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Research Article

Assessment of genetic variability and association studies for yield related traits in soybean

V. Vasanth[1], K. Anandhi[1*], S. Geetha[1], G.Senthilraja[2] and P. Meenakshi[3]

[1]Department of Pulses, Centre for Plant Breeding and Genetics, TNAU, Coimbatore-3.
[2]Department of Plant Pathology, Centre for Plant Protection Studies, TNAU, Coimbatore-3.
[3]Department of Biochemistry, Centre for Plant Molecular Biology and Biotechnology, TNAU,Coimbatore-3.
[*]**E-Mail**: anandhiagri@gmail.com

Abstract
Soybean is an important legume cum oil seed crop of the country. Generation of information on genetic control of traits and association among them could play a great role in targeted crop improvement. In this study, 76 soybean genotypes including five checks were characterized and evaluated during summer, 2023. The traits namely plant height, number of branches per plant, number of pods per plant, number of clusters per plant and single plant yield showed high GCV and PCV. High heritability and GAM were also observed for the above traits. Traits namely the number of pods per plant, number of branches per plant, number of clusters per plant, number pods per cluster, number of seeds per pod and plant height had significant correlation with yield and direct effects observed to be higher for number of pods per plant and plant height. This study suggested that selection for number of pods per plant, number of branches per plant and number of clusters per plant could be useful to improve the yield and evolve high yielding varieties.

Keywords: Soybean, Variability, Correlation, Path coefficient.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is one of the most important oilseed crop and legume crop in India as well as in the world. It is a diploid legume (2n=2X =40) and seed contains high protein (about 48%) and oil (22%) besides it has a protein mixture including alpha, beta and γ-conclycinins, glycinin, and other globulins(Friedman and Brandon, 2001). US ranks top in soybean production in the world with 119.884 million metric tonnes followed by Brazil, Argentina, China and India (Anonymous, 2022). India's total production stands at 11225.85 MT (Anonymous, 2021). Madhya Pradesh and Maharashtra are the two major contributors for soybean production in the country.

Improvement through selection depends upon the variability existing in the available genotypes, which may be either due to different genetic constitution of cultivars or variations in the growing environments (Baraskar *et al.,* 2014). Selection will be effective only when the observed variability in the population is heritable in nature. Genetic variability in a group of germplasm is a prerequisite for a successful breeding programme. Since, most of the characters influencing yield are polygenic, it is essential for plant breeders to estimate the type of variation available in the germplasm. The type of breeding programme for developing suitable varieties depends largely on the availability of genetic variability in a given species. Similar to genetic variability, heritability is also a main factor in plant breeding program. Heritability has main role in estimating the inheritance ability (Omoigui *et al*., 2006), by expressing the phenotypic value as breeding value. A trait with high heritability is not relatively affected by the environment, where its performance is mostly influenced by the genetic constitution. Therefore, heritability would also indicate the trait to be improved through selection

(Bekele *et al.,* 2012).Hence, it becomes necessary to partition the observed variability into heritable and non-heritable components measured as genotypic and phenotypic coefficients of variation (GCV and PCV) (Sureshrao *et al.,*2014).

Interrelationship of various yield components is important in predicting the correlated response to direct and indirect selection and in the detection of traits with much effect as marker traits (Jain *et al.,* 2015). Path coefficient analysis provides an effective means of partitioning correlation coefficients into unidirectional pathways and alternative pathways thus permitting a critical examination of specific factors that produce a given correlation, which can be successfully employed in formulating an effective selection programme. With this background in view, the present study was undertaken to assess the magnitude and nature of variation among different soybean genotypes with respect to various yield attributes which could be utilized in crop improvement programme. The analysis was also made on association between yield and its attributes in soybean.

MATERIALS AND METHODS

A total of 76 genotypes listed in the **Table 1** were evaluated in this study. Among them, 71 germplasm were received from Ramiah Gene Bank, Tamil Nadu Agricultural University. Two checks namely NRC 132 and NRC 142 were received from the National Research Centre for Soybean (NRCS), Indore and three checks namely MACS 1281, MACS 1460, MACS 1667 were from Maharashtra Association for the cultivation of Science Agharkar Research Institute, Pune. Source of seventy six genotypes were given in **Table 2.** The genotypes were raised during summer 2023 at Department of Pulses, TNAU, Coimbatore (located at latitude of 11.0232°N

