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Estimation of Trait Association and Path Analysis for Yield and Yield Contributing Characters in Sesame (*Sesamum indicum* L.)

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Authors' contributions

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

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Abstract

Sesame (*Sesamum indicum* L.) is a valuable oilseed crop, and effective improvement of seed yield requires an understanding of the relationships among yield-contributing traits. This study assessed genotypic and phenotypic correlations and path coefficients for seed yield and nine contributing traits in 30 sesame

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genotypes. The experiment was conducted under irrigated conditions at the College of Agriculture, Latur, during summer 2025–26 using a randomised block design with two replications. Data were recorded for days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds per capsule, 1000-seed weight, oil content, and seed yield per plant. Analysis of variance indicated significant differences among the genotypes for all ten traits. Seed yield per plant showed significant positive correlations with 1000-seed weight, number of seeds per capsule, number of capsules per plant, and plant height at both genotypic and phenotypic levels. Path analysis showed that 1000-seed weight had the largest positive direct effect on seed yield, followed by number of seeds per capsule and number of capsules per plant. Plant height contributed mainly through indirect effects involving these yield components. The findings indicate that 1000-seed weight, number of seeds per capsule, and number of capsules per plant may serve as useful selection criteria for improving seed yield in the evaluated germplasm. Validation across seasons and environments is required before these traits are adopted as stable breeding criteria.

Keywords: Sesamum indicum L.; genetic variability; trait association; genotypic correlation; phenotypic correlation; path coefficient analysis; seed yield; yield components; selection criteria

1. Introduction

Sesame (*Sesamum indicum* L.), a member of the Pedaliaceae family, is one of the oldest cultivated oilseed crops, with a history spanning more than 3,000 years. Commonly known as til or gingelly, this diploid crop (2n = 26) thrives in tropical and subtropical climates and is valued for its drought tolerance, making it suitable for rainfed and marginal lands. It is often referred to as the "Queen of Oilseeds" because of the exceptional quality and stability of its oil. Sesame seeds contain 50–55% oil, 18–25% protein, and natural antioxidants such as sesamin, sesamolin, and sesamol. It is a predominantly self-pollinated, short-duration crop that matures within 80–120 days, allowing it to fit readily into multiple cropping systems. Recent work has further demonstrated that sesame remains a valuable raw material for nutrient-oriented food applications, while evaluations of diverse accessions have revealed substantial variation in yield- and quality-related traits that can be used in breeding (Shingane et al., 2025; Sonaniya et al., 2023).

Available FAO data indicate that Sudan is the world's largest producer of sesame seed, producing approximately 1.37 million tonnes annually, followed by India, Myanmar, China, and Nigeria (Food and Agriculture Organization of the United Nations [FAO], 2025). Globally, India occupies a prominent position, ranking first in total harvested area, accounting for a substantial proportion of global sesame acreage, and second in production; it is also one of the leading exporters of sesame seeds worldwide (FAO, 2025). In India, 2025 estimates indicate that sesame was cultivated on more than 14.50 lakh hectares, with total annual production reaching approximately 8.02 lakh tonnes and average productivity of approximately 485–500 kg/ha (Ministry of Agriculture & Farmers Welfare, 2025). Recent multi-environment analyses have shown that capsule number per plant, capsule stem length, thousand-seed weight, and related architectural traits contribute to variation in sesame seed yield, while molecular mapping has identified genomic regions associated with yield-related characters (Wang et al., 2024; Xu et al., 2024). Under different seedbed and irrigation conditions, capsule number per plant and seed index also showed strong direct contributions to seed yield in path analysis (Mohamed et al., 2025).

