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CORRELATION AND PATH ANALYSIS FOR SEED YIELD AND ITS COMPONENT TRAITS IN INDIAN MUSTARD (*BRASSICA JUNCEA* L. CZERN AND COSS.)

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ABSTRACT

This study examined the interrelationships among yield components and their direct and indirect effects on seed yield in Indian mustard. Thirty-six genotypes were evaluated using a randomized complete block design with three replications across 13 traits. The analysis revealed significant genetic variation among the genotypes, with minimal environmental influence, indicating consistent performance across treatments. The analysis of variance demonstrated significant differences for all traits. The genotypic and phenotypic correlations indicated that traits such as the number of siliquae on the main shoot, total siliqua per plant, seeds per siliqua, siliqua length, siliqua beak length, test weight, and harvest index all positively correlated with seed yield per plant. Furthermore, path coefficient analysis showed that test weight, total siliqua per plant, seeds per siliqua, harvest index and plant height had positive direct effects on seed yield. Therefore, these traits should be prioritized for selection and breeding to enhance seed yield in mustard genotypes.

Key words : Indian mustard, Correlation coefficient, Genotype, Path analysis.

Introduction

Mustard (*Brassica* spp.) is one of the primary oilseeds crops globally, especially important in South Asia, Europe, and North America, contributing significantly to edible oil production and serving as an essential income source for farmers and agricultural industries (Sharma *et al.*, 2016; Singh *et al.*, 2018). With an oil content ranging from 35-40%, mustard is valued for its high-quality oil, which is rich in unsaturated fatty acids, making it beneficial for human health and increasingly relevant in food security and agricultural sustainability efforts (Kumar *et al.*, 2020). As global demands for edible oil rise, breeding high-yielding and quality-improved mustard varieties has become crucial for meeting these needs (Verma *et al.*, 2017). Understanding the genetic relationships among traits that contribute to yield is fundamental for effective selection in breeding programs. Correlation analysis helps breeders identify associations between yield and yield-contributing traits, such as plant height, seed yield, days to flowering, and oil content, facilitating indirect selection for yield improvement (Yadava *et al.*, 2015). However, correlation coefficients alone do not distinguish direct effects from indirect effects among traits, which can lead to biased selection if the interactions are not well-understood (Dixit *et al.*, 2019). To address this, path analysis provides a deeper insight by breaking down correlation coefficients into direct and indirect effects, allowing researchers to discern which traits directly influence yield and which exert their effects indirectly through other traits (Ali *et al.*, 2021). This approach has proven invaluable in identifying the most critical selection traits in mustard breeding programs (Patel and Chauhan, 2019). By integrating both correlation and path analysis, breeders can prioritize traits that significantly impact yield and establish selection criteria that are more effective and targeted. While studies on yield-related traits in mustard exist, limited research has combined correlation and path analysis to explore these relationships comprehensively. This study aims to fill this gap by applying both analytical methods to a diverse set of mustard genotypes, offering insights that can enhance selection efficiency and contribute to developing high-yielding mustard cultivars capable of thriving under varying environmental conditions.

Materials and Methods

In this study, thirty-six Indian mustard (*Brassica juncea* L.) genotypes were evaluated using a randomized block design (RBD) with three replications. Each genotype was planted in a plot size of 1.5 × 3 meters, with a spacing of 30 cm between rows and plants. The experiment was conducted at the Agricultural Research Farm, Santiniketan, Department of Genetics and Plant Breeding, Palli Siksha Bhavana, Visva-Bharati University, Birbhum, over two consecutive rabi seasons (2017-18 and 2018-19). Standard recommended agricultural practices were followed to ensure optimal crop growth. Data were collected on thirteen quantitative traits, including days to 50% flowering, plant height, number of primary and secondary branches per plant, days to maturity, number of siliquae on the main shoot, total number of siliquae per plant, number of seeds per siliqua, siliqua length, siliqua beak length, test weight, harvest index and seed yield per plant. Statistical analyses were performed using the INDOSTAT version 9.2 software, based on the mean values of each trait for each genotype. Correlations at both genotypic and phenotypic levels were calculated from the analysis of variance and covariance, following Searle's (1961) methodology. The genotypic and phenotypic correlations obtained from the thirty-six genotypes were further analyzed using path analysis, as per Wright (1921) and expanded by Dewey and Lu (1959). Seed yield per plant was designated as the dependent variable in the path analysis, while all other observed traits served as independent variables.