Table 1. List of genotypes used in the study

S.No.	Genotypes	S.No.	Genotypes	S.No.	Genotypes
1	AGS 48	25	HIMSO 1521	49	PS 93108
2	AGS 797	26	HIMSO1563	50	PUNJAB 1
3	AMS 19	27	HIMSO 1566	51	DT 21
4	Chepra 64	28	IC 10755	52	IC 109554
5	AVRDC 5	29	IC 13048	53	TNAU 20049
6	DS 12-13	30	IC 9462	54	SL 525
7	DS 1433	31	IC 55898	55	SL 794
8	DS 24110	32	IC 15560	56	SL 88-W
9	DSb 15	33	IC 13043	57	RKS 7
10	EC 10076	34	KB 221	58	KB 97
11	EC 1021	35	SL 443	59	TNAU 20053
12	EC 14425	36	SL 46	60	WILLIAMS 8211
13	EC 15961	37	SL 518	61	TNAU 20056
14	EC 220	38	LU 22	62	TS 9
15	EC 395	39	LU 38	63	LU 65
16	EC 39719	40	LU 46	64	IC 15092
17	EC 4290	41	LU 50	65	IC 15156
18	EC 7048	42	LU 96	66	IC 94549
19	EC 799	43	NRC 52	67	G 34
20	EC 94625	44	NRC 55	68	TNAU 20039
21	G 03	45	NRC 56	69	HIMSO 1676
22	G 141	46	PK 1029	70	LPA 5-2
23	G 88	47	PK 52	71	WILLIAMS
24	G 91	48	PLSO 90		
	CHECKS				
72	NRC 132				
73	NRC 142				
74	MACS 1281				
75	MACS 1460				
76	MACS 1667				

Table 2. Source/Origin of 76 soybean germplasm accessions used in this study

S. No.	Genotypes	Source/Origin
1	AGS48	Asian Vegetable Research and Development Center, Taiwan
2	AGS 797	Asian Vegetable Research and Development Center, Taiwan
3	AMS 19	Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
4	Chepra 64	Collected by Sh. H. B. Singh P.I.O and Mr. P. P.Khanna for Nepal Expedition 22/4/61
5	AVRDC 5	Asian Vegetable Research and Development Center, Taiwan
6	DS 12-13	Indian Agricultural Research Institute (IARI), New Delhi
7	DS 1433	Indian Agricultural Research Institute (IARI), New Delhi
8	DS 24110	Indian Agricultural Research Institute (IARI), New Delhi
9	DSb 15	University of Agricultural Sciences, Dharwad
10	EC 10076	International Soybean Program, University of Illinios, USA
11	EC 1021	University of Wisconsin-Madison, USA.
12	EC 14425	Integrating Crop physiology into the Australian soybean improvement program, Australia.
13	EC 15961	Dr. W.Hartley, Principal plant introduction officer , CSIRO, Divivsion of plant industry, Australia.
14	EC 220	-
15	EC 395	Plantagol, Division, Tsze pi iou from Tangxi Kindergrten, Zhejiang, China.
16	EC 39719	Minnesota crop improvement program, St. Paul campus of the University of Minnesota, USA.
17	EC 4290	Collected by Sh. H. B. Singh P.I.O and Mr. P. P.Khanna for Nepal Expedition 22/4/61
18	EC 7048	Collected by Sh. H. B. Singh P.I.O and Mr. P. P.Khanna for Nepal Expedition 22/4/61
19	EC 799	Collected by Sh. H. B. Singh P.I.O and Mr. P. P.Khanna for Nepal Expedition 22/4/61
20	EC 94625	Dr. D.E. Byth, University of Queensland, Agricultural dept., Lucia, Australia.
21	G 03	Asian Vegetable Research and Development Center, Taiwan
22	G 141	Asian Vegetable Research and Development Center, Taiwan
23	G 88	Asian Vegetable Research and Development Center, Taiwan
24	G 91	Asian Vegetable Research and Development Center, Taiwan
25	HIMSO 1521	Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur.
26	HIMSO 1563	Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya
27	HIMSO 1566	Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya
28	IC 10755	West Bengal
29	IC 13048	West Bengal (T-33)
30	IC 9462	Sikkim
31	IC 55898	-
32	IC 15560	-
33	IC 13043	West Bengal
34	KB 221	Sakthi Soyas Ltd., Race Course road, Coimbatore, India.
35	SL 443	PAU, Ludhiana, Punjab.
36	SL 46	PAU, Ludhiana, Punjab.
37	SL 518	PAU, Ludhiana, Punjab.
38	LU22	PAU, Ludhiana, Punjab.
39	LU38	PAU, Ludhiana, Punjab.
40	LU46	PAU, Ludhiana, Punjab.
41	LU50	PAU, Ludhiana, Punjab.
42	LU96	PAU, Ludhiana, Punjab.
43	NRC52	Indian Institute of Soybean Research, Indore
44	NRC55	Indian Institute of Soybean Research, Indore
45	NRC56	Indian Institute of Soybean Research, Indore
46	PK1029	Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Uttarkhand

Table 2 .Continued..

