38942	0.72201	-0.69332	-0.12323	0.08302	-0.023
HI	-0.22767	-0.2624	0.75832	0.90987	-1.20624	-0.0119	0.85972	0.8197**
SYPP	0.20834	0.12007	0.12656	0.16942	0.13869	-0.02298	0.8197	1**

Residual: - 0.2906

4. CONCLUSION

The present study revealed that genotypes were significantly associated with physiological growth parameters as well as seed yield. which gives an opportunity to plant breeders for the enhancement of these traits. The high heritability (0.8) values coupled with high genetic advance as percentage mean (66.4) were recorded for LAI 1 (30 DAS). It indicates that the trait is governed by additive gene action and directional selection for this trait would be more effective for desired genetic improvement. Correlation coefficient study indicated that important physiological traits i.e., LAI 1, LAD 1 and HI were found a significant positive association with seed yield. This suggests a common genetic or physiological basis among these traits. Hence, synchronized improvement of these traits would be possible. In this study, there is no consistent relationship was found between seed filling duration and seed yield. However, the harvest index showed a significant positive direct effect along with a positive correlation with seed yield and can be considered as suitable selection criteria for the development of high-yielding soybean genotypes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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