Character Association and Path Analysis for Seed Yield and Yield-Contributing Traits in Soybean (*Glycine max* (L.) Merrill)

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Abstract— The present investigation entitled "Character Association and Path Analysis for Seed Yield and Yield-Contributing Characters in Soybean (*Glycine max* (L.) Merrill)" was conducted to evaluate correlation and path coefficient analysis in eight soybean genotypes. The experiment was laid out in a Randomized Block Design with three replications during Kharif 2024 at the School of Agricultural Sciences, G. H. Raisoni University, Saikheda. Observations were recorded for nine traits: days to 50% flowering, days to maturity, plant height, number of primary branches per plant, pod length, number of pods per plant, number of seeds per pod, 100-seed weight, and seed yield per plant. Correlation analysis revealed that genotypic correlations were generally higher than phenotypic ones, indicating a genetic basis for the observed associations. Seed yield per plant showed significant positive correlations with number of primary branches, pods per plant, seeds per pod, 100-seed weight, and pod length. Path coefficient analysis indicated that number of pods per plant, 100-seed weight, and number of seeds per pod exerted strong positive direct effects on seed yield, whereas plant height had a negative effect at the phenotypic level. The low residual effects (0.0182 at genotypic and 0.0369 at phenotypic levels) suggested that most of the variation in seed yield was explained by the studied traits. Overall, the study highlights that additive gene action predominated in traits such as number of branches, pods per plant, 100-seed weight, and seed yield, which can serve as reliable selection indices for soybean improvement.

Index Terms — Soybean (*Glycine max*), character association, correlation analysis, path coefficient, seed yield, yield-attributing traits, genetic improvement.

I. INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a globally important oilseed and pulse crop valued for its dual role in human nutrition and livestock feed. Its seeds contain about 40% protein and nearly 20% oil, along with essential amino acids, vitamins, and unsaturated fatty acids, making it a "Golden Bean" of the twentieth century (Gopalan *et al*., 1994; FAO, 2024). Besides being a rich nutritional source, soybean contributes to soil fertility through symbiotic nitrogen fixation, making it an integral component of sustainable cropping systems (Wani and Lee, 1992). Globally, it occupies around 135 million hectares, producing nearly 390 million metric tonnes annually, with Brazil, the United States, and Argentina being the leading producers. In India, soybean cultivation covers about 12.7 million hectares, with Madhya Pradesh, Maharashtra, Rajasthan, and Uttar Pradesh as the main producing states (MoAFW, 2024).

Improving seed yield remains a major objective in soybean breeding; however, yield is a complex quantitative trait controlled by multiple interrelated characters. Understanding the relationships among yield and its component traits is essential to enhance selection efficiency. Correlation analysis provides information on the degree and direction of association among traits, thereby helping identify characters that contribute positively to yield. Nevertheless, correlation alone does not reveal whether these associations are due to direct influence or indirect effects through other traits. Path coefficient analysis, originally proposed by Dewey and Lu (1959), addresses this limitation by partitioning correlations into direct and indirect effects, thus clarifying the true contribution of each trait to seed yield.

Several studies have highlighted that traits such as number of pods per plant, number of seeds per pod, and 100-seed weight are often positively correlated

with seed yield and also exert significant direct effects, making them reliable selection indices (Divya Ramakrishnan *et al*., 2018). Hence, combining correlation and path coefficient analyses provides a more dependable basis for identifying yield-attributing traits in soybean.

Considering the economic and nutritional significance of soybean, the present investigation entitled "Character Association and Path Analysis for Seed Yield and Yield-Contributing Characters in Soybean (*Glycine max* (L.) Merrill)" was undertaken to assess the association among yield and its component traits, and to identify those exerting positive direct effects that may serve as effective selection criteria in soybean improvement programs.

II. MATERIAL AND METHODS

The present investigation was conducted during the Kharif season of 2024 at the Research Farm, School of Agricultural Sciences, G.H. Raisoni University, Saikheda, using eight soybean genotypes (KDS 726, KDS 992, DS 228, MAUS 71, MAUS 81, MAUS 162, MAUS 612, and JS 335). The experiment was laid out in a Randomized Block Design with three replications, maintaining a plot size of 3 m × 3 m with spacing of 45 cm between rows and 5 cm between plants. Observations were recorded on nine quantitative traits, viz., days to 50% flowering, days to maturity, plant height, number of primary branches per plant, pod length, number of pods per plant, number of seeds per pod, 100-seed weight, and seed yield per plant.