S. No.	Genotypes	Source/Origin
47	PK52	Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Uttarkhand
48	PLSO90	-
49	PUNJAB1	PAU, Ludhiana, Punjab.
50	DT 21	-
51	IC 109554	GBPUA&T, Pantnagar, Uttarakhand
52	TNAU 20049	Department of Pulses, Tamil Nadu Agricultural University, Tamil Nadu, India
53	SL 525	PAU, Ludhiana, Punjab.
54	SL 794	PAU, Ludhiana, Punjab.
55	SL 88-W	PAU, Ludhiana, Punjab.
56	RKS 7	Maharatna Pratap University Agriculture and Technology, Udaipur, Rajasthan.
57	KB 97	Sakthi Soyas Ltd., Race Course road, Coimbatore, India.
58	TNAU 20053	Department of Pulses, Tamil Nadu Agricultural University, Tamil Nadu, India
59	WILLIAMS 8211	-
60	TNAU 20056	Department of Pulses, Tamil Nadu Agricultural University, Tamil Nadu, India
61	TS 9	-
62	LU 65	PAU, Ludhiana, Punjab.
63	IC 15092	Himachal Pradesh
64	IC 15156	-
65	IC 94549	-
66	PS 93108	Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Uttarkhand
67	G 34	Asian Vegetable Research and Development Center, Taiwan
68	TNAU 20039	Department of Pulses, Tamil Nadu Agricultural University, Tamil Nadu, India
69	HIMSO 1676	Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur
70	LPA 5-2	PAU, Ludhiana, Punjab.
71	WILLIAMS	-
72	NRC 132	National Research Center for Soybean (NRCS), Indore
73	NRC 142	National Research Center for Soybean (NRCS), Indore
74	MACS 1281	Maharastra Association for the cultivation of Science' Agharkar Research Institute
75	MACS 1460	Maharastra Association for the cultivation of Science' Agharkar Research Institute
76	MACS 1667	Maharastra Association for the cultivation of Science' Agharkar Research Institute

and the longitude of 76.9293°E with altitude of 426.72 m above MSL) in Augmented block design-II in single row plots with 3m row length and the cropping area was divided into five blocks in which checks were replicated once in each block while germplasm were un-replicated and adopting a spacing of 30 x 5 cm.

The observations were recorded for nine yield related traits namely, days to 50 percent flowering, number of branches per plant, number of pods per plant, number of clusters per plant, number of pods per cluster, plant height, hundred seed weight, number of seeds per pod and single plant yield. Among the observed traits, single plant yield was the dependent trait while others were independent traits. Analysis of variance was performed by using GRAPES software V 1.1.0. (Gopinath *et al*., 2020) The phenotypic and genotypic coefficients of variability (PCV and GCV) were calculated using the approach recommended by Burton (1952). Heritability (h^2) was determined based on the method proposed by Johnson *et al*. (1955). Correlations and path coefficient values were analysed using the techniques outlined by Webber and Murthy (1952) and Dewey and Lu (1959) respectively.

RESULTS AND DISCUSSION

The analysis of variance indicated that the mean squares owing to genotypes were highly significant for all the nine traits investigated, indicating the varietal differences **(Table 3).** Significant difference among the genotypes based on the analysis of variance indicated the sufficient amount of variability among the tested genotypes (Raulji *et al.,* 2014).

