Assessment of Polygenic Traits Association with Yield in Soybean Genotypes

ABSTRACT

Soybean is one of the important oilseed crop at global level with special concern to India. Despite its global dominance, India's contribution to the soybean scene remains relatively modest, with a production ranking of fourth but only a 5% share of the world's output. For this concern, the analysis of the relationships among yield attributing characters and their associations with seed yield is essential to establish selection criteria. The experimental material used in the present study comprised of fourteen lines (8 F1s and 6 parental lines).

The characters *viz.*, number of pods/plant, primary branches/plant, harvest index, plant height, secondary branch/plant, biological yield, 100-seed weight and days-to-50% flowering recorded significant positive correlation coefficient with seed yield both at genotypic and phenotypic level.

Path coefficient analysis further pinpointed 100-seed weight, harvest index, and pods per plant as the traits with the most direct positive impact on seed yield. Additionally, the study identified plant height, pods/plant, primary branches/plant, 100-seed weight, and the harvest index as the key contributors to soybean yield, suggesting these traits as primary targets for manipulation in breeding programs aimed at yield improvement.

Keywords: Soybean, correlation coefficient, path analysis

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill), a miracle legume, originating in ancient China, has blossomed into a global oilseed crop. From north-eastern part of China, it spread to USA, Europe, South American and South Asian countries. With its impressive protein content (40-42%), oil reserves (18-22%) and other nutrients, it's no wonder this versatile crop has earned the nickname "wonder crop." Holding the coveted title of the world's leading source of edible oil, the soybean finds its way into our kitchens in countless forms – from *tofu* and *tempeh* to cooking oil and even hidden ingredients in processed foods.

Despite its global dominance, India's contribution to the soybean scene remains relatively modest, with a production ranking of fourth but only a 5% share of the world's output.

However, within the country, a quiet revolution is brewing. States like Madhya Pradesh, rightfully nicknamed the "Soya State," are leading the charge, alongside Maharashtra, Uttar Pradesh, Rajasthan, and Karnataka. These regions are increasingly embracing the soybean's potential, recognizing its ability to address India's growing protein and oil demands.

While progress is undeniable, challenges persist. India's soybean productivity lags behind the global average, highlighting the need for innovative solutions. Cultivating high-yielding varieties presents a promising avenue, offering the potential to boost production and solidify India's position in the global soybean market. Additionally, addressing infrastructural limitations like inadequate storage facilities and transportation networks will be crucial for ensuring efficient distribution and preventing post-harvest losses (Lodhi et al., 2023; Ngalamu, 2013).

"The analysis of the relationships among yield attributing characters and their associations with seed yield is essential to establish selection criteria". [26] Biometrical technique such as correlation and path analysis provide information about the relative contribution of various component traits towards seed yield. Correlation determines the mutual relationship among numerous plant characters and helps in analyzing the grain yield components on which indirect selection can be based for genetic improvement in the grain yield of soybean. "The path coefficient analysis helps to determine the direct contribution of these characters and their indirect contributions via other characters". [26] For this reason, in this study the correlation and path analyses have been conducted in soybean to find out real contribution of characters among them to increase seed yield.

MATERIAL AND METHODS

Experimental material:

The experimental material used in the present study comprised of fourteen lines (8 F1s and 6 parental lines). The experiment was laid down in a Randomized Block Design (RBD) with three replications. All agronomic practices were followed as per package of practices. Here, each experimental entry was planted in a single 3.0 m row with a plant to plant and row to row spacing of 23 cm and 40 cm, respectively.

Observations recorded:

Observations were recorded on plot as well as single plant basis. Observations were recorded plot basis for days to 50% flowering and days to maturity. The data were recorded on the five competitive plants selected randomly from each plots for characters plant height (cm), primary branches per plant, secondary branches per plant, pods per plant, pod length (cm), 100-seed weight (g), seeds yield per plant (g), biological yield per plant (g) and harvest index (%) were used for statistical analysis.