The collected data were analyzed using correlation coefficient analysis and path coefficient analysis. Correlation analysis was employed to assess the degree of association among yield and its contributing traits at both genotypic and phenotypic levels. Path coefficient analysis was further used to partition the correlation coefficients into direct and indirect effects, thereby identifying the relative contribution of individual traits towards seed yield. The residual effect was also estimated to account for the unexplained variation in seed yield.

III. RESULT AND DISCUSSION

1. CORRELATION ANALYSIS:

Correlation coefficient analysis was carried out to determine the association among nine yield-contributing characters in soybean at both genotypic and phenotypic levels (Table 4.2 and 4.3).

Days to 50% flowering:
At the genotypic level, days to 50% flowering showed a significant and positive correlation with number of pods per plant (0.7935*), while it also exhibited positive but non-significant associations with plant height (0.5352) and seed yield per plant (0.3992). A negative non-significant correlation was recorded with 100-seed weight (–0.1512).
At the phenotypic level, it also revealed a highly significant positive correlation with pods per plant (0.7702**) and a significant positive association with plant height (0.4777*) and seed yield (0.3899). Its correlation with 100-seed weight was negative and non-significant (–0.1363).

Days to maturity:
At the genotypic level, days to maturity exhibited positive but non-significant correlations with branches per plant (0.6931), pod length (0.6951), and seed yield per plant (0.3306). Its relation with 100-seed weight was negative and non-significant (–0.0358).
At the phenotypic level, days to maturity showed a highly significant positive association with branches per plant (0.6696**) and pod length (0.6056**), along with a positive but non-significant correlation with seed yield (0.3142). The relation with 100-seed weight remained negative and non-significant (–0.0450).

Plant height:
At the genotypic level, plant height showed a significant positive correlation with number of pods per plant (0.7104*) and seed yield per plant (0.6937). It also exhibited positive but non-significant correlations with pod length (0.5790), seeds per pod (0.3125), and 100-seed weight (0.3839).
At the phenotypic level, plant height was positively and highly significantly associated with pods per plant (0.6039**), seed yield (0.6079**), and pod length (0.5453**), while it showed positive but non-significant correlations with seeds per pod (0.3501) and 100-seed weight (0.3425).

Number of primary branches per plant:
At the genotypic level, branches per plant had positive but non-significant correlations with pod length

(0.902), seed yield per plant (0.6472), seeds per pod (0.5685), and 100-seed weight (0.4711).
At the phenotypic level, branches per plant showed a highly significant positive correlation with pod length (0.7916**), seed yield (0.6341**), seeds per pod (0.4544*), and 100-seed weight (0.4644*).

Pod length:
At the genotypic level, pod length displayed a significant positive correlation with seed yield per plant (0.7563*) and positive but non-significant correlations with seeds per pod (0.6919) and 100-seed weight (0.5039).
At the phenotypic level, it showed a highly significant positive correlation with seed yield (0.6884**) and seeds per pod (0.6689**), along with a significant positive relation with 100-seed weight (0.4335*).

Number of pods per plant:
At the genotypic level, pods per plant showed a positive but non-significant correlation with seed yield per plant (0.5768) and a negative non-significant correlation with 100-seed weight (–0.0837).
At the phenotypic level, it revealed a positive but non-significant correlation with seed yield (0.3605), while the association with 100-seed weight was highly significant and positive (0.5557**).

Seeds per pod:
At the genotypic level, seeds per pod exhibited a highly significant and positive correlation with seed yield per plant (0.9422**) and a positive but non-significant association with 100-seed weight (0.6636).
At the phenotypic level, it also showed a highly significant positive correlation with seed yield (0.8042**) and a positive but non-significant correlation with 100-seed weight (0.5285).

100-seed weight:
At the genotypic level, 100-seed weight exhibited a significant positive correlation with seed yield per plant (0.736*).
At the phenotypic level, this association was highly significant and positive (0.7164**).

Seed yield per plant:
At the genotypic level, seed yield per plant recorded a highly significant positive correlation with seeds per pod (0.9422**) and significant positive associations with 100-seed weight (0.736*) and pod length (0.7563*). Positive but non-significant correlations were observed with branches per plant (0.6472) and plant height (0.6937).
At the phenotypic level, seed yield per plant showed highly significant positive correlations with seeds per pod (0.8042**), 100-seed weight (0.7164**), pod length (0.6884**), and branches per plant (0.6341**), along with a significant positive correlation with plant height (0.6079**).

2. PATH ANALYSIS

Path coefficient analysis was carried out to partition the correlation of yield with its component traits into direct and indirect effects at both genotypic and phenotypic levels (Table 4.3).

