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Original Research Article

Character Association and Co-heritability analyses for Physiological, Pod and Yield traits in Soybean Genotypes

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A B S T R A C T

An investigation was conducted in Kharif 2016 with twenty six genotypes of soybean isolated from different crosses to estimate the co-heritability, genetic variability, heritability, genetic advance, correlation coefficient, path coefficient of Pod and Yield Characters. Considerable amount of genetic variability was exhibited for all the characters under study which revealed that exploitable level of variability exists among genotypes. High or moderate heritability coupled with high or moderate genetic advance was observed for most of the characters under study. On the basis of co-heritability analysis the substantial co-heritability was observed for days to 50% flowering, days to maturity, plant height at maturity, number of primary branches per plant, number of nodes per plant, number of pod clusters per plant, number of pods per plant, number of seeds per pod, number of seeds per plant, biological yield, harvest index and 100 seed weight, these characters are also co-heritable among themselves. Hence, breeders may utilize them for the simultaneous improvement of the significant characters. Correlation and path analyses revealed that the characters *viz.*, biological yield, number of pod clusters per plant, number of pods per plant, number of seeds per pod and number of seeds per plant have been found significant, direct selection of these characters may be effective for the improvement of and enhancement in the yielding potential of soybean genotypes. The categorization of genotypes on the basis of pod characters indicated that JS 21-68, JS 21-69, JS 20-69 and JS 21-49 are having higher number of pods as well as higher percentage of three seeded pods. Whereas, JS 21-58, JS 21-53, JS 21-55 and JS 21-54 exhibited higher expression of four seeded and three seeded pods. Hence, hybridization between these two groups may contribute profuse podding with higher frequencies of four seeded and three seeded pods which ultimately enhance the number of seeds per plant.

Keywords

Co-heritability, soybean genotypes

Introduction

Soybean [*Glycine max* (L.) Merrill], a self-pollinated diploid (2n = 2x = 40) food legume belonging to family *Leguminosae* syn. *Fabaceae*, subfamily *Papilionoideae* is originated in north and central China. Soybean ranks first amongst oilseed crops in the world and India both. India ranks fourth in terms of soybean area in the world behind only to USA, Brazil and Argentina. In 2016-17, soybean area reached to 109 lakh ha with production of 1150 lakh tones and productivity 1047 kg/ha in India and 54 lakh ha with production of 57 lakh tones and productivity 1059 kg/ha in Madhya Pradesh

(SOPA, 2016). Madhya Pradesh has played a major role ever in the development and expansion of soybean cultivation and contributes substantially in all respect and is known as "Soya State".

The yield level of soybean in our country is hovering around 1.2 ton/ha which is quite low in comparison to the major soybean growing countries of the world. Yield is a complex entity influenced by several phenological, physiological, pod and yield characters and environment. This may be due to narrow genetic base of the released varieties as well as their lower genetic yielding potential and stability to varied climatic changes. The most important goal of many soybean breeding programmes is the development of stable genotypes with enhanced seed yield. The three major components of soybean yield *viz.,* number of pods per plant; numbers of seeds per plant and seed size are easily identifiable characters which have assisted selection for higher yield. However, an increase in yield often results from the increase in the number of seeds per pod (Zhu and Sun, 2006).

It has also been realized in preliminary observations that increased proportion of three seeded pods or four seeded pods has great influence on quantum increase in number of seeds per plant and consequently substantial enhancement in yield. Besides this, physiological characters like faster biomass accumulation in vegetative phase and total biomass production coupled with high harvest index keeps an immense value in the enhancement of economic yield. Hence, it becomes imperative to assess the co-heritability, variability, heritability, genetic advance, correlation, direct and indirect effects of various characters on yield. The present study aims to identify and categorize superior genotypes on the basis of *per se* performance, pod characters.

Materials and Methods

The experimental material comprised of 26 genotypes of soybean. Experiment was laid out in a randomized complete block design with three replications at the Seed Breeding Farm, J.N.K.V.V., Jabalpur (M.P.) during the *Kharif* season 2016. Size of each plot was kept 3.0 m x 1.6 m with 5 rows of 4 m length and 40 cm row to row distance. Two phonological, two physiological, six morphological and eight economic (yield) characters were recorded on the basis of five random competitive plants selected from each line in each replication. The mean data of 5 plants were subjected to Co-heritability (Janssens, 1979), correlation computed by following the procedure of Miller *et al.*, (1958) and path coefficient analysis was conducted according to the procedure by Dewey & Lu (1959).