Table 1: List of Soybean genotypes

S. No.	Name of genotypes
1	JS 97-52
2	JS 95-60
3	RVS 2001-4
4	JS 335
5	JS 93-05
6	RVS 24
7	JS 93-05 X JS 97-52
8	JS 93-05 X JS 95-60
9	JS 93-05 X RVS 2001-4
10	JS 93-05 X JS 335
11	RVS 24 X JS 97-52
12	RVS 24 X JS 95-60
13	RVS 24 X RVS 2001-4
14	RVS 24 X JS 335

Statistical analysis:

Correlation coefficient analysis:

Phenotypic, genotypic and environmental correlation coefficient between characters were computed utilizing respective components of variance and co-variance, by following formula suggested by Miller *et al.* (1958).

To test the significance of phenotypic and environmental correlation coefficient, the estimated values were compared with the tabulated values of Fisher and Yates (1938) at t-2 d.f. at two levels of probability, *viz.*, 5% and 1%.

Path coefficient analysis:

The proportion of direct and indirect contributions of various characteristics to the total correlation coefficient with seed yield was estimated through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). Residual effect, which measures the contribution of the characters not considered in the causal scheme, was also obtained.

RESULTS

Correlation coefficient analysis:

Seeds yield per plant showed a significant positive correlation with the number of pods/plant (0.80 and 0.941), primary branches/plant (0.860 and 0.899), harvest index (0.781 and 0.783), plant height (0.628 and 0.693), secondary branch/plant (0.575 and 0.765), biological yield (0.477 and 0.600), 100-seed weight (0.523 and 0.666), days-to-50% flowering (0.477 and 0.555) at both phenotypic and genotypic levels, whereas days-to-maturity (0.470) found to have a significant and positive correlation only at genotypic level.

Harvest index exhibited a significant positive correlation with biological yield (0.381 and 0.374), pods/plant (0.674 and 0.600), and primary branches/plant (0.571 and 0.471) both at phenotypic and genotypic levels, whereas pod length (-0.502), plant height (0.353), days-to-maturity (0.426) and days-to-50% flowering (0.426) had a significant correlation only at the genotypic level.

Biological yield/plant found to have a significant positive correlation with pod length (0.321 and 0.887), primary branches per plant (0.447 and 0.490), pods/plant (0.436 and 0.438), plant height (0.399 and 0.610), and days-to-50% flowering (0.351 and 0.665) at both the genotypic and phenotypic levels, whereas 100-seed weight (0.502), secondary branches per plant (0.455) and days-to-maturity (0.355) were found to have a significant positive correlation only at genotypic level.

The 100-seed weight had significant positive correlation with pods per plant (0.565 and 0.801), secondary branches/plant (0.958 and 0.982), primary branches/plant (0.602 and 0.894), plant height (0.652 and 0.710) and days-to-50% flowering (0.349 and 0.481) at both genotypic and phenotypic levels, while pod length (0.417) exhibited significant positive correlation at genotypic level only.

Pod length found to have a significant positive correlation with days-to-50% flowering (0.368) at genotypic level only.

Pods per plant had significant positive association with secondary branches per plant (0.617 and 0.909), primary branches per plant (0.905and0.938), plant height (0.672 and 0.799) and days-to-50% flowering (0.393 and 0.473) at both phenotypic and genotypic levels, however days-to-maturity (0.482) exhibited a significant positive correlation only at genotypic level.

Secondary branches per plant showed a significant positive correlation with primary branches/plant (0.633 and 0.995), plant height (0.632 and 0.717) at phenotypic and genotypic levels, whereas days-to-50% flowering (0.469) had significant and a positive correlation at genotypic level only.

Primary branches per plant had a significant and positive correlation with plant height (0.661 and 0.898), days-to-maturity (0.311 and 0.681) and days-to-50% flowering (0.498 and 0.652) both at phenotypic and genotypic levels.