Days to 50% Flowering:
At the genotypic level, days to 50% flowering had a positive but non-significant correlation with seed yield (0.3992), though its direct effect was negative and negligible (–0.0422). Positive indirect effects were exerted through pods per plant (0.4456), seeds per pod (0.0803), and days to maturity (0.0397).

At the phenotypic level, it correlated positively with seed yield (0.3257) and showed a negative direct effect (–0.1156). Indirect effects were positive via pods per plant (0.4106), seeds per pod (0.0726), and maturity duration (0.0397).

Days to Maturity:
Genotypically, days to maturity exhibited a positive but non-significant correlation with seed yield (0.3306) and a positive direct effect (0.1103). Major indirect contributions were via pods per plant (0.4249), seeds per pod (0.0645), and 100-seed weight (0.0201).
Phenotypically, it also correlated positively (0.2098) with a positive direct effect (0.1366). Indirect effects were channeled through pods per plant (0.3174), seeds per pod (0.0581), and 100-seed weight (0.0169).

Plant Height:
At the genotypic level, plant height correlated positively with seed yield (0.6937) and showed a moderate direct effect (0.1386). Indirect positive effects were observed through pods per plant (0.3943), seeds per pod (0.0630), and maturity (0.0283).
At the phenotypic level, it had a positive highly significant correlation (0.6079**) with a strong direct effect (0.3746). Indirect positive contributions came

via pods per plant (0.3072), seeds per pod (0.0567), and branches per plant (0.0360).

4.5.4 Number of Branches per Plant

Genotypically, branches per plant correlated positively with yield (0.6472) and exerted a strong direct effect (0.5157). Indirect effects were mainly through pod length (0.4183), pods per plant (0.1771), and seeds per pod (0.0450).

Phenotypically, it also correlated positively highly significant (0.6341**) with a high direct effect (0.4567). Positive indirect effects were exerted via pod length (0.3651), pods per plant (0.1387), and seeds per pod (0.0398).

4.5.5 Pod Length

At the genotypic level, pod length showed a strong positive correlation with seed yield (0.7563*) and a positive direct effect (0.4636). Indirect contributions were mostly through branches per plant (0.4802), pods per plant (0.2018), and seeds per pod (0.0566).

Phenotypically, pod length was correlated positively and highly significant (0.6884**) with a high direct effect (0.4132). Indirect positive effects were exerted via branches per plant (0.3615), pods per plant (0.1759), and seeds per pod (0.0519).

4.5.6 Number of Pods per Plant

Genotypically, pods per plant correlated positively with yield (0.5768) and exerted a strong direct effect (0.6287). Indirect positive contributions were observed through seeds per pod (0.0802), branches per plant (0.0804), and pod length (0.1495).

Phenotypically, it also correlated positively and highly significant (0.5557**) with a high direct effect (0.6485). Indirect effects were mainly through seeds per pod (0.0719), branches per plant (0.0634), and pod length (0.1436).

4.5.7 Seeds per Pod

At the genotypic level, seeds per pod showed a very strong correlation with seed yield (0.9422**) and a high direct effect (0.8950). Indirect contributions were through pod length (0.0687), pods per plant (0.0898), and 100-seed weight (0.0652).

At the phenotypic level, seeds per pod also correlated strongly (0.8042**) with a high direct effect (0.7320). Indirect effects were exerted through pod length (0.0732), pods per plant (0.0789), and 100-seed weight (0.0588).

4.5.8 100-Seed Weight

Genotypically, 100-seed weight correlated positively with seed yield (0.7360*) and showed a strong direct effect (0.6401). Indirect contributions came from seeds per pod (0.1056), pod length (0.0884), and pods per plant (0.0962).

Phenotypically, it also showed a positive correlation (0.7164**) with a direct effect of 0.6014. Positive indirect effects were exerted via seeds per pod (0.0985), pod length (0.0795), and pods per plant (0.0846).

Table 4.2 Genotypic correlation coefficient matrix between seed yield per plant (g) and other parameters in soyabean

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	Pod length (cm)	No. of pods per plant	No. of seeds per pod	100 seed weight (g)	Seed yield per plant (g)
Days to 50% flowering	1.000**	0.2399	0.5352	0.0337	0.4019	0.7935*	0.3106	-0.1512	0.3992
Days to maturity		1.000**	0.3829	0.6931	0.6951	0.2541	0.4649	-0.0358	0.3306
Plant height (cm)			1.000**	0.6465	0.579	0.7104*	0.3125	0.3839	0.6937
No. of primary branches per plant				1.000**	0.902	0.3041	0.5685	0.4711	0.6472
Pod length (cm)					1.000**	0.4175	0.6919	0.5039	0.7563*
No. of pods per plant						1.000**	0.4214	-0.0837	0.5768
No. of seeds per pod							1.000**	0.6636	0.9422**
100 seed weight (g)								1.000**	0.736*

