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Rajendra Kumar
Department of Genetics and Plant Breeding, Bundelkhand University, Jhansi, Uttar Pradesh, India

Ashok Kumar
Department of Genetics and Plant Breeding, Bundelkhand University, Jhansi, Uttar Pradesh, India

Tarkeshwar
Department of Genetics and Plant Breeding, Acharya Narendra Deva University of Agriculture and Technology, Ayodhya, Uttar Pradesh, India

Dheerendra Kumar
Department of Soil Science and Agriculture Chemistry, Acharya Narendra Deva University of Agriculture and Technology, Ayodhya, Uttar Pradesh, India

Corresponding Author:
Tarkeshwar
Department of Genetics and Plant Breeding, Acharya Narendra Deva University of Agriculture and Technology, Ayodhya, Uttar Pradesh, India

Assessment of correlation and path coefficients for yield and its attributing traits in Indian mustard [*Brassica juncea* (L.) Czern & Coss.]

Rajendra Kumar, Ashok Kumar, Tarkeshwar and Dheerendra Kumar

Abstract
India is the second largest rapeseed–mustard cultivating country in the world after China and third in production after China and Canada, rapeseed-mustard holds a prominent place in the country's economy. The present investigation has been carried out to study the inter-relationships and direct and indirect effects of yield contributing traits toward seed yield. The experiment was carried out at the Research Farm, Institute of Agriculture Science, Bundelkhand University, Jhansi (UP). The experimental material comprising 100 treatments *viz*., (10 parents + 45 F_1's + 45 F_2's) were evaluated in Randomized Block Design with three replications during *rabi* 2021- 2022. The observations were taken for fourteen metric traits. Seed yield/plant exhibited a positive highly significant association at genotypic level with harvest index followed by number of siliquae/plant, leaf area index, biological yield/plant, number of seeds/siliqua, number of secondary branches/plant, 1000-seed weight, plant height, number of primary branches/plant, days to maturity in F_1's as well as F_2's. The path coefficient revealed that the harvest-index followed by biological yield/plant and leaf area index were the highest direct contributors in seed yield while, harvest index exhibited high order of positive indirect effects on seed yield/plant *via* number of siliquae/plant followed by leaf area index, number of seeds/siliqua and 1000-seeds weight in both the generations.

Keywords: Indian mustard, *Brassica juncea*, correlation coefficient, path coefficient, direct and indirect effect

Introduction
Brassica juncea (L.) Czern & Coss (AABB) is the second most important edible oilseed crop in India after the soybean (Saroj *et al*., 2021) [13]. Cytological studies have revealed that *B. juncea* is a natural allotetraploid or amphidiploid (2n=36), of two diploid species *viz*., *Brassica rapa* (also known as *Brassica campestris*) (AA) (2n=20) and *Brassica nigra* (BB) followed by natural chromosome doubling (2n=16) (Tomar *et al*., 2017; Tarkeshwar *et al*., 2022) [19, 18]. The species has probably evolved in the Middle East, where its putative diploid progenitors are sympatric (Prakash and Hinata, 1980; Singh *et al*., 2022) [8, 16].
India is the second-largest rapeseed–mustard-cultivating country in the world after China and third in production after China and Canada (Kumari *et al*., 2019) [5]. During 2018–2019, rapeseed–mustard was cultivated over an area of 5.96 million hectares with production and productivity of 8.32 million tons and 1,397 Kg/ha, respectively in India (Directorate of Economics & Statistics, and Dac&Fw., 2019) [2].
The yield of any crop is a complex trait and thus is highly influenced by various environmental factors. So, selecting superior genotypes among a large set of genotypes based on their arithmetic mean performance may influence the accuracy (Piepho *et al*., 2008) [7]. Additionally, the yield of a crop is also influenced by various yield contributing characters like plant height, primary and secondary branches per plant, length of main raceme, length of siliqua, seeds per siliqua, etc. (Saroj *et al*., 2021) [13]. Thus, improvement in seed yield is challenging to achieve by direct selection (Singh *et al*., 2022) [16]. Hence, plant breeders often focus on the selection of such traits in combination, each of which was assigned to have a certain level of economic weight based on their importance toward seed yield to form a selection index (Smith, 1936; Hazel, 1943) [17, 3]. Path analysis is useful in the selection of characters that have direct and indirect effects on yield. Thus, the present investigation has been conducted to estimate the extent of inter-relationships among various traits in Indian mustard.