Plant height expressed significant positive relationship with days-to-50% flowering (0.314) only at the genotypic level. Similarly, the days-to-maturity found to have highly significant positive association with days-to-50% flowering (0.715 and 0.933) both at the phenotypic and genotypic levels.

Table 2: Phenotypic and genotypic correlation coefficients among eleven characters in eight crosses of soybean

Characters		Harvest index (%)	Biological yield per plant (g)	100 seed weight (g)	Pod length (cm)	Pods per plant (No.)	Secondary branch per plant (No.)	Primary branches per plant (No.)	Plant height (cm)	Days to maturity	Days to 50% flowering
Seeds yield per plant (g)	**P**	0.781**	0.477**	0.523**	-0.050	0.80**	0.575**	0.860**	0.628**	0.300	0.477**
	G	0.783**	0.600**	0.666**	-0.097	0.941**	0.765**	0.899**	0.693**	0.470**	0.555**
Harvest index (%)	**P**		0.381*	-0.121	-0.169	0.674**	-0.028	0.571**	0.265	0.219	0.283
	G		0.374*	0.059	-0.502**	0.600**	0.210	0.471**	0.353*	0.426**	0.324*
Biological yield per plant (g)	**P**			0.242	0.321*	0.436**	0.182	0.447**	0.399**	0.255	0.351*
	G			0.502**	0.887**	0.438**	0.455**	0.490**	0.610**	0.355*	0.665**
100-seed weight (g)	**P**				0.165	0.565**	0.958**	0.602**	0.652**	0.170	0.349*
	G				0.417**	0.801**	0.982**	0.894**	0.710**	0.234	0.481**
Pod length (cm)	**P**					-0.067	0.053	-0.023	0.190	0.153	0.160
	G					-0.101	0.222	0.029	0.216	0.232	0.368*
Pods per plant	**P**						0.617**	0.905**	0.672**	0.290	0.393*
	G						0.909**	0.938**	0.799**	0.482**	0.473**
Secondary branches per plant	**P**							0.633**	0.632**	0.152	0.304
	G							0.995**	0.717**	0.259	0.469**

Primary branches per plant	**P**								0.661^{**}	0.311^{*}	0.498^{**}
	G								0.898^{**}	0.681^{**}	0.652^{**}
Plant height (cm)	**P**									0.224	0.274
	G									0.265	0.314^{*}
Days to maturity	**P**										0.715^{**}
	G										0.933^{**}

*, ** significant at 5% and 1%, respectively.

Path coefficient analysis

The estimate of path coefficient has been furnished in Table 3. "In general the genotypic direct effects as well as indirect effects were slightly higher in magnitude as compared to corresponding phenotypic direct indirect effects". [26] The measurement of the direct and indirect effects were characterize as negligible (0.00 to 0.09), low (0.10 to 0.19), moderate (0.20 to 0.29), high (0.30 to 0.99) and very high (> 1.00) as suggested by Lenka and Mishra (1973).

At the phenotypic level, the harvest index (0.85218) recorded the highest positive and direct effect on grain yield/plant followed by pods/plant (0.64450), 100-seed weight (0.04353), days-to-50% flowering (0.04033), and biological yield/plat plant (0.00113). On the other hand, primary branches/plant (-0.05631) closely followed by secondary branches/plant (-0.01458), days-to-maturity (-0.01456), pod length (-0.01239), and plant height (-0.00689) exhibited a negative direct effect on seed yield/plant.

At genotypic level, 100-seed weight (0.87646) had the highest positive and direct effect on seed yield/plant closely followed by harvest index (0.80905), pods per plant (0.48515), days-to-maturity (0.03698) and pod length (0.00975). Contrarily, negative and direct effect on grain yield/plant was observed for secondary branches/plant (-0.193) followed by plant height (-0.0459), primary branches/plant (-0.013), and biological yield/plant (0.00913).