Seed yield per plant (g)									1.000**

*,** Significant at 5% and 1% levels, respectively

Table 4.3 Genotypic correlation coefficient matrix between seed yield per plant (g) and other parameters in soyabean

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	Pod length (cm)	No. of pods per plant	No. of seeds per pod	100 seed weight (g)	Seed yield per plant (g)
Days to 50% flowering	1.000**	0.2399	0.5352	0.0337	0.4019	0.7935*	0.3106	-0.1512	0.3992
Days to maturity		1.000**	0.3829	0.6931	0.6951	0.2541	0.4649	-0.0358	0.3306
Plant height (cm)			1.000**	0.6465	0.579	0.7104*	0.3125	0.3839	0.6937
No. of primary branches per plant				1.000**	0.902	0.3041	0.5685	0.4711	0.6472
Pod length (cm)					1.000**	0.4175	0.6919	0.5039	0.7563*
No. of pods per plant						1.000**	0.4214	-0.0837	0.5768
No. of seeds per pod							1.000**	0.6636	0.9422**
100 seed weight (g)								1.000**	0.736*
Seed yield per plant (g)									1.000**

*,** Significant at 5% and 1% levels, respectively

Table 4.4 Estimates of genotypic and phenotypic path analysis showing direct (diagonal and bold) and indirect effects of different characters on seed yield per plant in eight genotypes of soyabean

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	Pod length (cm)	No. of pods per plant	No. of seeds per pod	100 seed weight (g)	Seed yield per plant (g)
Days to 50% flowering	rG	-0.0422	0.0397	-0.0174	-0.0021	-0.0051	0.4456	0.0803	-0.0996	0.3992
	rP	0.0432	0.0214	-0.0353	0.0022	-0.0001	0.3793	0.0659	-0.0867	0.3899
Days to maturity	rG	-0.0101	0.1653	-0.0125	-0.0427	-0.0088	0.1427	0.1202	-0.0236	0.3306
	rP	0.0106	0.0874	-0.0222	0.0451	-0.0002	0.1288	0.0933	-0.0285	0.3142
Plant height (cm)	rG	-0.0226	0.0633	-0.0325	-0.0398	-0.0073	0.3989	0.0808	0.2529	0.6937
	rP	0.0206	0.0263	-0.0740	0.0362	-0.0002	0.2974	0.0838	0.2178	0.6079**
No. of primary branches per plant	rG	-0.0014	0.1145	-0.0210	-0.0616	-0.0114	0.1708	0.1470	0.3104	0.6472
	rP	0.0014	0.0585	-0.0398	0.0673	-0.0002	0.1426	0.1089	0.2953	0.6341**
Pod length (cm)	rG	-0.0170	0.1149	-0.0188	-0.0556	-0.0126	0.2345	0.1789	0.3320	0.7563*
	rP	0.0147	0.0528	-0.0403	0.0533	-0.0003	0.1751	0.1596	0.2746	0.6884**
No. of pods per plant	rG	-0.0335	0.0420	-0.0231	-0.0187	-0.0053	0.5616	0.1090	-0.0551	0.5768
	rP	0.0332	0.0229	-0.0447	0.0195	-0.0001	0.4924	0.0862	-0.0537	0.5557**
No. of seeds per pod	rG	-0.0131	0.0768	-0.0102	-0.0350	-0.0087	0.2366	0.2585	0.4372	0.9422**
	rP	0.0119	0.0341	-0.0259	0.0307	-0.0002	0.1775	0.2147	0.4102	0.8042**
100 seed weight (g)	rG	0.0064	-0.0059	-0.0125	-0.0290	-0.0063	-0.0470	0.1716	0.6588	0.736*
	rP	-0.0059	-0.0039	-0.0159	0.0273	-0.0001	-0.0388	0.1423	0.6129	0.7164**

Genotypic residual effect = 0.0182, Phenotypic residual effect = 0.0369

IV. CONCLUSION

Correlation and path coefficient analyses indicated that seed yield per plant in soybean is predominantly governed by the number of pods per plant, seeds per pod, and 100-seed weight. Both genotypic and phenotypic evaluations revealed strong positive associations of these traits with yield, with the number of pods per plant demonstrating the highest direct effect in path analysis. Other traits, such as plant height and days to maturity, contributed mainly through indirect pathways and had minimal direct influence. The low residual effects suggest that the selected yield-contributing traits adequately explained the majority of variability in seed yield. These findings highlight the critical role of pod- and seed-related components in yield enhancement and provide a reliable basis for selection in soybean breeding programs.

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