Materials and Methods

Experimental Details

The experiment was carried out at the Research Farm, Institute of Agriculture Science, Bundelkhand University, Jhansi (UP). The basic material in the present investigation comprised ten varieties/strains of Indian mustard namely, Urvashi, Azad Mahak, R.H.30, Pusa Mustard-25, Kranti, Pusa Mahak-7, NDR-8501, Bio-902, CS-52 and NRCDR-2 were taken from the germplasm maintained at Oilseed Section, Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.). Ten genetically diverse genotypes of Indian mustard were subjected to diallel fashion mating design (excluding reciprocals) was attempted during *rabi* 2019–2020. The F_1 seeds of 45 crosses were advanced during the Rabi season of 2020-2021 to raise the F_1's and were selfed in order to obtain F_2's seeds. The parents were also maintained through selfing. The experimental material comprising 100 treatments *viz*., (10 parents + 45 F_1's + 45 F_2's) were evaluated in RBD with three replications during *rabi* 2021- 2022. Each parent, F_1's and F_1's planted in one row of 5m long 45cm apart; plant to plant distance was maintained 15cm by thinning. All the recommended packages of practices were adopted for raising a good crop.

Observations Recorded

Five competitive plants in parents, F_1's as well as F_2's were taken randomly for each treatment in each replication and tagged for recording fourteen quantitative traits *viz*., days to 50% flowering, days to maturity, leaf area index (cm^2), plant height (cm), number of primary branches per plant, number of secondary branches per plant, length of main raceme (cm), number of siliquae on main raceme, number of seeds per siliqua, biological yield per plant (g), harvest index (%), 1000-seed weight (g), oil content (%) and seed yield per plant (g).

Statistical Analyses

This data was undertaken to estimate the extent of the Correlation coefficient and direct and indirect effects of yield attributing traits on seed yield as suggested by Searle (1961) [14] and Dewey and Lu (1959) [1], respectively.

Results and Discussion

Correlation Coefficient Analysis

Estimates of phenotypic and genotypic correlation coefficients between all possible pairs among all the 14 characters separately for parents + F_1's and parents + F_2's were computed. The results are presented in Tables 1 & 2.

The phenotypic correlation coefficients and genotypic correlation coefficients for 14 traits were analyzed in the 45 cross combinations along with parents in both generations. Differences in magnitude as well as in direction were observed for different traits. However, both genotypic correlation coefficient and phenotypic correlation coefficient exhibited similar signs with few exceptions. In general, both positive and negative character associations were observed among different traits. Further, it was also observed that the estimates of the genotypic correlation coefficient were higher than the corresponding phenotypic correlations in most of the cases.

Parents + F_1's

Seed yield/plant exhibited positive highly significant association at genotypic level with harvest index (0.839) followed by number of siliquae/plant (0.738), leaf area index (0.627), biological yield/plant (0.568), number of seeds/siliqua (0.510), number of secondary branches/plant (0.439), 1000-seed weight (0.380), plant height (0.265), number of primary branches/plant (0.243), days to maturity (0.204), while it did not show significant negative association with any trait. Previously, Singh *et al*. (2022) [16] also observed similar results with primary branches per plant, secondary branches per plant, siliquae per plant, biological yield per plant, harvest index, test weight and oil content.

Highly significant and positive correlations were recorded between days to 50% flowering with days to maturity (0.773) followed by plant height (0.517), number of siliquae/plant (0.418), harvest index (0.224) and leaf area index (0.186), whereas, non-significant and positive correlation with test weight. While, significant and negative correlation was recorded with biological yield/plant (-0.196) followed by oil content (-0.215). Days to maturity showed highly significant positive correlation with plant height (0.663) followed by number of siliquae/plant (0.450), harvest index (0.313), and leaf area index (0.276). It had significant negative correlation with oil content (-0.194).