Results and Discussion

The analysis of variance revealed significant differences among the thirty-six genotypes for all thirteen quantitative traits (Table 1). The estimates of genotypic and phenotypic correlation coefficients (Table 1) indicated that genotypic correlation coefficients were consistently higher than their phenotypic counterparts. This suggests a strong inherent association among the various traits, with the environmental factors exerting less influence on the phenotypic expression of these correlations in Indian mustard. Similar observations have been reported by Kumar and Pandey (2013), Shrivastava *et al*. (2023), and Choudhary *et al*. (2023).

In the genotypic correlation analysis (Table 2; Fig. 1 a & b), the strongest correlation was found between seed yield per plant and test weight (0.656), followed by a significant correlation with the number of secondary branches per plant (0.436). Additional correlations included seed yield per plant and the number of siliqua on the main shoot (0.323), seed yield per plant and siliqua length (0.310), seed yield per plant and harvest index (0.288), and seed yield per plant and total number of siliqua per plant (0.255).

The phenotypic correlation values (Table 3; Fig. 2a & b) were generally lower than the genotypic

Table 1 : Analysis of variance for thirteen mustard characters.

Source of variations	Replication	Environments	Interactions	Overall Sum	Treatments	Error
df	**2**	**1**	**2**	**5**	**35**	**175**
Days to 50% flowering	16.320	13.500**	1.293	9.745	132.019***	16.252
Plant height (cm)	367.853	19.542***	0.402	151.210	929.699***	353.567
Primary branch per plant	228.949	32.589***	0.063	98.123	1029.771***	174.033
Secondary branch per plant	0.006	116.454***	0.001	23.294	3.039***	0.487
Days to Maturity	0.000	0.346***	0.012	0.074	1.705***	0.238
No. of siliqua on main shoot	5.160	85.277***	3.930	20.691	59.162***	10.806
Total no. of siliqua per plant	104.633	64.419	270.137*	162.792	591.744***	67.569
No. of seed per siliqua	0.734	8.089***	0.514	2.117	2.341**	1.307
Siliqua Length (cm)	0.011	0.024*	0.006	0.011	0.675***	0.076
Siliqua Beak length (cm)	0.000	0.021***	0.000	0.004	0.152***	0.023
Test weight	0.010	1.830***	0.000	0.370	4.006***	0.025
Harvest index	1.386	183.283***	0.002	37.212	11.362***	4.974
Seed yield per plant (gm)	0.587	25.737***	0.002	5.383	2.442***	0.642

*, ** and *** = Significant at 5 %, 1 % and 0.001 levels, respectively.

Table 2 : Genotypic correlations among 13 different traits of mustard.

	DFF	PH	PB	SB	DM	NSMS	TNSPP	NSPS	SL	SBL	TW	HI	SYPP
DFF		0.496***	-0.0187	-0.152*	0.370***	0.135*	0.0598	-0.511***	-0.1231	0.0816	-0.0415	-0.368	-0.216***
PH			-0.247***	0.200***	0.417***	0.536***	0.197***	-0.180**	0.174*	0.240***	0.247***	-0.531***	0.102
PB				-0.245***	0.307***	-0.159*	0.0562	-0.706***	0.171*	0.184**	0.3008	0.149*	-0.0425
SB					-0.063	0.288***	-0.0516	0.330***	-0.305***	-0.143*	0.185**	0.332***	0.436***
DM						-0.061	0.367***	0.0696	-0.103	-0.325***	-0.264***	-0.375***	0.0415
NSMS							-0.0557	0.051	-0.198***	-0.0837	0.322***	-0.158*	0.323***
TNSPP								0.179**	0.0529	-0.294***	-0.448***	-0.503***	0.255***
NSPS									0.530***	0.0409	-0.0813	-0.1122	0.0992
SL										0.550***	0.342***	0.156*	0.310***
SBL											0.475***	0.344***	0.178**
TW												0.558***	0.656***
HI													0.288***