The days-to-50% flowering had the highest positive indirect effect through100-seed weight (0.42116) followed by the HI (0.26251), day to maturity (0.03452), and pods length (0.00359), while plant height, primary branches/plant, secondary branches/plant, pods/plant and biological yield/plant had a negative indirect effect.

The days-to-maturity had highest positive indirect effect through harvest index (0.34447) followed by 100-seed weight (0.20501), and pods length (0.00227), while days-to-50 % flowering, plant height, primary branches/plant, secondary branches/plant, pods/plant and biological yield/plant exhibited a negative indirect effect.

Plant height exhibited highest positive indirect effect through 100-seed weight (0.62240) followed by harvest index (0.28590), days-to-maturity (0.00979) pods length (0.00211), days-to-50% flowering, primary and secondary branches/plant, and pods/plant while biological yield/plant exhibited negative indirect effect.

Primary branches per plant showed the highest positive and indirect effect on seed yield through 100-seed weight (0.78365) succeeded by the harvest index (0.38120), days-to-maturity (0.02518), and pods length (0.00028), while days-to-50% flowering, plant height, secondary branches/plant, pods/plant and, biological yield/plant exhibited a negative indirect effect on seed yield/plant.

The secondary branches/plant had the highest positive and indirect effect on seed yield/plant through the trait 100-seed weight (0.86036) followed by harvest index (0.16950), days-to-maturity (0.00958), and pods length (0.00216). In contrast to this, the days-to-50% flowering, plant height, primary branches/plant, pods/plant, and biological yield/plant exhibited a negative and indirect effect on the seed yield/plant.

The number of pods/plants found to have the highest positive indirect effect on seed yield/plant through 100-seed weight (0.70188) followed by days-to-maturity (0.01782); however, days-to-50% flowering, plant height, primary branches/plant, secondary branches/plant, and biological yield/plant exhibited a negative indirect effect on the seed yield/plant.

Pod length found to have the highest positive indirect effect through the 100-seed weight (0.36515) followed by days-to-maturity (0.00859) and pods/plant (0.00160). In contrast to it, the days to 50% flowering, pods/plant (0.436 and 0.438), plant height, primary and secondary branches/plant, and biological yield/plant showed a negative indirect effect.

The 100-seed trait exhibited the highest positive but indirect effect through the harvest index (0.04749) closely succeeded by the number of days-to-maturity (0.00865), and pods length (0.00406), while the number of days-to-50% flowering, plant height, primary and secondary branches/plant, number of pods/plant and the biological yield/plant exhibited a negative indirect effect on seed yield/plant.

The trait biological yield per plant exerted the highest positive and indirect effect through the 100-seed weight (0.43971), followed by the harvest index (0.30293) days-to-maturity (0.01314), and pods length (0.00864). As against it, the number of days-to-50% flowering, primary and secondary branches/plant, and pods/plant exhibited a negative indirect effect.

The harvest index found to have the highest positive indirect effect through 100-seed weight (0.05145) followed closely by the number of days-to-maturity (0.01575) while the number of days-to-50% flowering, pod length, pods/plant, primary and secondary branches/plant, and biological yield/plant exhibited negative indirect effect on the seed yield/plant.