Plant height exhibited positive highly significant association at genotypic level with number of siliquae/plant (0.525) followed by leaf area index (0.405), harvest index (0.206) and biological yield per plant (0.192). It did not show any significant negative correlation with any trait. Highly significant and positive correlations were recorded between length of main raceme with number of primary branches/plant (0.634) followed by number of secondary branches/plant (0.628), number of seeds/siliqua (0.507), 1000-seed weight (0.442), leaf area index (0.379), and harvest index (0.154). It showed negatively and significant association with oil content (-0.805). Leaf area index showed positive and highly significant correlation with number of primary branches/plant (0.625), number of secondary branches/plant (0.882), number of siliquae/plant (0.641), number seeds/siliqua (0.750), 1000-seed weight (0.392), biological yield/plant (0.460) and harvest index (0.460).

Number of primary branches/plant exhibited positive highly significant association at genotypic level with number of secondary branches/plant (0.806), number of siliquae/plant (0.300), number seeds/siliqua (0.684), 1000-seed weight (0.511), biological yield/plant (0.301) respectively and negative association with oil content (-0.433). It was non-significant positive correlation with harvest index. Highly significant and positive correlations were recorded between number of secondary branches/plant with number of siliquae/plant (0.545), number seeds/siliqua (0.803), 1000-seed weight (0.615), biological yield/plant (0.466) and harvest index (0.223) respectively. It was significant negative correlation with oil content (-0.382).

Number of siliquae/plant exhibited positive highly significant association at genotypic level with number seeds/siliqua (0.622), 1000-seed weight (0.513), biological yield/plant (0.542) and harvest index (0.548) respectively. It was significant negative correlation with oil content (-0.325). Number of seeds/siliqua showed highly significant and positive correlation with 1000-seed weight (0.799) followed by biological yield/plant (0.478) and harvest index (0.293)

respectively. It had significant negative correlation with oil content (-0.510). 1000-seeds weight showed positive and highly significant correlation with biological yield/plant (0.346) and harvest index (0.247) respectively. While, significant negative associated with oil content (0.447). Biological yield/plant showed highly significant and positive correlation with oil content (0.262). While, harvest index showed significant negative associated with content (-0.284). Prasad and Patil (2018) [9], Ray *et al.* (2019) [11] and Tripathi *et al.* (2020) [20] also recorded same observations for most of these traits under study.

Parents + F_2's:

Seed yield/plant exhibited positive highly significant association at genotypic level with harvest index (0.928) followed by number of siliquae/plant (0.757), leaf area index (0.628), biological yield/plant (0.675), number of seeds/siliqua (0.516), number of secondary branches/plant (0.423), 1000-seed weight (0.367), plant height (0.315) and number of primary branches/plant (0.210), while it showed a significant negative association with oil content (-0.193). These results have similarity with the earlier reports of Saroj *et al.* (2021) [13] who observed positive associations among seed yield with days to flowering initiation, plant height at maturity, siliquae on the main shoot, main shoot length, and siliqua length.

Highly significant and positive correlations were recorded between days to 50% flowering with days to maturity (0.690) followed by plant height (0.457), number of siliquae/plant (0.383) and harvest index (0.211), whereas, non-significant and positive correlation with test weight. While, significant and negative correlation was recorded with oil content (-0.222). Days to maturity showed highly significant positive correlation with plant height (0.795) followed by number of siliquae/plant (0.525), leaf area index (0.243) and 1000-seeds weight (0.183). It had non-significant negative correlation with length of main raceme. Plant height exhibited positive highly significant association at genotypic level with number of siliquae/plant (0.547) followed by leaf area index (0.343), harvest index (0.303) and biological yield per plant (0.209). It did not show any significant negative correlation with any trait. Highly significant and positive correlations were recorded between length of main raceme with number of secondary branches/plant (0.686) followed by number of primary branches/plant (0.693), number of seeds/siliqua (0.596), 1000-seed weight (0.461), leaf area index (0.452, and number of siliquae/plant (0.331). It showed negatively and significant association with oil content (-0.765).