Table 3 : Phenotypic correlations among 13 different traits of mustard.

	DFF	PH	PB	SB	DM	NSMS	TNSPP	NSPS	SL	SBL	TW	HI	SYPP
DFF		0.6768 ***	0.4515 ***	-0.063	0.1713 *	0.3865***	0.0922	0.3245***	-0.0574	0.0453	-0.0287	-0.0498	0.379***
PH			0.4882 ***	0.1392 *	0.2816 ***	0.5512***	0.1720 *	0.4493***	0.2218 **	0.1568 *	0.1154	-0.0979	0.640***
PB				-0.1264	0.1454 *	0.2166 **	0.1449 *	0.2505***	0.0889	0.0723	0.1949 **	0.1508 *	0.550***
SB					0.1301	0.2083 **	-0.128	0.0643	-0.0803	-0.0886	0.1151	-0.0296	0.197***
DM						0.0181	0.2239***	0.0229	0.1298	-0.1653 *	-0.1831 **	-0.3405***	-0.0038
NSMS							-0.0902	0.4708***	-0.0216	0.0009	0.2039 **	-0.2084 **	0.460***
TNSPP								-0.0123	0.0277	-0.1875 **	-0.3369***	-0.0382	0.244***
NSPS									0.2225***	0.0259	-0.0312	-0.0659	0.466***
SL										0.4677***	0.2520***	-0.049	0.163*
SBL											0.4006***	0.1412 *	0.140*
TW												0.2676***	0.372***
HI													0.258***

*, ** and *** = Significant at 5 %, 1 % and 0.001 levels, respectively.

DFF: Days to 50% Flowering, PH: Plant height (cm), PB: Primary Branch per plant, SB: Secondary Branch per plant, DM: Days to Maturity, NSMS: No. of Siliqua on main Shoot, TNSPP: Total no. of siliqua per plant, NSPS: No. of Seed per Siliqua, SL: Siliqua Length (cm), SBL: Siliqua Beak Length (cm), TW: Test weight, HI: Harvest Index, SYPP: Seed yield per plant (gm)