Results and Discussion

The genetic variability is the raw material of plant breeding on which selection acts to evolve superior genotypes. Thus, higher the amount of variation present for a concerned character in the breeding materials, greater is the scope for its improvement through selection. The phenotypic coefficient of variation was significantly higher in magnitude than that of genotypic coefficient of variation for all the characters under study (Table. 1). Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are categorized as low (<10%), moderate (10-20%) and high (> 20%) as suggested by Sivasubramanian and Madhavamenon (1973).

GCV and PCV for physiological, yield and yield contributing characters are summarized in Table. 1. Number of pods per plant recorded the highest PCV and GCV followed by number of seeds per plant, seed

yield, fresh weight at 30 DAS, dry weight at 30 DAS, biological yield per plant, number of pod clusters per plant, 100 seed weight and number of primary branches per plant. Plant height at maturity, plant height at 30 DAS, harvest index, number of nodes per plant and number of seeds per pod observed as moderate estimates of PCV and GCV and the low PCV and GCV recorded for chlorophyll content at full flowering days to 50% flowering, chlorophyll content at 30 DAS and days to maturity.

Heritability in broad sense was estimated for all the traits under study and presented in Table 1. Heritability estimates were classified as high (> 70%), moderate (50-70%) and low (< 50%).

The high heritability estimates were observed for 100 seed weight, days to maturity, days to 50% flowering, number of seeds per pod, number of seeds per plant, harvest index, number of pods per plant, number of pod clusters per plant, plant height at maturity, seed yield per plant, biological yield per plant and dry weight at 30 DAS.

Genetic advance as percentage of mean was estimated for all the characters under study and presented in Table 1. The genetic advance was classified as suggested by Johnson *et al.,* (1955) i.e., high (> 20%), moderate (10-20%) and low (< 10%). The high genetic advance as percentage of mean (at 5% selection intensity) was recorded for number of seeds per plant, number of pods per, seed yield per plant, number of pod clusters per plant, 100 seed weight, biological yield per plant, plant height at maturity, dry weight at 30 DAS, harvest index and plant height at 30 DAS, while moderate for number of primary branches per plant, number of seeds per pod, fresh weight at 30 DAS, days to 50% flowering, chlorophyll content at full flowering, number of nodes per plant and days to maturity.

In agreement with the present findings, Aditya *et al.,* (2011) and Sureshrao *et al.,* (2014) for number of pods per plant and seed yield per plant, Athoni and Basavaraja (2012) for plant height, Patil *et al.,* (2011) for plant height, seed yield per plant and number of pods per plant, Ghodrati *et al.,* (2013) for number of branches per plant, plant height and number of pods per plant, Mahbub *et al.,* (2015) for seed yield per plant and Jha (2016) for the number of seeds per plant, number of pod clusters per plant, biological yield per plant, 100 seed weight and number of pods per plant.

Co-heritability

Co-heritability is simultaneous inheritance of pair of characters in the progeny indicating the genetic progress which would result from the joint selection for these characters. It is better genetic parameter than genetic correlation as it considers environmental variance as well. The genetic improvement for character having low heritability can be achieved by applying strong selection to a character which has high heritability and co-inherites with the former character. It is the regression coefficient of response to selection differential for a character when selection is actually practiced for another character (Janssens, 1979). Present analysis of Co-heritability of characters above is given in Table 2. The positive and substantial co-heritability estimates (>1) were recorded by days to 50% flowering with fresh weight at 30 DAS, dry weight at 30 DAS, plant height at 30 DAS, chlorophyll content at 30 DAS and harvest index, plant height at maturity with fresh weight at 30 DAS, dry weight at 30 DAS, number of seeds per pod and

harvest index. Days to maturity with chlorophyll content at 30 DAS number of seeds per pod, number of nodes per plant, chlorophyll content at full flowering, fresh weight at 30 DAS with number of pods per plant, number of seeds per plant, number of seeds per pod, dry weight at 30 DAS with number of pods per plant and number of seeds per plant, plant height at 30 DAS with number of seeds per plant and number of pods per plant, chlorophyll content at 30 DAS with biological yield per plant, dry weight at 30 DAS, number of seeds per plant, harvest index, number of pod clusters per plant and number of pods per plant, chlorophyll content at full flowering with chlorophyll content at 30 DAS, plant height at 30 DAS, plant height at maturity, fresh weight at 30 DAS, dry weight at 30 DAS, number of pod clusters per plant and number of seeds per pod, number of nodes per plant with plant height at 30 DAS, dry weight at 30 DAS, fresh weight at 30 DAS, 100 seed weight, number of seeds per pod and harvest index, number of primary branches per plant with harvest index, number of pod clusters per plant with number of seeds per pod, whereas number of seeds per pod with biological yield per plant and harvest index. As per the available literatures, Shrivastava and Jain (1994) for biological yield and pods per plant and Yadav (2007) for seed yield per plant with all characters in soybean which are similar to the present findings. In general, as the sign and magnitude of co-heritability estimates obtained were satisfactory, selection pressure mounted on co-heritable pair of characters may lead to simultaneous improvement of physiological and yield characters. Overall on the basis of co-heritability study, the substantial co-heritability was observed for days to maturity, number of seeds per pod, 100 seed weight, harvest index, plant height at maturity, number of pod clusters per plant, number of nodes per plant, number of seeds per plant and number of pods per plant with seed yield and it is also important to note that these characters are also co-heritable among themselves. Hence, breeders may utilize this finding for the simultaneous improvement of the important characters.