Phenotypic and genotypic correlation coefficients were calculated to assess the magnitude and direction of the relationships between seed yield and its contributing traits. These estimates were obtained from variance and covariance components following the standard biometrical procedures described by Johnson et al. (1955) and Al-Jibouri et al. (1958). Using the standard biometrical approach developed by Dewey and Lu (1959), genotypic correlation coefficients were partitioned into direct and indirect effects through path analysis to examine the contributions of individual traits to seed yield. This approach helps establish selection criteria for identifying genotypes with high yield potential for use in hybridisation programmes. However, trait associations and their direct effects may vary with genotype and growing environment, and evidence is limited for the present set of 30 sesame genotypes under summer irrigated conditions at Latur. A location-specific evaluation combining genotypic and phenotypic correlations with path coefficient analysis is therefore needed to identify dependable selection criteria within this material. The objective of the present study was to estimate genotypic and phenotypic associations between seed yield and nine yield-contributing traits and to partition these relationships into direct and indirect effects through path coefficient analysis in 30 sesame genotypes.

2. Materials and Methods

2.1 Experimental Setup

The present investigation evaluated 30 germplasm accessions, comprising 28 genotypes [TS-14, TS-110, TS-20, TS-24A, TS-50, TS-113, TLT-7, TS-25, RT-372, TS-61, RT-54, RT-351, TS-13, TBS-09, R-09, TBS-06, TBS-05, V-32, V-22, TBS-07, TLT-05, V-21, V-34, R-22, TBS-02, RT-346, TS-11-2, TS-102] and two standard checks (TLT-10 and AKT-101), sourced from the Bhabha Atomic Research Centre (BARC) and the Oilseeds Research Station (ORS), Latur. The field experiment was conducted during the summer season of 2025–26 under irrigated conditions at the experimental farm of the Department of Botany, College of Agriculture, Latur, Maharashtra. The experimental site had medium black cotton soil, and the weather during crop growth was moderate, with temperatures of approximately 33–35°C.

The accessions were sown in a randomised block design (RBD) with two replications. Each plot measured 5 m × 13 m, with 30 cm between rows and 10 cm between plants. Standard agronomic practices, including ploughing, land levelling, and basal fertiliser application, were followed uniformly to establish a healthy crop.

2.2 Statistical Analysis

To evaluate the magnitude and direction of the relationships between seed yield and its associated traits, phenotypic and genotypic correlation coefficients were calculated by estimating the respective variance and covariance components following the standard biometrical procedures established by Johnson et al. (1955) and Al-Jibouri et al. (1958). To examine the direct and indirect effects of individual traits, path coefficient analysis was used to partition the genotypic correlations into direct and indirect components following the methodology developed by Dewey and Lu (1959). All statistical analyses were performed using RStudio.

3. Results and Discussion

Genetic variability within the base population is a fundamental prerequisite for a successful breeding programme. Analysis of variance (ANOVA) revealed highly significant differences among the 30 sesame genotypes for all ten quantitative traits evaluated (Table 1), indicating substantial genetic variability.

Estimates of the genotypic and phenotypic correlation coefficients describing the relationships between seed yield and its contributing traits are presented in Table 2.

Significant positive correlations with seed yield per plant were recorded for 1000-seed weight (rg = 0.684, rp = 0.686), number of seeds per capsule (rg = 0.555, rp = 0.519), number of capsules per plant (rg = 0.550, rp = 0.491), and plant height (rg = 0.395, rp = 0.350) at both genotypic and phenotypic levels. Capsule length (rg = 0.176, rp = 0.103), number of branches per plant (rg = 0.114, rp = 0.139), days to 50 per cent flowering (rg = 0.080, rp = 0.118), and oil content (rg = 0.081, rp = 0.062) showed positive but non-significant relationships with seed yield per plant. Days to maturity (rg = -0.225, rp = -0.208) was the only trait to show a negative but non-significant association with seed yield at both levels.