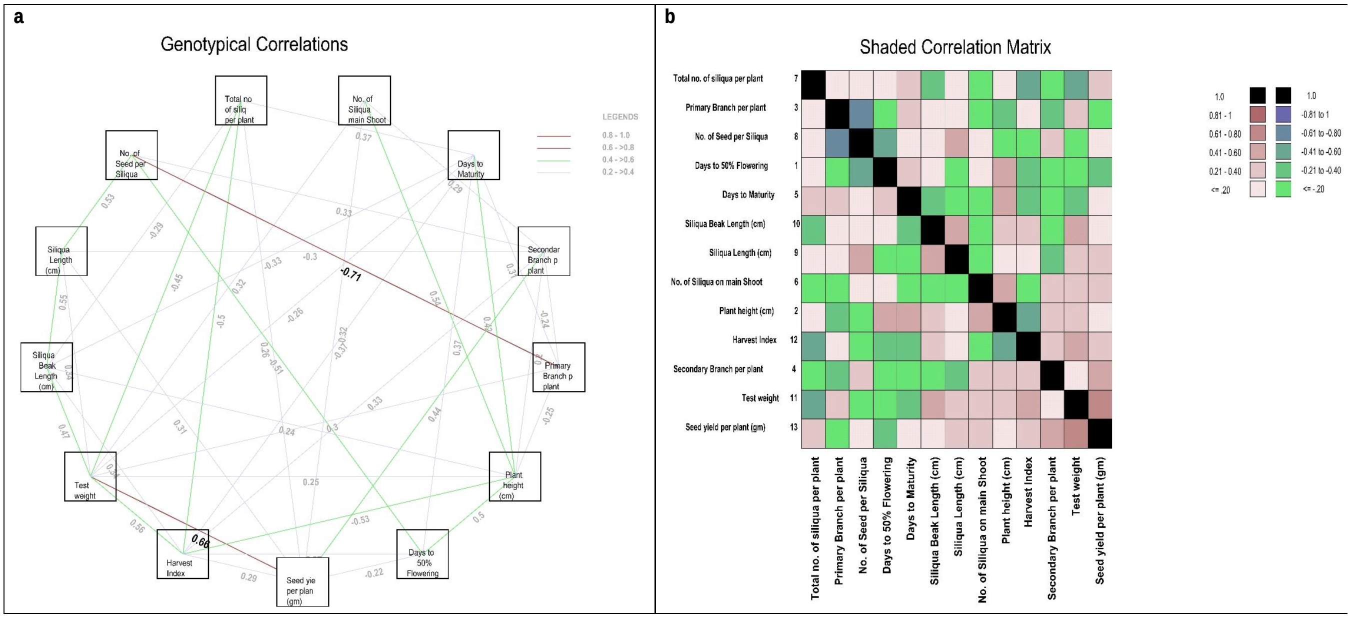

Figure 1 : a) Genotypic correlations matrix and b) shaded correlation matrix among 13 different traits of mustard.