Pod characters analysis

In the present investigation, the distribution and frequencies of 4, 3, 2 and 1 seeded pods per plant were studied among the genotypes is presented in Table.3. Out of the twenty six genotypes, the maximum number of pods per plant was exhibited by JS 21-68, JS 21-69, JS 21-63, JS 20-69 and JS 21-49. JS 21-58 had expressed 23.26% four seeded pods and 63.28% of three seeded pods which contributes 86.54% of the total pods. Similarly, JS 21-53 had 11.84% four seeded pods and 67.52% of three seeded pods which contributes 79.36% of the total pods, JS 21-55 had 10.16% four seeded pods and 68.29% of three seeded pods which contributes 78.45% of the total pods and JS 21-54 had 12.57% four seeded pods and 61.70% of three seeded pods which contributes 74.27% of the total pods. Similar findings have been reported by Woodwarth (1932), William (1950), Kato *et al.,* (1954) that most common soybean varieties predominantly contain two or three seeds per pod, Gour *et al.,* (1992), Zhu and Sun (2006), Chauhan (2007) found that among four seeded pod cultures 81.50% pods were contributed by pods having higher number of seeds, Shrivastava *et al.,* (2011) and Khare (2011). On the basis of overall pod analysis, out of the twenty five genotypes, JS 21-68, JS 21-69, JS 20-69 and JS 21-49 are having higher number of pods as well as higher percentage of three seeded pods. Whereas JS 21-58 exhibits the highest expression for four seeded pods and three seeded pods towards the contribution of the total pods followed by JS 21-53, JS 21-55

and JS 21-54. The crosses between genotypes having higher number of pods expressing higher frequencies of four seeded pods and three seeded pods may lead to recombinants having more number of seeds per plant.

Correlation Coefficient analysis

Correlations indicate the magnitude of linear association between pairs of characters and form the basis of selection index, thereby aiding the breeder in crop improvement programmes. For a rational approach towards improvement of yield, selection has to be made for the components of yield. Phenotypic correlation between different characters of plant often arises because of linkage or pleiotropy. In biological system most of the characters are associated with each other by one or more paths. In the present investigation, correlations were worked out at phenotypic level in all possible character combination of all the soybean genotypes.

Phenotypic correlation coefficient (Table. 3) was studied considering eighteen component characters out of which ten characters *viz.*, days to maturity, plant height at maturity, number of nodes per plant, number of primary branches per plant, number of pod clusters per plant, number of pods per plant, number of seeds per plant, biological yield per plant, 100 seed weight and harvest index had significant positive correlation with seed yield per plant. Days to 50% flowering showed the highest and significant positive association with days to maturity, number of seeds per plant, number of pods per plant, number of pod clusters per plant, number of nodes per plant, plant height at 30 DAS and number of primary branches per plant. Days to maturity recorded highly significant positive correlation with number of pods per plant, number of seeds per plant, number of pod clusters per plant, plant height at maturity, number of primary branches per plant, biological yield per plant and seed yield, while chlorophyll content at full flowering, dry weight at 30 DAS.