Leaf area index showed positive and highly significant correlation with number of primary branches/plant (0.588), number of secondary branches/plant (0.822), number of siliquae/plant (0.638), number seeds/siliqua (0.637), 1000-seed weight (0.410), biological yield/plant (0.816) and harvest index (0.383) and negative association with oil content (-0.209). Number of primary branches/plant exhibited positive highly significant association at genotypic level with number of secondary branches/plant (0.770), number of siliquae/plant (0.330), number seeds/siliqua (0.638), 1000-seed weight (0.477), biological yield/plant (0.469) respectively and negative association with oil content (-0.460). It was non-significant positive correlation with harvest index. Highly significant and positive correlations were recorded between number of secondary branches/plant with number of siliquae/plant (0.539), number seeds/siliqua (0.798), 1000-seed weight (0.581), biological yield/plant (0.674) and harvest index (0.195) respectively. It had significant negative correlation with oil content (-0.371).

Number of siliquae/plant exhibited positive highly significant association at genotypic level with number of seeds/siliqua (0.650), 1000-seed weight (0.531), biological yield/plant (0.606) and harvest index (0.663) respectively. It was significant negative correlation with oil content (-0.381). Number of seeds/siliqua showed highly significant and positive correlation with 1000-seed weight (0.753) followed by biological yield/plant (0.612) and harvest index (0.344) respectively. It had significant negative correlation with oil content (-0.514). 1000-seeds weight showed positive and highly significant correlation with biological yield/plant (0.439) and harvest index (0.241) respectively. While, significant negative associated with oil content (0.504). Biological yield/plant showed highly significant and positive correlation with harvest index (0.354). While, harvest index showed significant negative associated with content (-0.216). Most of these results are in agreement with the earlier reports of Kumar *et al.* (2018) [4].

Path Coefficient Analysis

The direct and indirect effects of 13 characters on seed yield/plant estimated by path coefficient analysis using genotypic and phenotypic correlations have been depicted in Table 2 & 3, respectively.

At genotypic level, the highest positive direct effect on seed yield/plant was exerted by harvest-index (0.7827) followed by biological yield/plant (0.5610) and leaf area index (0.1839) and highest negative direct effect by number of secondary branches/plant (-0.1806) in F_1's, while in F_2's, harvest-index (0.7972) followed by biological yield/plant (0.4052). The direct effect of rest of the traits in both generations were either negative or too low to be of any consequences.

In genotypic path analysis in both the generations, harvest index exhibited high order of positive indirect effects on seed yield/plant *via* number of siliquae/plant (0.4287 and 0.5288) followed by leaf area index (0.3598 and 0.3057), number of seeds/siliqua (0.2290 and 0.2741), 1000-seeds weight (0.1774 and 0.1919), number of secondary branches/plant (0.1744 and 0.1557), days to 50% flowering (0.1756 and 0.1683) and length of main raceme (0.1207 and 1135) respectively in both in F_1's and F_2's, whereas, harvest index *via* days to maturity (0.2447) in F_1 only, and *via* biological yield per plant (0.2818) only in F_2 was also exerted high order of indirect effect on seed yield.

The trait biological yield per plant exerted high order of indirect effects on seed yield in both the generations *via* leaf area index (0.2579 and 0.3308) followed by number of siliquae/plant (0.3043 and 0.2455), number of secondary branches/plant (0.2612 and 0.2733), number of seeds/siliqua (0.2681 and 0.2482), 1000-seeds weight (0.1941 and 0.1778) and number of primary branches/plant (0.1688 and 0.1901), whereas, it also exerted considerable positive effects *via* plant height (0.1078) and oil content (0.1468) in F_1 only; while, *via* harvest index (0.1433) only in the F_2 generation. The remaining traits exerted either negative or too low amount of positive indirect effect on seed yield to be any consequences. The estimate of residual factors 0.00115 in F_1 and 0.00099 in F_2, obtained in this path analysis was low. Similar findings were reported by Singh *et al.* (2017) [15], Rout *et al.* (2018) [12], Rauf and Rahim (2018) [10], Nur-E-Nabi *et al.* (2019) [6] and Tripathi *et al.* (2020) [20].