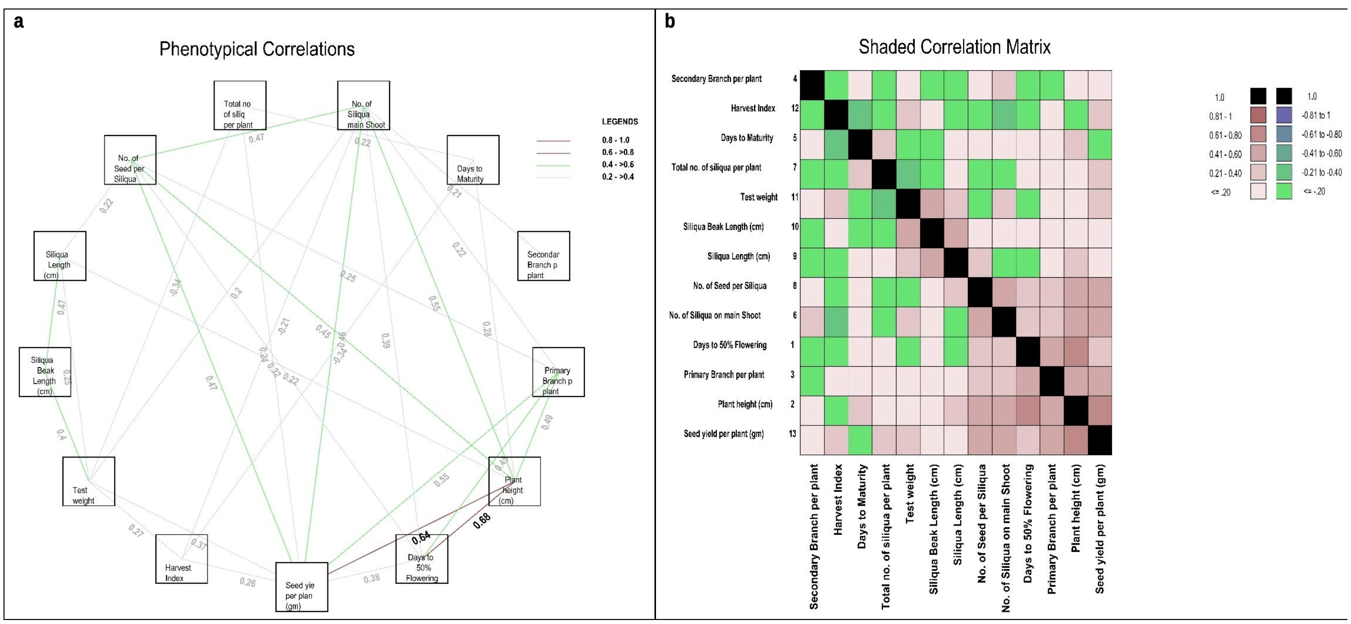

Fig. 2 : a) Phenotypic correlations matrix and b) shaded correlation matrix among 13 different traits of mustard.

correlations. The highest phenotypic correlation was observed between seed yield per plant and plant height (0.640), followed by correlations with the number of primary branches per plant (0.550), number of seeds per siliqua (0.466), number of siliqua on the main shoot (0.460), days to 50% flowering (0.460), test weight (0.372), harvest index (0.258), and number of secondary branches per plant (0.197).

Research indicates that several traits, including the number of siliqua on the main shoot, total number of siliqua per plant, number of seeds per siliqua, siliqua length (cm), siliqua beak length (cm), test weight, and harvest index, exhibit positive correlations at both phenotypic and genotypic levels. These traits should be prioritized in selection efforts aimed at improving seed yield per plant, as they significantly influence yield outcomes. Supporting studies conducted by Singh *et al.* (2011), Shekhawat *et al.* (2014), Begum *et al.* (2018), Kumar *et al.* (2019), Choubey *et al.* (2022) and Gupta *et al.* (2022) reinforce these findings, aligning with existing literature.

In conducting a path coefficient analysis, seed yield per plant was designated as the dependent variable, while the remaining twelve traits—including days to 50% flowering, plant height (cm), primary branches per plant, secondary branches per plant, days to maturity, number of siliqua on the main shoot, total number of siliqua per