Table.1 Parameters of genetic variability for physiological and Yield characters in soybean genotypes

S.N.	Characters	Mean	Range		PCV (%)	GCV (%)	h^2b (%)	GA as % of mean
			Min.	Max.				5%
1	DFF (days)	45.23	36.33	54.00	08.28	07.96	92.64	15.79
2	DM (days)	104.83	90.33	115.33	05.59	05.38	92.80	10.68
3	Fresh Wt. /plant at 30 DAS (g)	04.71	03.21	06.74	29.26	15.77	61.92	17.50
4	Dry wt at 30 DAS (g)	00.83	00.55	01.20	26.97	19.39	70.80	28.70
5	Plant Ht. at 30 DAS (cm)	17.28	12.35	20.67	15.27	12.63	68.47	21.53
6	Plant Ht. at maturity (cm)	40.74	26.08	52.71	16.96	16.17	90.84	31.74
7	Chlorophyll content at 30 DAS (SPAD)	33.11	30.36	37.36	07.36	04.82	42.96	06.51
8	Chlorophyll content at full flowering (SPAD)	37.45	30.94	42.14	09.31	07.62	66.86	12.83
9	No. of nodes/ plant	12.01	09.20	13.73	12.11	08.09	44.61	11.13
10	No. of primary branches /plant	04.90	03.33	06.80	20.41	13.74	45.29	19.04
11	No. of pod clusters /plant	26.63	17.20	43.46	24.27	23.15	90.97	45.47
12	No. of pods /plant	56.32	34.46	101.66	33.02	31.53	91.15	62.01
13	No. of seeds /pod	02.23	01.84	02.66	10.01	09.60	92.03	18.98
14	No. of seeds /plant	125.46	63.80	215.26	32.89	31.50	91.74	62.16
15	Bio. yield /plant (g)	26.57	17.50	43.99	26.84	23.56	77.05	42.60
16	100 seed wt (g)	10.95	06.72	16.14	21.55	21.21	96.83	42.99
17	Harvest index (%)	50.42	39.93	59.30	12.44	11.90	91.46	23.44
18	Seed yield /plant (g)	13.33	07.38	24.24	31.94	30.11	88.87	58.46

PCV and GCV: high >20%, Moderate 10-20%, Low <10%
Classes of Heritability (%): High >70%, Moderate 50-70%, Low <50%
Classes of GA as percentage of mean at 5%: high >20%, Moderate 10-20%, Low <10%

Table.2 Co-heritability for physiological and yield characters in soybean genotypes

Characters	DM (days)	Fresh Wt. /plant at 30 DAS (g)	Dry wt. at 30 DAS (g)	Plant Ht. at 30 DAS (cm)	Plant Ht. at maturity (cm)	Chlorophyll content at 30 DAS (SPAD)	Chlorophyll content at full flowering (SPAD)	No. of nodes/ plant	No. of primary branches /plant	No. of pod clusters /plant	No. of pods / plant	No. of seeds / pod	No. of seeds / plant	Bio. yield / plant (g)	100 seed wt. (g)	Harvest index (%)	Seed yield / plant (g)
DFF (days)	0.9938	1.1178	1.0962	1.0827	0.9777	1.0785	0.9155	0.9517	0.8686	0.9611	0.9605	0.4537	0.9543	0.8061	0.9836	1.0558	0.8615
DM (days)		0.9730	0.91211	0.9748	0.9350	1.1639	1.0359	1.0734	0.8830	0.9619	0.9636	1.1054	0.9557	0.9155	0.9513	0.9963	0.9419
Fresh Wt. /plant at 30 DAS (g)			0.6760	0.6461	2.0911	-0.1001	1.2952	1.7224	-1.1046	-0.2456	1.3704	1.0883	1.2378	0.8023	0.9727	0.5027	0.8250
Dry wt. at 30 DAS (g)				0.6918	1.2802	2.6504	1.2563	1.9224	-0.9027	0.2984	1.1751	0.9932	1.0994	0.8326	0.9649	0.8266	0.8586
Plant Ht. at 30 DAS (cm)					0.7325	0.5199	1.4670	3.2332	-1.3453	-1.5478	1.0327	-0.0770	1.0624	0.6550	0.9678	0.8247	0.8478
Plant Ht. at maturity (cm)						0.5705	1.3533	0.8606	0.8203	0.9198	0.8980	1.0711	0.9192	0.8765	0.9090	1.0102	0.9196
Chlorophyll content at 30 DAS (SPAD)							2.5872	-1.8107	-0.8598	1.4469	1.2117	0.9460	1.7450	2.7694	0.8283	1.6132	-1.5451
Chlorophyll content at full flowering (SPAD)								0.3820	0.9144	1.0453	0.9641	1.0267	0.8499	0.6505	0.8686	0.8990	-0.0372
No. of nodes/ plant									0.8805	0.9037	0.9553	1.0562	0.9598	0.7416	1.1617	1.0195	0.8813
No. of primary branches /plant										0.7875	0.7459	-1.7887	0.7632	0.7404	0.8267	1.0941	0.7207
No. of pod clusters /plant											0.9091	2.5513	0.9173	0.8963	0.9544	0.9497	0.8989
No. of pods /plant												0.5775	0.9159	0.8723	0.9823	0.9301	0.8811
No. of seeds /pod													0.9929	1.1219	0.9881	1.0323	0.9395
No. of seeds /plant														0.8605	0.9777	0.9477	0.8813
Bio. yield /plant (g)															0.9396	0.8964	0.8716
100 seed wt (g)																-1.1328	0.9258
Harvest index (%)																	0.9258