A significant positive association between seed yield and number of seeds per capsule was also reported by Kante et al. (2022), Maheetha et al. (2025), and Hatkar et al. (2025). The strong positive correlations of yield with 1000-seed weight and number of capsules per plant are supported by the findings of Baraki et al. (2020), Sumathi et al. (2007), Navaneetha et al. (2019), and Shaikh et al. (2024). The significant positive correlation between plant height and seed yield is consistent with the biometrical evaluations reported by Srikanth and Ghodke (2022), Kumar et al. (2022), Gohil et al. (2022), and Hatkar et al. (2025).

For the traits showing positive but non-significant relationships, similar directional associations have been documented in the literature. The positive relationships of capsule length and oil content with seed yield are consistent with the associations observed by Srikanth and Ghodke (2022). The positive trend for number of branches per plant is supported by the correlation findings of Kumar et al. (2022). Additionally, the positive association between days to 50 per cent flowering and seed yield agrees with the character-association analysis conducted by Singh and Bisen (2018). Finally, the negative relationship between days to maturity and seed yield is consistent with similar trends reported by Aye et al. (2024), Disowja et al. (2020), and Kumari and Shah (2023).

Table 1. Analysis of variance (ANOVA) of RBD for ten characters in Sesame (*Sesamum indicum*)

S.O.V	D.F.	DFF	DTM	PH	NBPP	NCPP	NSPC	CL	1000-SW	OC	YPP
Replication	1	2.017	16.017	42.336	0.081	5.34	21.361	0.059	0.005	1.714	0.171
Treatment	29	9.051**	19.334**	146.853**	0.249**	116.267**	426.107**	0.05**	0.04**	24.51**	4.942**
Error	29	1.534	4.465	12.703	0.063	8.065	7.681	0.015	0.011	1.735	0.707

* Indicates significance at 5% level

** Indicates significance at 1% level

DFF = Days to 50% Flowering, DTM = Days to Maturity, PH = Plant Height, NBPP = Number of branches per plant, NCPP = Number of Capsules Per Plant, NSPC = Number of Seeds Per Capsule, CL = Length of Capsule, 1000-SW = 1000 – Seed Weight, OC = Oil Content, YPP = Yield per plant

Table 2. Estimates of genotypic (G) and phenotypic (P) correlations for yield and yield contributing traits in sesame

Sr. No	Name of the Characters		Days to 50% Flowering	Days to Maturity	Plant height (cm)	No. of branches per plant	No. of capsules per plant	No. of seed per capsule	Length of capsule (cm)	1000 seed weight (g)	oil Content (%)	Seed yield per plant (g)
1	Days to 50% Flowering	G	1	0.800**	0.356	0.129	-0.015	0.027	-0.033	0.125	-0.221	0.08
		P	1	0.656**	0.317*	0.145	-0.015	0.026	-0.013	0.129	-0.18	0.118
2	Days to Maturity	G		1	0.226	0.11	-0.091	-0.28	0.004	-0.117	-0.062	-0.225
		P		1	0.182	0.088	-0.077	-0.257*	0.044	-0.163	-0.05	-0.208
3	Plant height (cm)	G			1	0.072	0.289	0.185	0.323	0.308	0.029	0.395*
		P			1	0.054	0.251	0.178	0.327*	0.299*	0.028	0.350**
4	No. of branches per plant	G				1	0.33	-0.134	-0.079	0.106	0.13	0.114
		P				1	0.299*	-0.111	-0.111	0.141	0.112	0.139
5	No. of capsules per plant	G					1	0.07	0.361*	0.391*	0.393*	0.550**
		P					1	0.063	0.275*	0.321*	0.361**	0.491**
6	No. of seed per capsule	G						1	-0.299	0.044	-0.241	0.555**
		P						1	-0.254*	0.043	-0.224	0.519**
7	Length of capsule (cm)	G							1	0.397*	0.358	0.176
		P							1	0.274*	0.270*	0.103
8	1000 seed weight (g)	G								1	0.006	0.684**
		P								1	0.009	0.686**
9	oil Content (%)	G									1	0.081
		P									1	0.062
10	Seed yield per plant (g)	G										1
		P										1

Table 3. Genotypic and phenotypic path analysis for direct and indirect effects of yield components on seed yield in sesame (*Sesamum indicum* L.).