Table 1: Estimates of genotypic correlation coefficient computed between 14 traits of Indian mustard at genotypic level

Characters	Generations	Days to maturity	Plant height (cm)	Length of main raceme (cm)	Leaf area index	Number of primary branches/plant	Number of secondary branches/plant	Number of siliquae/plant	Number of seeds/siliqua	1000-seed weight (g)	Biological yield/plant (g)	Harvest index (%)	Oil Content%	Seed yield/plant (g)
Days to 50% flowering	F1	0.773**	0.517**	0.044	0.186*	-0.028	-0.007	0.418**	-0.010	0.132	-0.201**	0.224**	-0.215**	0.074
	F2	0.690**	0.457**	-0.002	0.150	-0.057	0.037	0.383**	-0.014	0.147	-0.048	0.211**	-0.222**	0.145
Days to maturity	F1		0.663**	-0.029	0.276**	-0.004	0.125	0.450**	0.108	0.104	-0.087	0.313**	-0.194*	0.204**
	F2		0.795**	-0.129	0.243**	-0.023	0.083	0.525**	0.087	0.183*	0.117	0.046	-0.087	0.079
Plant height (cm)	F1			-0.080	0.405**	-0.060	0.093	0.585**	0.026	0.023	0.192*	0.206**	0.053	0.265**
	F2			0.035	0.343**	0.008	0.130	0.547**	0.130	0.065	0.209**	0.303**	0.027	0.315**
Length of main raceme (cm)	F1				0.379**	0.634**	0.628**	0.180*	0.507**	0.442**	-0.033	0.154*	-0.805**	0.122
	F2				0.452**	0.686**	0.693**	0.331**	0.596**	0.461**	0.329**	0.142	-0.765**	0.249**
Leaf area index	F1					0.625**	0.882**	0.641**	0.750**	0.392**	0.460**	0.460**	-0.207**	0.627**
	F2					0.588**	0.822**	0.638**	0.637**	0.410**	0.816**	0.383**	-0.209**	0.628**
No primary branches/plant	F1						0.806**	0.300**	0.684**	0.511**	0.301**	0.085	-0.433**	0.243**
	F2						0.770**	0.330**	0.638**	0.477**	0.469**	0.023	-0.460**	0.210**
No secondary branches/pl.	F1							0.545**	0.803**	0.615**	0.466**	0.223**	-0.382**	0.439**
	F2							0.539**	0.798**	0.581**	0.674**	0.195*	-0.371**	0.423**
Number of siliquae/plant	F1								0.622**	0.513**	0.542**	0.548**	-0.325**	0.738**
	F2								0.650**	0.531**	0.606**	0.663**	-0.381**	0.757**
Number of seeds/siliqua	F1									0.799**	0.478**	0.293**	-0.400**	0.510**
	F2									0.753**	0.612**	0.344**	-0.514**	0.516**
1000-seed weight (g)	F1										0.346**	0.227**	-0.447**	0.380**
	F2										0.439**	0.241**	-0.504**	0.367**
Biological yield/plant (g)	F1											0.030	0.262**	0.568**
	F2											0.354**	-0.038	0.675**
Harvest index (%)	F1												-0.284**	0.839**
	F2												-0.216**	0.928**
Oil Content%	F1													-0.101
	F2													-0.193*

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

Table 2: Estimates of phenotypic correlation coefficient computed between 14 traits of Indian mustard at phenotypic level