Table 3: Result of path coefficient analyses at phenotypic and genotypic level

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches per plant	Secondary branch per plant	Pods per plant	Pod length (cm)	100 seed weight (g)	Biological yield per plant (g)	Harvest index (%)	Seeds yield per plant (g)
Days to 50% flowering	**P**	**0.04033**	-0.01041	-0.00189	-0.02803	-0.00443	0.01709	-0.00198	0.22468	0.00040	0.24144	0.477
	G	**-0.03993**	0.03452	-0.01438	-0.00850	-0.09053	-0.00749	0.00359	0.42116	-0.00607	0.26251	0.55488
Days to maturity	**P**	0.02885	**-0.01456**	-0.00155	-0.01749	-0.00221	0.01262	-0.00189	0.10939	0.00029	0.18673	0.30018
	G	-0.03727	**0.03698**	-0.01214	-0.00887	-0.05002	-0.00763	0.00227	0.20501	-0.00324	0.34447	0.46956
Plant height (cm)	**P**	0.01104	-0.00327	**-0.00689**	-0.03721	-0.00921	0.02925	-0.00235	0.42025	0.00045	0.22605	0.62811
	G	-0.01252	0.00979	**-0.04588**	-0.01170	-0.13842	-0.01265	0.00211	0.62240	-0.00557	0.28590	0.69346
Primary branches per plant	**P**	0.02008	-0.00452	-0.00455	**-0.05631**	-0.00923	0.03941	0.00029	0.38800	0.00051	0.48628	0.85996
	G	-0.02605	0.02518	-0.04120	**-0.01303**	-0.19217	-0.01485	0.00028	0.78365	-0.00448	0.38120	0.89853
Secondary branches per plant	**P**	0.01226	-0.00221	-0.00435	-0.03564	**-0.01458**	0.02685	-0.00066	0.61716	0.00021	-0.02402	0.57502
	G	-0.01872	0.00958	-0.03288	-0.01296	**-0.19312**	-0.01439	0.00216	0.86036	-0.00415	0.16950	0.76538

Pods per plant	**P**	0.01583	-0.00422	-0.00463	-0.05098	-0.00899	**0.64450**	0.00083	-0.36438	0.00049	0.57412	0.80257
	G	-0.01889	0.01782	-0.03667	-0.01222	-0.17561	**0.48515**	-0.00099	0.70188	-0.00400	-0.01583	0.94064
Pod length (cm)	**P**	0.00646	-0.00222	-0.00131	0.00132	-0.00077	-0.00290	**-0.01239**	0.10623	0.00036	-0.14442	-0.0496
	G	-0.01471	0.00859	-0.00992	-0.00038	-0.04279	0.00160	**0.00975**	0.36515	-0.00809	-0.40613	-0.09693
100-seed weight (g)	**P**	0.01406	-0.00247	-0.00449	-0.03390	-0.01396	0.02461	-0.00204	**0.04353**	0.00027	-0.10333	0.52325
	G	-0.01919	0.00865	-0.03258	-0.01165	-0.18958	-0.01268	0.00406	**0.87646**	-0.00458	0.04749	0.6664
Biological yield/plant (g)	**P**	0.01417	-0.00372	-0.00275	-0.02517	-0.00266	0.01899	-0.00398	0.15593	**0.00113**	0.32459	0.47653
	G	-0.02655	0.01314	-0.02798	-0.00639	-0.08781	-0.00693	0.00864	0.43971	**-0.00913**	0.30293	0.59963
Harvest index (%)	**P**	0.01143	-0.00319	-0.00183	-0.03213	0.00041	0.02933	0.00210	-0.07815	0.00043	**0.85218**	0.78058
	G	-0.01296	0.01575	-0.01621	-0.00614	-0.04046	-0.00949	-0.00489	0.05145	-0.00342	**0.80905**	0.78268

DISCUSSION

"In the present investigation attempt has been made with the objective to get the information about the nature, extent and direction of relationship and selection pressure practice to achieve practical and usable results. High magnitude of positive correlation coefficient at genotypic level indicates strong linkage at genetic level, but high values of correlation coefficient at phenotypic levels may not always show strong association and it may be broken up with the change. When the characters having direct bearing on the yield were selected, their association with other characters was to be simultaneously considered as it would directly affect the yield. Path coefficient analysis was carried out using genotypic and phenotypic correlation coefficients and taking seed yield per plant as the dependent variable in order to see the causal factor(s) and to identify the best components which were responsible for producing high seed yield. Thus, the information obtained from this technique, also helps in making selection based on component characters of yield". [26]