Variability parameters: Plant height ranged from 9 to 48.83 with a mean value of 31.23, number of branches per plant ranged from 1.33 to 5.67 with an average of 5.7,

Table 3. Analysis of variance of nine quantitative characters

S.No.	Characters	Mean sum of square	
		MSg	MSe
	Treatment	75	16
1	Plant height	60.26**	1..17
2	Days to 50 percent flowering	8.27*	0.16
3	Number of branches per plant	0.93**	0.07
4	Number of pods per plant	4349.56**	1.39
5	Number of clusters per plant	35.04**	0.87
6	Number of pods per cluster	1.04**	0.04
7	Number of seeds per pod	0.158*	0.03
8	Hundred seed weight	2.89*	0.05
9	Single plant yield	99.2**	0.9

MSg = genetic mean square, MSe = error mean square. **significant at level of 1%, * significant at level of 5%.

number of pods per plant had a range of 13.3- 260.50 with a mean of 67.28, number of clusters per plant had a range of 5.33 to 35.33 with an average of 16.67, number of pods per cluster had a range of 2.33 to 7 with an average of 4.50. Number seeds per pod ranged from 2.0 - 3.35 with an average of 2.23, hundred seed weight ranged from 7.90-12.10 with an average of 9.43, days to 50 percent flowering had a range of 38 to 56 days with an average of 41.04 and single plant yield ranged from 1.93 to 66.20 with mean of 16.60.

The calculations of phenotypic (PCV) and genotypic (GCV) coefficients of variation (**Table 4**) revealed that the PCV values were higher than the GCV values. However, the gap between these two estimates was relatively narrow for most of the traits under study. This suggests that genetic factors played a more significant role in determining the variation in the studied traits and the influence of environmental factors was comparatively less pronounced. Similar outcomes were reported in soybean by Karnwal and Singh, 2009; Yadav and Singh, 2015. Higher GCV and PCV were observed for plant height, number of branches per plant, number of pods per plant, number of clusters per plant and single plant yield. A similar outcome for number of branches per plant was reported by Malik *et al.* (2006) in soybean and for number of pods per plant by Kuswantoro (2017) in soybean. Similar findings for single plant yield was noted in soybean by Baraskar *et al.* (2014) and Gohil *et al.* (2006). The number of pods per cluster fell under medium GCV category although it had high PCV , It indicated the higher environmental influence in inheritance of the trait. Number of seeds per pod had GCV and PCV in medium category. Days to 50 percent flowering recorded low GCV and PCV. Similar findings were reported by Baraskar *et al.* (2014) in soybean. Though the hundred seed weight recorded medium PCV, it was observed to record low GCV.

Relying solely on the genotypic coefficient of variation is insufficient for assessing the heritability of a trait. Therefore, having information about the heritability of a characteristic is valuable for plant breeders as it enables them to anticipate the genetic advancements possible for quantitative traits and assists in implementing appropriate selection strategies. High heritability was observed by plant height, Number of branches per plant, number of pods per plant, number of clusters per plant, number of pods per cluster, number of seeds per pod, days to 50 percent flowering, hundred seed weight and single plant yield. These traits will respond to any intense selection exercise and could be used in crop improvement programmes. Kuswantoro (2017), Ojo and Ayuba (2016) and Baraskar *et al.* (2014) reported similar findings in soybean for days to 50 percent flowering, number of pods per plant and seed yield.

The traits namely plant height, number of branches per plant, number of pods per plant, number of cluster per plant, number of pods per cluster, number of seeds per pod and single plant yield had high heritability and genetic advance as percent of mean which indicated that the heritability was most likely due to additive gene action and selection for these traits would be rewarding. Similar outcomes were reported earlier in soybean by Sureshrao *et al.,*2014; Koraddi and Basavaraja, 2019 and Akram *et al.,*2016. High heritability and low to medium genetic advance as percent mean were observed for days to 50% flowering and hundred seed weight indicated that non-additive gene action and selection for such trait may not be effective. Similar observation was noted in soybean by Baraskar *et al.* (2014) for days to 50 percent flowering.

Corrrelation analysis: The phenotypic correlation of the yield and eight yield attributing traits are furnished in **Fig.1.** Among the nine characters studied, single

Table 4. Genetic variability parameters for nine characters in soybean.