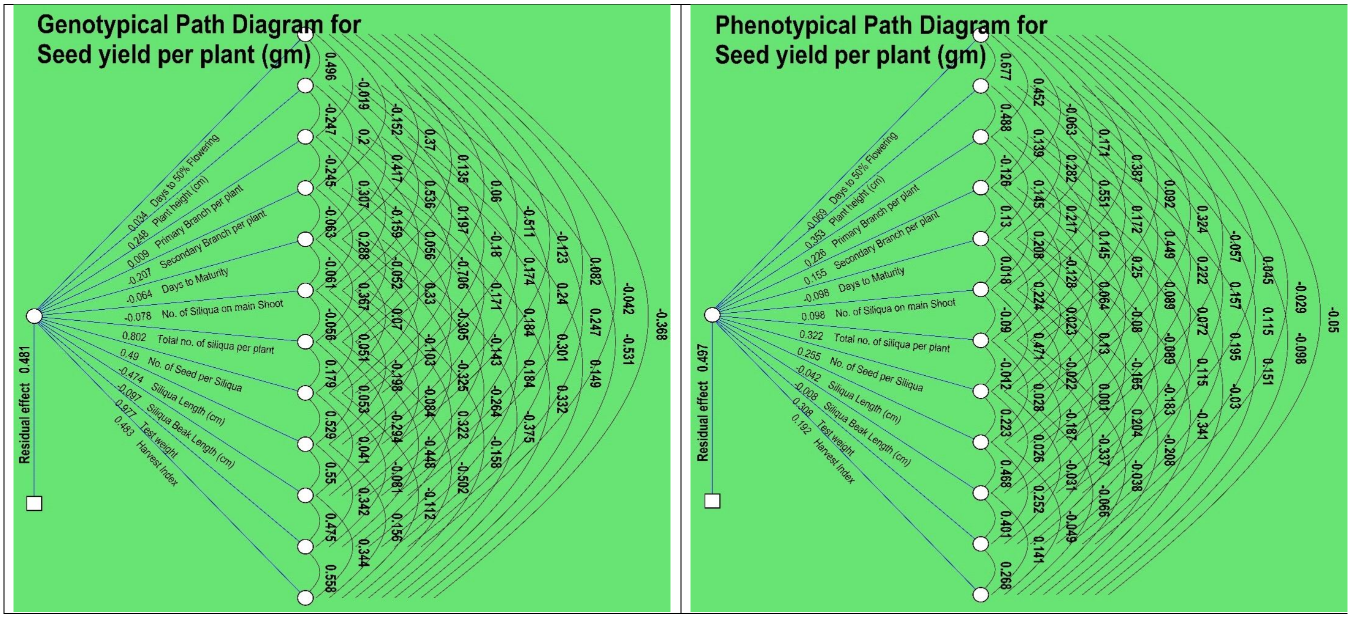

Fig. 3 : Path diagram of Direct (diagonal) and indirect effects of yield components on seed yield per plant at a) Genotypic and, b) Phenotypic level in mustard genotypes.

plant, number of seeds per siliqua, siliqua length (cm), siliqua beak length (cm), test weight, and harvest index—served as independent variables. The results of this analysis, which include the direct and indirect effects of different traits, are summarized in Tables 3 and 4. The minimal direct effects observed for the other characters indicate their negligible contributions to seed yield per plant.

At the genotypic level (Table 5 and Fig. 3a), the traits with the most significant direct positive effect on seed yield per plant were test weight (0.9772), total number of siliqua per plant (0.8023), number of seeds per siliqua (0.4896), harvest index (0.4832) and plant height (0.2485). Conversely, the traits exerting the highest negative direct effects included siliqua length (-0.4735), secondary branches per plant (-0.2073), siliqua beak length (-0.0973), number of siliqua on the main shoot (-0.0776) and days to maturity (-0.0644).

The analysis also revealed several traits that exerted a high indirect positive effect on seed yield per plant at the genotypic level. For instance, plant height positively influenced seed yield via test weight (0.2414), while the number of siliqua on the main shoot had a similar effect through test weight (0.3143). Additionally, the siliqua length (0.3341) and siliqua beak length (0.4638) also positively impacted seed yield through test weight, and the harvest index contributed positively as well (0.1661). On the other hand, indirect negative effects were observed with days to 50% flowering impacting the number of seeds per siliqua (-0.2503), plant height affecting the harvest index (-0.2564) and primary branches per plant negatively influencing the number of seeds per siliqua (-0.3456).

At the phenotypic level, the traits with the highest direct positive effects on seed yield per plant included plant height (0.3526), total number of siliqua per plant (0.3218), test weight (0.3078), number of seeds per siliqua (0.2547) and primary branches per plant (0.2261). In contrast, the highest negative direct effect on seed yield was observed for days to maturity (-0.0417), followed by days to 50% flowering (-0.0687), siliqua length (-0.0417) and siliqua beak length (-0.0082).

The analysis also identified various traits exhibiting high indirect positive effects on seed yield per plant at the phenotypic level (Table 4 and Fig. 3b), For example, days to 50% flowering had a positive influence through plant height (0.2386) and number of seeds per siliqua (0.0826). Plant height also positively affected the number of seeds per siliqua (0.1144) and primary branches per plant (0.1104). Other notable indirect positive effects included the total number of siliqua per plant via plant height (0.0606) and the number of seeds per siliqua via plant height (0.1584).

In contrast, high indirect negative effects on seed yield per plant at the phenotypic level were associated with test weight negatively influencing the total number of siliqua per plant (-0.1084), while days to maturity negatively affected the harvest index (-0.2564). Moreover, other traits such as primary branches per plant via the number of seeds per siliqua (-0.3456) and days to maturity via test weight (-0.0563) also exhibited negative impacts.