Sr. No	Name of the Characters		Days to 50% Flowering	Days to Maturity	Plant height (cm)	No. of branches per plant	No. of capsules per plant	No. of seed per capsule	Length of capsule (cm)	1000 seed weight (g)	oil Content (%)	Seed yield per plant (g)
1	Days to 50% Flowering	G	-0.00491	0.00201	0.02329	0.00331	-0.0035	0.01418	0.00119	0.07045	-0.02637	0.08
		P	0.0349	0.00542	0.00688	0.00286	-0.0036	0.01256	0.00034	0.0752	-0.01662	0.118
2	Days to Maturity	G	-0.00393	0.00251	0.01479	0.00282	-0.02117	-0.14677	-0.00016	-0.06573	-0.00741	-0.225
		P	0.02288	0.00827	0.00396	0.00173	-0.01829	-0.12629	-0.00119	-0.09479	-0.00461	-0.208
3	Plant height (cm)	G	-0.00175	0.00057	0.06546	0.00183	0.06721	0.09666	-0.01164	0.17301	0.00349	0.395*
		P	0.01105	0.00151	0.02173	0.00107	0.0595	0.08745	-0.00878	0.1741	0.00256	0.350**
4	No. of branches per plant	G	-0.00063	0.00028	0.00469	0.02562	0.0768	-0.07031	0.00284	0.05942	0.01555	0.114
		P	0.00507	0.00073	0.00118	0.0197	0.07071	-0.05444	0.00299	0.08233	0.01032	0.139
5	No. of capsules per plant	G	0.00007	-0.00023	0.01892	0.00846	0.23255	0.03682	-0.01303	0.21933	0.04681	0.550**
		P	-0.00053	-0.00064	0.00546	0.00588	0.23683	0.03099	-0.0074	0.18724	0.03335	0.491**
6	No. of seed per capsule	G	-0.00013	-0.0007	0.01208	-0.00344	0.01635	0.5238	0.01078	0.02498	-0.02873	0.555**
		P	0.00089	-0.00212	0.00386	-0.00218	0.01491	0.49218	0.00683	0.02521	-0.02073	0.519**
7	Length of capsule (cm)	G	0.00016	0.00001	0.02111	-0.00202	0.08396	-0.1565	-0.03609	0.22308	0.04267	0.176
		P	-0.00044	0.00037	0.0071	-0.00219	0.06523	-0.12512	-0.02687	0.15962	0.02491	0.103
8	1000 seed weight (g)	G	-0.00062	-0.00029	0.02018	0.00271	0.09086	0.02331	-0.01434	0.56136	0.00071	0.684**
		P	0.00451	-0.00135	0.00649	0.00278	0.07613	0.0213	-0.00736	0.58248	0.00084	0.686**
9	oil Content (%)	G	0.00109	-0.00016	0.00192	0.00334	0.0913	-0.12621	-0.01291	0.00335	0.11923	0.081
		P	-0.00628	-0.00041	0.0006	0.0022	0.08548	-0.11045	-0.00724	0.00532	0.09239	0.062

Although correlation coefficients provide insight into the associations between yield and its component traits, path coefficient analysis partitions genotypic and phenotypic correlations into direct and indirect effects, thereby providing a clearer indication of how each trait contributes to seed yield.

3.1 Direct Effects on Seed Yield

The value of a trait in a breeding programme is indicated by its direct effect on yield. When a high direct effect corresponds with a strong positive correlation, the trait may be considered a useful selection criterion.

The direct and indirect effects of the different characters on seed yield per plant, as determined through genotypic and phenotypic path analyses, are presented in Table 3.