Table.3 Distribution and frequency (%) of number of 4, 3, 2 and 1 seeded pods in soybean genotypes

S. No.	Genotypes	No. of Four Seeded pods	% of Four Seeded pods	No. of Three Seeded pods	% of Three Seeded pods	No. of Two Seeded pods	% of Two Seeded pods	No. of One Seeded pods	% of One Seeded pods	Mean no. of pods /plant	Seed yield /plant (g)
1	**JS 21 - 49**	0.07	0.10	28.33	42.93	**37.07**	**56.16**	0.53	0.81	**66.00**	**15.03**
2	**JS 21 - 50**	0.00	0.00	9.07	21.52	**31.40**	**74.53**	1.67	3.96	42.13	10.84
3	**JS 21 - 51**	0.07	0.11	19.67	32.89	**38.33**	**64.10**	1.73	2.90	**59.80**	**14.23**
4	**JS 21 - 52**	0.00	0.00	3.27	9.44	**27.73**	**80.15**	3.60	10.40	34.60	8.68
5	**JS 21 - 53**	4.67	11.84	**26.61**	**67.52**	7.87	19.96	0.27	0.68	39.40	10.96
6	**JS 21 - 54**	4.33	12.57	**21.27**	**61.70**	8.33	24.18	0.53	1.55	34.47	8.30
7	**JS 21 - 55**	5.00	10.16	**33.60**	**68.29**	10.07	20.46	0.53	1.08	49.20	10.80
8	**JS 21 - 56**	0.00	0.00	19.13	38.52	**28.20**	**56.78**	2.33	4.70	49.67	10.69
9	**JS 21 - 57**	0.07	0.12	**32.93**	**59.66**	21.13	38.29	1.07	1.93	**55.20**	**18.02**
10	**JS 21 - 58**	**13.13**	**23.26**	**35.73**	**63.28**	7.53	13.34	0.07	0.12	56.47	13.79
11	**JS 21 - 59**	0.33	0.51	**36.40**	**55.94**	26.27	40.37	2.07	3.18	**65.07**	**14.33**
12	**JS 21 - 60**	0.00	0.00	21.60	33.23	**40.73**	**62.67**	2.67	4.10	65.00	14.08
13	**JS 21 - 61**	0.00	0.00	**33.33**	**51.71**	30.33	47.06	0.79	1.23	64.47	13.32
14	**JS 21 - 62**	0.00	0.00	29.27	44.66	**32.80**	**50.05**	3.47	5.29	**65.53**	**23.15**
15	**JS 21 - 63**	0.07	0.09	**42.87**	**54.96**	33.20	42.56	1.87	2.39	78.00	12.22
16	**JS 21 - 64**	0.00	0.00	12.20	28.50	**26.80**	**62.62**	3.80	8.88	42.80	11.40
17	**JS 21 - 65**	0.00	0.00	21.07	43.23	**25.07**	**51.44**	2.60	5.34	48.73	11.49
18	**JS 21 - 66**	0.00	0.00	5.47	11.70	**36.20**	**77.46**	5.07	10.84	46.73	13.49
19	**JS 21 - 67**	0.07	0.16	12.27	30.31	**26.53**	**65.57**	1.60	3.95	40.47	7.38
20	**JS 21 - 68**	0.00	0.00	27.00	26.56	**71.60**	**70.43**	3.07	3.02	**101.67**	**15.44**
21	**JS 21 - 69**	0.00	0.00	35.07	34.88	**63.27**	**62.93**	2.20	2.19	**100.53**	**24.24**
22	**JS 20 - 34**	0.00	0.00	**24.73**	**57.25**	16.93	39.20	1.53	3.55	43.20	11.41
23	**JS 20 - 29**	0.00	0.00	7.13	16.02	**36.33**	**81.59**	1.07	2.40	44.53	11.87
24	**JS 20 - 69**	0.00	0.00	**38.93**	**53.43**	32.47	44.56	1.47	2.01	**72.87**	**18.09**
25	**RVS 2002 -4**	0.00	0.00	17.73	42.77	**22.07**	**53.22**	1.67	4.02	41.47	10.03
	Mean	**1.11**	**2.36%**	**23.79**	**42.04%**	**29.53**	**51.99%**	**1.89**	**3.62%**		