Table 4 : Direct (diagonal) and indirect effects of yield components on seed yield per plant at phenotypic level in mustard genotypes.

	DFF	PH	PB	SB	DM	NSMS	TNSPP	NSPS	SL	SBL	TW	HI	SYPP
DFF	**-0.0687**	-0.0465	-0.031	0.0043	-0.0118	-0.0265	-0.0063	-0.0223	0.0039	-0.0031	0.002	0.0034	0.379***
PH	0.2386	**0.3526**	0.1721	0.0491	0.0993	0.1943	0.0606	0.1584	0.0782	0.0553	0.0407	-0.0345	0.640***
PB	0.1021	0.1104	**0.2261**	-0.0286	0.0329	0.049	0.0328	0.0566	0.0201	0.0163	0.0441	0.0341	0.550***
SB	-0.0098	0.0216	-0.0197	**0.1555**	0.0202	0.0324	-0.0199	0.01	-0.0125	-0.0138	0.0179	-0.0046	0.197***
DM	-0.0169	-0.0277	-0.0143	-0.0128	**-0.0984**	-0.0018	-0.022	-0.0023	-0.0128	0.0163	0.018	0.0335	-0.0038
NSMS	0.0378	0.0539	0.0212	0.0204	0.0018	**0.0978**	-0.0088	0.0461	-0.0021	0.0001	0.02	-0.0204	0.460***
TNSPP	0.0297	0.0554	0.0466	-0.0412	0.0721	-0.029	**0.3218**	-0.004	0.0089	-0.0603	-0.1084	-0.0123	0.244***
NSPS	0.0826	0.1144	0.0638	0.0164	0.0058	0.1199	-0.0031	**0.2547**	0.0567	0.0066	-0.0079	-0.0168	0.466***
SL	0.0024	-0.0092	-0.0037	0.0033	-0.0054	0.0009	-0.0012	-0.0093	**-0.0417**	-0.0195	-0.0105	0.002	0.163*
SBL	-0.0004	-0.0013	-0.0006	0.0007	0.0014	0	0.0015	-0.0002	-0.0039	**-0.0082**	-0.0033	-0.0012	0.140*
TW	-0.0088	0.0355	0.06	0.0354	-0.0563	0.0628	-0.1037	-0.0096	0.0776	0.1233	**0.3078**	0.0823	0.372***
HI	-0.0096	-0.0188	0.0289	-0.0057	-0.0653	-0.04	-0.0073	-0.0126	-0.0094	0.0271	0.0513	**0.1918**	0.258***
SYPP	0.3792	0.6403	0.5495	0.1969	-0.0038	0.4598	0.2444	0.4656	0.1631	0.14	0.3715	0.2575	
Partial R^2	-0.026	0.2258	0.1242	0.0306	0.0004	0.045	0.0786	0.1186	-0.0068	-0.0012	0.1143	0.0494	

Residual effect = 0.4970

Table 5 : Direct (diagonal) and indirect effects of yield components on seed yield per plant at Genotypic level in mustard genotypes.