Characters	Generations	Days to maturity	Plant height (cm)	Length of main raceme (cm)	Leaf area index	Number of primary branches/plant	Number of secondary branches/plant	Number of siliquae/plant	Number of seeds/siliqua	1000-seed weight (g)	Biological yield/plant (g)	Harvest index (%)	Oil Content%	Seed yield/plant (g)
Days to 50% flowering	F1	0.636**	0.468**	0.003	0.130	-0.056	0.077	0.274**	0.040	0.097	-0.140	0.201**	-0.193*	0.097
	F2	0.537**	0.412**	-0.067	0.100	-0.054	0.014	0.294**	0.051	0.126	-0.001	0.121	-0.072	0.100
Days to maturity	F1		0.348**	0.005	0.145	0.066	0.002	0.384**	-0.042	0.086	-0.109	0.116	-0.058	0.040
	F2		0.171*	0.020	0.142	-0.018	0.073	0.243**	-0.018	0.116	-0.007	0.229**	-0.159*	0.190*
Plant height (cm)	F1			-0.131	0.344**	-0.087	0.148	0.467**	0.065	0.006	0.195*	0.199*	-0.008	0.266**
	F2			-0.103	0.241**	-0.016	0.100	0.442**	0.054	0.041	0.209**	0.115	0.057	0.179*
Length of main raceme (cm)	F1				0.315**	0.594**	0.478**	0.179*	0.376**	0.419**	-0.091	0.144	-0.504**	0.084
	F2				0.386**	0.598**	0.604**	0.281**	0.505**	0.391**	0.226**	0.141	-0.518**	0.220**
Leaf area index	F1					0.488**	0.705**	0.525**	0.493**	0.374**	0.413**	0.419**	-0.227**	0.580**
	F2					0.492**	0.736**	0.517**	0.546**	0.379**	0.623**	0.335**	-0.181*	0.544**
No primary branches/plant	F1						0.623**	0.271**	0.484**	0.471**	0.234**	0.026	-0.238**	0.152
	F2						0.645**	0.318**	0.501**	0.456**	0.402**	0.010	-0.299**	0.181*
No secondary branches/pl.	F1							0.376**	0.677**	0.506**	0.405**	0.207**	-0.295**	0.398**
	F2							0.424**	0.637**	0.507**	0.582**	0.184*	-0.391**	0.399**
Number of siliquae/plant	F1								0.354**	0.490**	0.465**	0.423**	-0.199*	0.604**
	F2								0.435**	0.499**	0.511**	0.443**	-0.265**	0.583**
Number of seeds/siliqua	F1									0.571**	0.360**	0.280**	-0.232**	0.439**
	F2									0.573**	0.483**	0.233**	-0.255**	0.401**
1000-seed weight (g)	F1										0.321**	0.193*	-0.363**	0.342**
	F2										0.352**	0.218**	-0.378**	0.334**
Biological yield/plant (g)	F1											-0.021	0.108	0.519**
	F2											0.151	-0.017	0.545**
Harvest index (%)	F1												-0.299**	0.843**
	F2												-0.246**	0.910**
Oil Content%	F1													-0.207**
	F2													-0.223**

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

Table 3: Genotypic direct and indirect effect of 13 quantitative traits on seed yield per plant in Indian mustard