Several traits showed significant positive correlations with seed yield both at the genotypic and the phenotypic levels. These include pods per plant, primary branches per plant, harvest index, plant height, number of secondary branches/plant, biological yield, 100-seed weight, and days-to-50% flowering. The positive genotypic association between seed yield/plant and the number of pods/plant has been also reported by Patil et al. (2011), Amrita et al. (2014) and Ramgiry et al. (2016). Similarly, for No. of seeds/plant, 100-grain weight, harvest index and days to 50% flowering were reported by Amrita et al., (2014), Mahbub et al., (2015), Ramgiry et al., (2016), Baruah et al., (2014), Pawar et al., (2014) and Balla et al., (2017).

The analyses indicated interconnectedness among important traits like pods/plant, no. of primary branches/plant, harvest index, plant height, and days-to-50% flowering. Focusing on improving these interconnected traits could lead to more significant yield gains. This result is supported by those of Sarutayophat (2012), Pawar et al., (2014) and Balla et al., (2017) for pods per plant; Sirohi et al. (2007) for biological yield per plant; and Gohil et al., (2003) and Gaikwad et al., (2007) for days-to-maturity and days-to-50% flowering.

The identified traits with strong genetic correlations and positive associations with yield are valuable targets for breeders aiming to improve soybean production. Selecting and breeding for these traits can lead to the development of high-yielding soybean varieties with enhanced genetic potential.

The 100-seed weight had the strongest positive direct effect on seed yield per plant, followed by harvest index, no. of pods/plant, days-to-maturity, and pod length. These findings are consistent with previous research by Ferrari et al. (2018) for pods/plant, Silva et al. (2015) and Ramgiry et al. (2016) for seed yield/plant, and Narjesi et al. (2007) for the harvest index.

The trait days-to-50% flowering found to have a negative direct effect on seed yield/plant but a positive indirect effect through 100-seed weight. This suggests that selecting for earlier flowering could indirectly increase seed yield by promoting heavier seeds. Gaikwad et al. (2007) also observed similar results.

The days-to-maturity found to have a moderate positive direct effect on seed yield/plant and a positive indirect effect through harvest index. This indicates that later maturing plants (longer days to maturity) may yield more due to both their longer growth duration and improved harvest index.

The plant height, no. of primary and secondary branches/plant, and biological yield/plant all had negative direct effect on seed yield/plant but positive indirect effect through 100-seed weight. This suggests that while these traits themselves may not directly contribute to yield, they can indirectly influence it through their impact on seed size.

Pods per plant had a positive direct effect and negative indirect effect on seed yield, while harvest index and 100-seed weight had positive direct and indirect effects. This highlights the importance of balancing pod number with the seed size for optimal yield. Similar results were reported by Chettri et al. (2003), Turkec (2005), Silva et al. (2015) for pods/plant, and Malik et al. (2006), Gaikwad et al. (2007), and Karnwal and Singh (2009) for 100-seed weight.

This study emphasizes the importance of considering both direct and indirect effects when selecting for soybean yield improvement. Focusing on traits like 100-seed weight, harvest index, pods/plant, days-to-maturity, and pod length, while considering their complex interactions, can lead to more effective breeding strategies.

CONCLUSIONS

The analysis revealed a stronger influence of genetic factors compared to environmental factors on most traits, as indicated by higher genotypic correlations compared to phenotypic correlations. The characters *viz.*, number of pods/plant, primary branches/plant, harvest index, plant height, secondary branch/plant, biological yield, 100-seed weight and days-to-50% flowering recorded significant positive correlation coefficient with seed yield both at genotypic and phenotypic level.

Path coefficient analysis further pinpointed 100-seed weight, harvest index, and pods per plant as the traits with the most direct positive impact on seed yield. Additionally, the study identified plant height, pods/plant, primary branches/plant, 100-seed weight, and the harvest index as the key contributors to soybean yield, suggesting these traits as primary targets for manipulation in breeding programs aimed at yield improvement.

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