Table.4 Phenotypic correlation for physiological and yield characters in soybean genotypes

Characters	DFF (days)	DM (days)	Fresh Wt. /plant at 30 DAS (g)	Dry wt. at 30 DAS (g)	Plant Ht. at 30 DAS (cm)	Plant Ht. at maturity (cm)	Chlorophyll content at 30 DAS (SPAD)	Chlorophyll content at full flowering (SPAD)	No. of nodes/ plant	No. of primary branches /plant	No. of pod clusters /plant	No. of pods / plant	No. of seeds / pod	No. of seeds / plant	Bio. yield / plant (g)	100 seed wt. (g)	Harvest index (%)	Seed yield / plant (g)
DFF (days)	1.0000	0.7252**	-0.2660*	-0.2758*	-0.4578**	0.3651**	-0.1817	-0.4378**	0.4794**	0.3607**	0.5324**	0.5854**	0.0335	0.5957**	0.2016	-0.4554**	0.1820	0.2246
DM (days)		1.0000	-0.2807*	-0.3134**	-0.3015**	0.4595**	-0.1602	0.4148	0.2936*	0.3389**	0.4725**	0.5246**	-0.0951	0.4869**	0.3091**	-0.1879	0.1280	0.3234**
Fresh Wt. /plant at 30 DAS (g)			1.0000	0.9248**	0.7158**	-0.0114	0.1155	0.2347*	-0.1202	0.1209	0.0271	-0.0388	-0.1440	-0.0742	0.2251	0.3812**	-0.0269	0.2083
Dry wt. at 30 DAS (g)				1.0000	0.7057**	-0.0488	-0.0509	0.2612*	-0.1431	0.0531	0.0132	-0.0759	-0.1681	-0.1181	0.2032	0.3876**	-0.0703	0.1667
Plant Ht. at 30 DAS (cm)					1.0000	0.1379	0.1949	0.3192**	-0.0715	0.0428	0.0019	-0.1856	0.0195	-0.1881	0.1874	0.4257**	-0.0836	0.1513
Plant Ht. at maturity (cm)						1.0000	0.1500	-0.0192	0.5952**	0.4344**	0.5378**	0.4453**	0.2309*	0.5009**	0.5264**	0.0931	0.4333**	0.6440**
Chlorophyll content at 30 DAS (SPAD)							1.0000	0.0716	0.0369	0.1134	-0.1157	-0.1564	0.4104**	-0.0518	-0.0212	0.0804	0.0351	0.0176
Chlorophyll content at full flowering (SPAD)								1.0000	-0.1514	-0.1668	-0.1752	-0.1417	0.3206**	-0.0772	-0.0862	0.0229	0.1161	-0.0129
No. of nodes/ plant									1.0000	0.3596**	0.5243**	0.4560**	0.2615*	0.5211**	0.3400**	-0.2295*	0.3269**	0.3998**
No. of primary branches /plant										1.0000	0.7376**	0.5576**	-0.0149	0.5419**	0.5084**	-0.0853	0.1212	0.5002**
No. of pod clusters /plant											1.0000	0.8063**	0.0158	0.7973**	0.6686**	-0.1628	0.2621*	0.7008**
No. of pods /plant												1.0000	-0.0471	0.9672**	0.6461**	-0.3182**	0.3794**	0.7424**
No. of seeds /pod													1.0000	0.1979	-0.1142	-0.4555**	0.2221	-0.0259
No. of seeds /plant														1.0000	0.6154**	-0.4221**	0.4139**	0.7243**
Bio. yield /plant (g)															1.0000	0.2826*	0.1022	0.8708**
100 seed wt (g)																1.0000	0.0067	0.2835*
Harvest index (%)																	1.0000	0.4987**
Seed yield /plant (g)																		1.0000

Table.5 Genotypic path coefficient for physiological and yield characters in advanced genotypes of soybean