S.No.	Characters	Mean	Range		GCV (%)	PCV (%)	H^2	GA as %of mean
			Min.	Max.				
1	Plant height (cm)	31.23	9.00	48.83	65.91	67.08	98.25	53.10
2	Days to 50 per cent flowering(days)	41.04	38	56	6.91	7.01	98.07	14.1
3	Number of branches per plant	5.70	1.33	5.67	29.50	30.80	91.50	58.30
4	Number of pods per plant	67.28	13.30	260.50	64.73	64.78	99.90	133.46
5	Number of clusters per plant	16.67	5.33	35.33	38.30	38.70	97.80	78.30
6	Number of pods per cluster	4.50	2.33	7.00	19.20	20.40	94.70	40.40
7	Number of seeds per pod	2.23	2.00	3.35	11.90	14.40	68.50	20.38
8	Hundred seed weight (g)	9.43	7.90	12.10	9.80	13.70	60.50	15.80
9	Single plant yield (g)	16.60	1.93	66.20	66.90	67.20	99.20	137.65

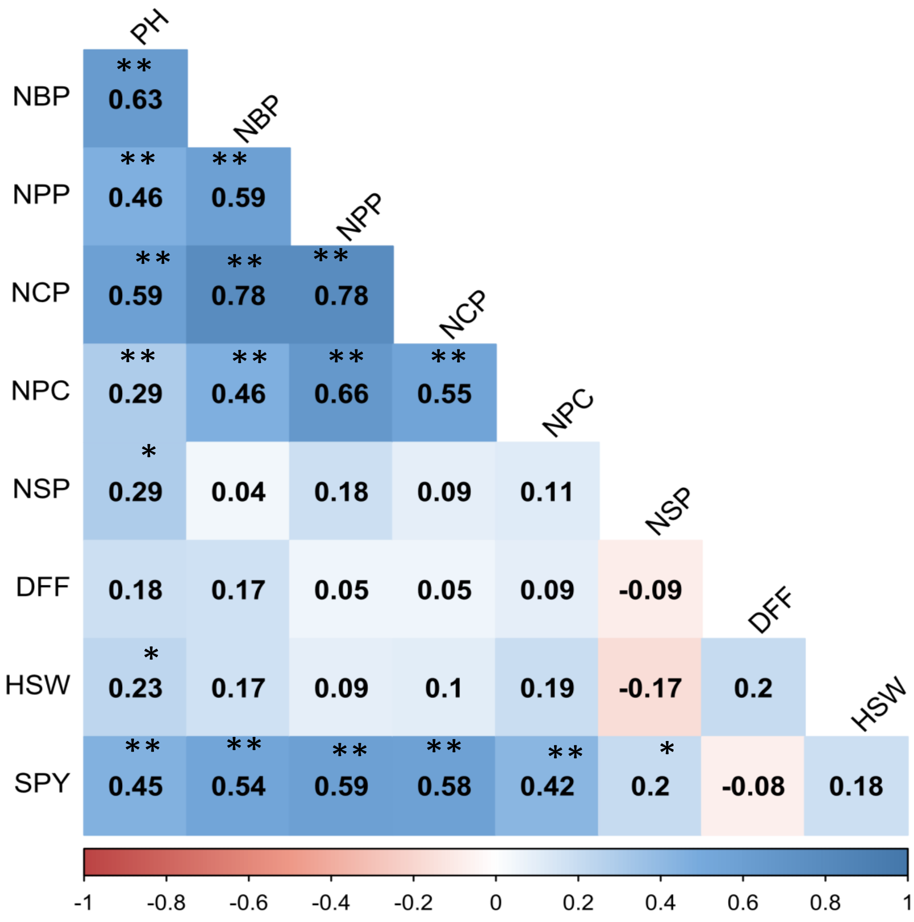

Fig.1. Correlation plot of yield and yield attributing traits.

** significant at level of 1%, * significant at level of 5%.

DFF	-	Days to 50 percent flowering (days)	NPC	-	Number of Pods per Cluster
PH	-	Plant Height (cm)	NSP	-	Number of Seeds per Pod
NBP	-	Number of Branches per Plant	HSW	-	Hundred Seed Weight (g)
NCP	-	Number of Clusters per Plant	SPY	-	Single Plant Yield (g)
NPP	-	Number of Pods per Plant			

plant yield was positively and significantly correlated with plant height (0.45), number of branches per plant (0.54), number of pods per plant (0.59), number clusters per plant (0.58), number of pods per cluster (0.42) and number of seeds per pod (0.20). This implies that these traits have a close relationship with yield and improvement of these traits might increase the seed yield. Iqbal *et al*. (2010), Banerjee *et al.* (2022) and Malik *et al*. (2006) also reported that grain yield per plant was positively and significantly correlated with number of pods per plant in soybean while Arshad *et al*. (2006) reported that number of branches had a significant correlation with yield and Patil *et al.* (2011), single plant yield had positive and significant correlation with plant height and number of pods per plant in soybean. The remaining traits were non-significantly correlated with single plant yield. The trait number of pods per plant (0.78), number of branches per plant (0.78) and plant height (0.59) were positively and significantly correlated with the number of clusters per plant. Plant height was positively and significantly correlated with number of branches per plant (0.63), number of pods per plant (0.46), number of clusters per pod (0.59), number of pods per cluster (0.29), number of seeds per pod (0.29), hundred seed weight (0.23) and single plant yield (0.45). Number of pods per plant had positive and significant correlation with number of clusters per plant (0.78), number of pods per cluster (0.66) and single plant yield (0.59). Similar findings in soybean were reported by Aditya *et al*. (2011) and Machado *et al.* (2017)