Characters	Generation	Days to 50% flowering	Days to maturity	Plant height (cm)	Length of main raceme (cm)	Leaf area index	Number of primary branches/plant	Number of secondary branches/plant	Number of siliquae/plant	Number of seeds/siliqua	1000-seed weight (g)	Biological yield/plant (g)	Harvest index (%)	Oil Content%	Seed yield/plant (g)
Days to 50% flowering	F1	0.0674	-0.0800	-0.0280	0.0020	0.0341	-0.0004	0.0013	0.0057	0.0006	0.0078	-0.1128	0.1756	0.0007	0.074
	F2	0.0032	-0.0015	0.0019	0.0000	0.0016	-0.0003	-0.0004	-0.0128	-0.0001	0.0005	-0.0193	0.1683	0.0039	0.145
Days to maturity	F1	0.0790	-0.0682	-0.0358	-0.0013	0.0507	-0.0001	-0.0226	0.0062	-0.0064	0.0062	-0.0489	0.2447	0.0006	0.204**
	F2	0.0044	-0.0011	0.0033	0.0009	0.0026	-0.0001	-0.0008	-0.0176	0.0005	0.0006	0.0475	0.0370	0.0015	0.079
Plant height (cm)	F1	0.0348	-0.0452	-0.0541	-0.0036	0.0744	-0.0008	-0.0167	0.0080	-0.0016	0.0014	0.1078	0.1610	-0.0002	0.265**
	F2	0.0014	-0.0009	0.0042	-0.0003	0.0037	0.0001	-0.0013	-0.0183	0.0008	0.0002	0.0848	0.2412	-0.0005	0.315**
Length of main raceme (cm)	F1	0.0030	0.0020	0.0043	0.0452	0.0696	0.0081	-0.1134	0.0025	-0.0303	0.0263	-0.0185	0.1207	0.0026	0.122
	F2	0.0000	0.0001	0.0001	-0.0071	0.0048	0.0039	-0.0069	-0.0111	0.0035	0.0015	0.1333	0.1135	0.0133	0.249**
Leaf area index	F1	0.0125	-0.0188	-0.0219	0.0171	0.1839	0.0080	-0.1593	0.0088	-0.0449	0.0233	0.2579	0.3598	0.0007	0.627**
	F2	0.0005	-0.0003	0.0014	-0.0032	0.0107	0.0034	-0.0082	-0.0213	0.0037	0.0013	0.3308	0.3057	0.0036	0.628**
No primary branches/plant	F1	-0.0019	0.0003	0.0032	0.0287	0.1149	0.0127	-0.1457	0.0041	-0.0409	0.0304	0.1688	0.0667	0.0014	0.243**
	F2	-0.0002	0.0000	0.0000	-0.0049	0.0063	0.0057	-0.0077	-0.0110	0.0038	0.0015	0.1901	0.0181	0.0080	0.210**
No secondary branches/pl.	F1	-0.0005	-0.0086	-0.0050	0.0284	0.1621	0.0103	-0.1806	0.0075	-0.0480	0.0366	0.2612	0.1744	0.0012	0.439**
	F2	0.0001	-0.0001	0.0005	-0.0050	0.0088	0.0044	-0.0100	-0.0180	0.0047	0.0019	0.2733	0.1557	0.0065	0.423**
Number of siliquae/plant	F1	0.0282	-0.0307	-0.0317	0.0081	0.1179	0.0038	-0.0985	0.0137	-0.0372	0.0305	0.3043	0.4287	0.0010	0.738**
	F2	0.0012	-0.0006	0.0023	-0.0024	0.0068	0.0019	-0.0054	-0.0335	0.0038	0.0017	0.2455	0.5288	0.0066	0.757**
Number of seeds/siliqua	F1	-0.0007	-0.0073	-0.0014	0.0229	0.1380	0.0087	-0.1450	0.0086	-0.0598	0.0476	0.2681	0.2290	0.0013	0.510**
	F2	0.0000	-0.0001	0.0005	-0.0043	0.0068	0.0037	-0.0080	-0.0218	0.0059	0.0024	0.2482	0.2741	0.0089	0.516**
1000-seed weight (g)	F1	0.0089	-0.0071	-0.0013	0.0200	0.0721	0.0065	-0.1111	0.0070	-0.0478	0.0595	0.1941	0.1774	0.0014	0.380**
	F2	0.0005	-0.0002	0.0003	-0.0033	0.0044	0.0027	-0.0058	-0.0178	0.0044	0.0032	0.1778	0.1919	0.0088	0.367**
Biological yield/plant (g)	F1	-0.0136	0.0060	-0.0104	-0.0015	0.0845	0.0038	-0.0841	0.0075	-0.0286	0.0206	0.5610	0.0232	-0.0008	0.568**
	F2	-0.0002	-0.0001	0.0009	-0.0024	0.0088	0.0027	-0.0067	-0.0203	0.0036	0.0014	0.4052	0.2818	0.0007	0.675**
Harvest index (%)	F1	0.0151	-0.0213	-0.0111	0.0070	0.0846	0.0011	-0.0403	0.0075	-0.0175	0.0135	0.0167	0.7827	0.0009	0.839**
	F2	0.0007	-0.0001	0.0013	-0.0010	0.0041	0.0001	-0.0020	-0.0222	0.0020	0.0008	0.1433	0.7972	0.0038	0.928**
Oil Content%	F1	-0.0145	0.0132	-0.0029	-0.0364	-0.0380	-0.0055	0.0689	-0.0045	0.0239	-0.0266	0.1468	-0.2219	-0.0032	-0.101
	F2	-0.0007	0.0001	0.0001	0.0055	-0.0022	-0.0026	0.0037	0.0128	-0.0030	-0.0016	-0.0154	-0.1721	-0.0174	-0.193*