Characters	DFF (days)	DM (days)	Fresh Wt. /plant at 30 DAS (g)	Dry wt. at 30 DAS (g)	Plant Ht. at 30 DAS (cm)	Plant Ht. at maturity (cm)	Chlorophyll content at 30 DAS (SPAD)	Chlorophyll content at full flowering (SPAD)	No. of nodes/ plant	No. of primary branches /plant	No. of pod clusters /plant	No. of pods / plant	No. of seeds / pod	No. of seeds / plant	Bio. yield / plant (g)	100 seed wt. (g)	Harvest index (%)
DFF (days)	**-0.3311**	-0.2574	0.1936	0.1444	0.2061	-0.1288	0.1028	0.1686	-0.2350	-0.1602	-0.1845	-0.2026	-0.0055	-0.2042	-0.0637	0.1566	-0.0691
DM (days)	0.1170	**0.1505**	-0.0822	-0.0589	-0.0555	0.0704	-0.0444	-0.0821	0.0737	0.0695	0.0744	0.0827	-0.0171	0.0759	0.0504	-0.0284	0.0208
Fresh Wt. /plant at 30 DAS (g)	-0.1151	-0.1075	**0.1969**	0.2006	0.1626	-0.0239	-0.0163	0.1326	-0.1298	-0.0515	-0.0044	-0.0296	-0.0657	-0.0436	0.066	0.1361	-0.0095
Dry wt. at 30 DAS (g)	0.0111	0.0099	-0.0258	**-0.0253**	-0.0181	0.0021	0.0054	-0.0140	0.0129	0.0023	-0.0003	0.0031	0.0067	0.0047	-0.0069	-0.0133	0.0023
Plant Ht. at 30 DAS (cm)	0.2297	0.1361	-0.3048	-0.2634	**-0.3691**	-0.0473	-0.0689	-0.2554	0.1545	0.0382	0.0014	0.0895	0.0007	0.0931	-0.0624	-0.1868	0.0322
Plant Ht. at maturity (cm)	0.0758	0.0911	-0.0236	-0.0164	0.0249	**0.1947**	0.0267	-0.0065	0.1567	0.1082	0.1059	0.0856	0.0527	0.0982	0.1074	0.0176	0.0935
Chlorophyll content at 30 DAS (SPAD)	-0.0112	-0.0107	-0.0030	-0.0076	0.0068	0.0050	**0.0362**	0.0125	-0.0055	-0.0080	-0.0097	-0.0110	0.0223	-0.0052	-0.0037	0.0037	0.0033
Chlorophyll content at full flowering (SPAD)	-0.0345	-0.0370	0.0456	0.0376	0.0469	-0.0023	0.0234	**0.0677**	-0.0072	-0.0188	-0.0159	-0.0119	0.0284	-0.0057	-0.0053	0.0017	0.009
No. of nodes/ plant	0.0563	0.0388	-0.0522	-0.0403	-0.0332	0.0638	-0.0121	-0.0084	**0.0793**	0.0558	0.059	0.0541	0.0342	0.062	0.0341	-0.0322	0.0414
No. of primary branches /plant	-0.1857	-0.1772	0.1004	0.0353	0.0397	-0.2133	0.0848	0.1064	-0.2704	**-0.3838**	-0.3473	-0.2485	-0.0158	-0.2463	-0.2446	0.0409	-0.0791
No. of pod clusters /plant	0.2936	0.2606	-0.0116	0.0072	-0.0019	0.2866	-0.1411	-0.1237	0.3918	0.4767	**0.5268**	0.4241	0.0233	0.4217	0.3771	-0.0872	0.1438
No. of pods /plant	0.9373	0.8421	-0.2301	-0.1882	-0.3716	0.6732	-0.4640	-0.2680	1.0465	0.9917	1.2332	**1.5319**	-0.0455	1.4834	1.0303	-0.5097	0.592
No. of seeds /pod	0.0062	-0.0427	-0.1251	-0.0988	-0.0007	0.1014	0.2315	0.1574	0.1617	0.0155	0.0166	-0.0111	**0.375**	0.0802	-0.0571	-0.1788	0.0937
No. of seeds /plant	-0.9259	-0.7573	0.3323	0.2769	0.3787	-0.7574	0.2162	0.1257	-1.1740	0.9635	-1.2021	-1.454	-0.3211	**1.5015**	-0.9459	0.6574	-0.643
Bio. yield /plant (g)	0.1105	0.1922	0.1925	0.1564	0.0971	0.3168	-0.0585	-0.0449	0.2471	0.366	0.4111	0.3863	-0.0874	0.3618	**0.5744**	0.1765	0.0627
100 seed wt. (g)	-0.0664	-0.0265	0.0970	0.0738	0.0710	0.0127	0.0145	0.0035	-0.0570	-0.015	-0.0232	-0.0467	-0.0669	-0.0615	0.0432	**0.1404**	-0.0011
Harvest index (%)	0.0458	0.0304	-0.0106	-0.0195	-0.0191	0.1053	0.0198	0.0293	0.1145	0.0452	0.0599	0.0848	0.0548	0.0939	0.0239	-0.0018	**0.2193**
Correlation with seed yield /plant (g)	0.2132	0.3354	0.2893	0.2137	0.1645	0.6591	-0.0440	0.0006	0.5597	0.5683	0.7007	0.7268	-0.0270	0.7069	0.9172	0.2928	0.5121