	DFF	PH	PB	SB	DM	NSMS	TNSPP	NSPS	SL	SBL	TW	HI	SYPP
DFF	**0.0337**	0.0167	-0.0006	-0.0051	0.0125	0.0045	0.002	-0.0172	-0.0041	0.0027	-0.0014	-0.0124	-0.216***
PH	0.1232	**0.2484**	-0.0613	0.0498	0.1036	0.1331	0.0489	-0.0447	0.0432	0.0595	0.0614	-0.1318	0.102
PB	-0.0002	-0.0023	**0.0095**	-0.0023	0.0029	-0.0015	0.0005	-0.0067	0.0016	0.0017	0.0029	0.0014	-0.0425
SB	0.0315	-0.0415	0.0507	**-0.2073**	0.013	-0.0597	0.0107	-0.0683	0.0632	0.0296	-0.0382	-0.0688	0.436***
DM	-0.0238	-0.0269	-0.0198	0.0041	**-0.0644**	0.0039	-0.0236	-0.0045	0.0066	0.021	0.017	0.0241	0.0415
NSMS	-0.0105	-0.0416	0.0123	-0.0224	0.0047	**-0.0776**	0.0043	-0.004	0.0154	0.0065	-0.025	0.0122	0.323***
TNSPP	0.048	0.158	0.0451	-0.0414	0.2941	-0.0447	**0.8023**	0.1434	0.0424	-0.2356	-0.3597	-0.4031	0.255***
NSPS	-0.2503	-0.0881	-0.3456	0.1614	0.0341	0.025	0.0875	**0.4896**	0.2592	0.02	-0.0398	-0.055	0.0992
SL	0.0583	-0.0824	-0.0808	0.1444	0.0488	0.0938	-0.025	-0.2507	**-0.4735**	-0.2604	-0.1619	-0.0737	0.310***
SBL	-0.0079	-0.0233	-0.0179	0.0139	0.0316	0.0081	0.0286	-0.004	-0.0535	**-0.0973**	-0.0462	-0.0334	0.178**
TW	-0.0406	0.2414	0.294	0.1802	-0.2584	0.3143	-0.4381	-0.0794	0.3341	0.4638	**0.9772**	0.5451	0.656***
HI	-0.1778	-0.2564	0.072	0.1604	-0.1811	-0.0763	-0.2428	-0.0542	0.0753	0.1661	0.2695	**0.4832**	0.288***
SYPP	-0.2164	0.102	-0.0425	0.4356	0.0415	0.323	0.2553	0.0992	0.3099	0.1776	0.6559	0.2879	
Partial R^2	-0.0073	0.0253	-0.0004	-0.0903	-0.0027	-0.0251	0.2048	0.0486	-0.1467	-0.0173	0.6409	0.1391	

Residual effect = 0.4807

A positive association between desirable traits is highly beneficial, enabling the concurrent development of multiple advantageous characteristics. Conversely, a negative correlation may hinder the simultaneous expression of several high-value traits, necessitating trade-offs or compromises. These findings are consistent with previous studies by Singh *et al*. (2010), Lodhi *et al*. (2014), Dipti and Priyanka (2016), Kumar *et al*. (2016), Roy (2018), Yadav *et al*. (2021) and Dwivedi *et al*. (2023). This study enhances our understanding of the relationships among yield-related traits within genotypes, clarifying the contributions of each trait to overall yield.

Conclusion

The correlation analyses revealed strong positive associations between seed yield per plant and several key traits, including the number of siliqua on the main shoot, total siliqua per plant, seeds per siliqua, siliqua length, siliqua beak length, test weight and harvest index at both genotypic and phenotypic levels. These findings align with prior research, underscoring the relevance of these traits in determining yield in Indian mustard. Path coefficient analysis further clarified the direct and indirect contributions of these traits to seed yield per plant, highlighting test weight, total siliqua per plant, seeds per siliqua, harvest index and plant height as primary contributors. Notably, high path coefficient values for these traits suggest substantial direct effects on yield, marking them as crucial selection targets in breeding programs aimed at yield enhancement.

Additionally, traits like average siliqua length and seeds per siliqua, while less commonly emphasized in breeding, exhibited notable direct effects on seed yield per plant, suggesting their potential value in selection criteria. Identifying these secondary traits as important for yield determination presents new possibilities for breeding strategies, potentially fostering more comprehensive approaches to yield improvement.

Overall, this study advances our understanding of the complex relationships among agronomic traits influencing yield in Indian mustard. By identifying traits with significant direct and indirect effects on yield, breeders can prioritize these traits to develop high-yielding varieties. Furthermore, these findings offer valuable insights for future research focused on optimizing yield potential and productivity in Indian mustard.

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