Path coefficient analysis: The path coefficient is a standardized partial regression which splits the correlation coefficient into direct and indirect effect. In the present study, number of pods per plant (0.36) showed high direct effect on single plant yield, hence selection based on this trait could result in yield improvement **(Table 5)** Similar findings have been reported by Pandey and Torrie (1973), Jain, *et al.* (2015), and Machikowa and Laosuwan (2011) in soybean**.** Plant height (0.21) registered moderate direct effect on yield , which is contradictory to the findings of Li *et al*. (2013) in soybean. while the number of pods per cluster (0.17), number of branches per plant (0.17) had low direct effect. Days to 50 percent flowering (-0.16) had negative direct effect on yield, hence early lines should be selected.

Number of clusters per plant (0.28), number of pods cluster (0.22) and number of branches per plant (0.2) had indirect effect on single plant yield through number of pods per plant. This revealed that number of pods per plant had a significant role in improving yield of crop because it had high direct as well as indirect effects. Other traits such as plant height and number of seeds per pod had low indirect effect on yield through the number of pods per plant. Plant height was observed to have an indirect effect on yield through the number of pods per plant and this agrees with the findings of Balla and Ibrahim (2017) n soybean. The residual value was observed to be 0.436 which showed that all the yield contributing trait were included in this study.

The current study indicated that there existed considerable diversity among the germplasm under study for various traits. Some of the genotypes were found to have favourable performance for multiple characteristics. As a result, these genotypes could be directly employed in breeding programs or incorporated into hybridization aimed at generating good segregants. The traits such as the number of pods per plant, number of branches per plant, number of clusters per plant and single plant yield exhibited a noteworthy combination of high genotypic coefficient of variability and phenotypic coefficient of variability, along with substantial heritability and genetic advance as percent of mean. These findings suggest that

Table 5. Direct (Diagonal) and indirect effect path coefficients

	PH	NBP	NPP	NCP	NPC	NSP	DFF	HSW	SPY
PH	**0.211**	0.1139	0.1696	0.0009	0.0503	0.02470	-0.0550	0.0149	0.45**
NBP	0.1372	**0.1753**	0.2057	0.00124	0.07557	0.01584	-0.0492	0.00821	0.54**
NPP	0.0992	0.0999	**0.3610**	0.00121	0.113	0.02280	-0.0443	0.00672	0.59**
NCP	0.1351	0.1402	0.2816	**0.00155**	0.0935	0.01710	-0.0459	0.00672	0.58**
NPC	0.0591	0.0736	0.2274	0.00080	**0.1799**	0.01647	-0.0361	0.01868	0.42**
NSP	0.0823	0.0438	0.1299	0.00042	0.0467	**0.06330**	-0.0110	-0.0052	0.20*
DFF	0.0717	0.0526	0.0970	0.00043	0.0390	0.00443	**-0.1640**	0.0179	-0.08^{NS}
HSW	0.0422	0.0192	0.0320	0.00014	0.0449	-0.0044	-0.0394	**0.0747**	0.18^{NS}

** significant at level of 1%, * significant at level of 5%.

Residual effect= 0.4365

DFF	-	Days to 50 percent flowering (days)
PH	-	Plant Height (cm)
NBP	-	Number of Branches per Plant
NCP	-	Number of Clusters per Plant
NPP	-	Number of Pods per Plant
NPC	-	Number of Pods per Cluster
NSP	-	Number of Seeds per Pod
HSW	-	Hundred Seed Weight (g)
SPY	-	Single Plant Yield (g)

the expression of the above traits is less influenced by environmental factors, making them more suitable for selection based on their genetic attributes. Correlation and path analysis also suggested the importance of the traits number of pods per plant, number of branches per plant, number of clusters per plant, which could play a pivotal role in soybean improvement.

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