R SQUARE = 1.0149 RESIDUAL EFFECT = SQRT (1- 1.0149)

Fresh weight at 30 DAS had highly significant positive association with dry weight at 30 DAS, plant height at 30 DAS, chlorophyll content at full flowering and 100 seed weight (Aditya *et al.,* 2011). Plant height at 30 DAS showed highly significant positive association with chlorophyll content at full flowering and 100 seed weight. Plant height at maturity showed highly significant positive correlation with number of nodes per plant, number of primary branches per plant, number of pod clusters per plant, number of pods per plant, number of seeds per pod, number of seeds per plant, biological yield per plant, harvest index and seed yield per plant.

Chlorophyll content at 30 DAS recorded highly significant positive association only with number of seeds per pod. Chlorophyll content at full flowering established highly significant positive association with only one character i.e., number of seeds per pod. Number of nodes per plant showed highly significant positive correlation estimates with number of pod clusters per plant, number of seeds per plant, number of pods per plant, number of primary branches per plant. Number of primary branches per plant exhibited highly significant positive association with number of pod clusters per plant, number of pods per plant, number of seeds per plant, seed yield per plant and biological yield per plant.

Number of pod clusters per plant established highly significant positive association with number of pods per plant, number of seeds per plant, biological yield per plant, seed yield per plant and harvest index. Number of pods per plant recorded highly significant positive association with number of seeds per plant, biological yield per plant, seed yield per plant and harvest index. Number of seeds per plant observed highly significant positive association with seed yield per plant, biological yield per plant and harvest index, while 100 seed weight showed highly significant negative association with number of seeds per plant. Biological yield per plant recorded significant positive association with seed yield per plant and 100 seed weight. 100 seed weight showed significant positive association with seed yield per plant. Harvest index exhibited highly significant positive association with seed yield.

Significant positive correlation of different characters with seed yield per plant have also been reported by Badkul *et al.,* (2014) for biological yield, number of pods per plant, number of seeds per plant, plant height harvest index and number of seeds per pod, Koraddi *et al.,* (2015) for days to 50% flowering, plant height, number of branches per plant, number of pods per plant, 100 seed weight, biomass and harvest index, Alpna *et al.,* (2015) for number of pods per plant, 100 seed weight, harvest index and dry matter weight per plant, Mahbub and Shirazy (2016) for plant height, number of seeds per pod, number of pods per plant, 100 seed weight, branches per plant and number of seeds per pod, Akram *et al.,* (2016) for number of branches per plant, number of pods per plant, number of seeds per plant and 100 seed weight.

Overall correlation study indicated that the characters *viz.* biological yield per plant, number of pods per plant, number of seeds per plant, number of pod clusters per plant, number of primary branches per plant, harvest index and 100 seed weight are of greater importance in the improvement of yield.

Path Coefficients analysis

Path coefficient analysis was carried out taking seed yield per plant as the dependent

variable in order to see the causal factor(s) and to identify the best components which are responsible for producing seed yield. If the correlation between yield and character is due to the direct effects of character, it reflects true relationship between them, selection for such a character in order to improve yield, however if correlation is due to indirect effect of the character through another component character, the breeder has to select for the latter character through which indirect effect is exerted. The path analysis of the present investigation revealed that substantial positive direct effect on seed yield was exerted by number of pods per plant and number of seed per plant. The high estimate of positive direct effect was recorded by biological yield per plant, number of pod clusters per plant and number of seeds per pod, while harvest index, fresh weight at 30 DAS, plant height at maturity and 100 seed weight recorded low positive direct effect on seed yield per plant.

The high magnitude of negative direct effect on seed yield per plant was exhibited by number of primary branches per plant, plant height at 30 DAS and days to 50% flowering. Similar findings have also been reported by Machikowa and Laosuwan (2011) for fresh weight at full flowering, Salami and Moradi (2012) and Silva *et al.*, (2014) for number of seed per plant, Jain *et al.*, (2015) for biological weight, Abady *et al.*, (2013), Badkul *et al.*, (2014), Salimi and Moradi (2012), Malek *et al.*, (2014) and Jain *et al.*, (2015) for 100 seed weight and Mishra *et al.*, (2015) for number of seed per plant,100 seed weight and number of pods per plant. On the basis of path analysis, characters viz., number of seed per plant, number of pods per plant, biological yield per plant, pod cluster per plant and number of seed per pod have been found most important in the improvement of seed yield as they exhibited substantial direct effect.

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