The 1000-seed weight exerted the highest positive direct effect on seed yield at both the genotypic (0.561) and phenotypic (0.582) levels. The similarity between these direct effects and the corresponding correlation coefficients (G = 0.684, P = 0.686) indicates that seed weight is an important direct contributor to yield in sesame (Baraki et al., 2020; Sumathi et al., 2007; Abate & Mekbib, 2015; Madhu et al., 2023). Number of seeds per capsule exhibited the second-highest positive direct effect (G = 0.523, P = 0.492), indicating that increased seed set within the capsule contributes directly to seed yield per plant (Srikanth & Ghodke, 2022; Ismaila & Usman, 2014; Aye et al., 2024). Number of capsules per plant showed a substantial positive direct effect at both the genotypic (0.232) and phenotypic (0.236) levels, highlighting the importance of sink capacity, as a greater number of capsules contributes directly to higher productivity (Sumathi et al., 2007; Abate & Mekbib, 2015; Navaneetha et al., 2019; Kumar & Vivekanandan, 2009; Biabani & Pakniyat, 2008; Elareny et al., 2025).

Oil content (G = 0.119), plant height (G = 0.065), and number of branches per plant (G = 0.025) had low positive direct effects. In contrast, capsule length (G = -0.036), days to 50% flowering (G = -0.004), and days to maturity (G = 0.002) had negligible direct effects, suggesting that these traits may have limited direct influence on yield (Aye et al., 2024; Singh & Bisen, 2018).

3.2 Indirect Effects via Other Traits

Path analysis helps reveal how traits that appear important because of their correlations with yield may influence yield indirectly through other traits.

Plant height had a significant positive correlation with yield at the genotypic level (G = 0.395), but its direct effect was low (0.065). Path analysis showed that the association between plant height and yield was primarily attributable to positive indirect effects through 1000-seed weight (0.173), number of seeds per capsule (0.096), and number of capsules per plant (0.067). This pattern suggests that taller plants may support more capsules and improved seed filling, rather than plant height itself directly determining yield (Kumar et al., 2022; Gnanasekaran et al., 2008; Umamaheswari et al., 2019; Sumathi & Muralidharan, 2010; Kumar et al., 2024).

Although number of capsules per plant had a strong direct effect, its total correlation with yield (G = 0.550) was strengthened by a positive indirect effect through 1000-seed weight (0.219). This finding indicates a positive relationship between capsule number and seed weight in the evaluated germplasm, as plants producing more capsules also tended to produce heavier seeds (Satankar et al., 2019; Ismaila & Usman, 2014; Elareny et al., 2025; Kumar et al., 2024).

4. Conclusion

The evaluation of 30 sesame genotypes revealed significant genetic variability for all ten quantitative traits, indicating adequate scope for selection within the studied material. Seed yield per plant was positively and significantly associated with 1000-seed weight, number of seeds per capsule, number of capsules per plant, and plant height at both genotypic and phenotypic levels. Path coefficient analysis clarified that 1000-seed weight exerted the greatest positive direct effect on seed yield, followed by number of seeds per capsule and number of capsules per plant. Although plant height was positively correlated with yield, its contribution was largely indirect through seed weight, seed number, and capsule number. These results suggest that simultaneous selection for 1000-seed weight, number of seeds per capsule, and number of capsules per plant may support the identification of higher-yielding sesame genotypes. However, the findings were obtained from a single-season, single-location experiment with two replications. Consequently, multi-environment testing across seasons and locations is necessary to determine the stability of these trait associations and to confirm their value as selection criteria in sesame breeding programmes.

5. Limitation

The experiment was conducted at one location during a single season with only two replications, limiting assessment of genotype-by-environment interactions and the broader applicability of the results. Correlation and path coefficient analyses describe statistical associations and partitioned effects but do not establish biological causation. The identified selection traits should therefore be validated using additional replications and multi-season, multi-location trials before being regarded as stable criteria for sesame improvement.

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Declaration of AI Use

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Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

Competing Interests

Authors have declared that no competing interests exist.

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