Residual effects: 0.00115 (F1): 0.00067 (F2)

Table 4: Phenotypic direct and indirect effect of 13 quantitative traits on seed yield per plant in Indian mustard

Characters	Generation	Days to 50% flowering	Days to maturity	Plant height (cm)	Length of main raceme (cm)	Leaf area index	Number of primary branches/plant	Number of secondary branches/plant	Number of siliquae/plant	Number of seeds/siliqua	1000-seed weight (g)	Biological yield/plant (g)	Harvest index (%)	Oil Content%	Seed yield/plant (g)
Days to 50% flowering	F1	0.0022	0.0053	-0.0027	0.0000	0.0002	0.0003	-0.0004	-0.0051	0.0003	0.0000	-0.0768	0.1722	0.0016	0.097
	F2	0.0018	-0.0002	-0.0003	-0.0004	0.0005	-0.0003	-0.0002	-0.0043	-0.0001	0.0005	-0.0004	0.1029	0.0007	0.100
Days to maturity	F1	0.0014	0.0084	-0.0020	0.0001	0.0002	-0.0003	0.0000	-0.0071	-0.0003	0.0000	-0.0600	0.0997	0.0005	0.040
	F2	0.0010	-0.0004	-0.0001	0.0001	0.0008	-0.0001	-0.0010	-0.0036	0.0000	0.0004	-0.0031	0.1944	0.0015	0.190*
Plant height (cm)	F1	0.0010	0.0029	-0.0057	-0.0015	0.0006	0.0004	-0.0008	-0.0087	0.0004	0.0000	0.1073	0.1704	0.0001	0.266**
	F2	0.0007	-0.0001	-0.0007	-0.0006	0.0013	-0.0001	-0.0013	-0.0065	-0.0001	0.0002	0.0886	0.0975	-0.0005	0.179*
Length of main raceme (cm)	F1	0.0000	0.0000	0.0008	0.0114	0.0005	-0.0027	-0.0025	-0.0033	0.0025	0.0002	-0.0503	0.1237	0.0041	0.084
	F2	-0.0001	0.0000	0.0001	0.0054	0.0020	0.0032	-0.0079	-0.0041	-0.0006	0.0014	0.0960	0.1198	0.0049	0.220**
Leaf area index	F1	0.0003	0.0012	-0.0020	0.0036	0.0017	-0.0022	-0.0037	-0.0097	0.0033	0.0002	0.2266	0.3587	0.0018	0.580**
	F2	0.0002	-0.0001	-0.0002	0.0021	0.0053	0.0026	-0.0096	-0.0076	-0.0007	0.0014	0.2646	0.2847	0.0017	0.544**
No primary branches/plant	F1	-0.0001	0.0006	0.0005	0.0068	0.0008	-0.0045	-0.0032	-0.0050	0.0033	0.0002	0.1285	0.0223	0.0019	0.152
	F2	-0.0001	0.0000	0.0000	0.0032	0.0026	0.0053	-0.0084	-0.0047	-0.0006	0.0016	0.1706	0.0086	0.0028	0.181*
No secondary branches/pl.	F1	0.0002	0.0000	-0.0008	0.0054	0.0012	-0.0028	-0.0052	-0.0070	0.0046	0.0002	0.2228	0.1775	0.0024	0.398**
	F2	0.0000	0.0000	-0.0001	0.0033	0.0039	0.0034	-0.0131	-0.0062	-0.0008	0.0018	0.2470	0.1566	0.0037	0.399**
Number of siliquae/plant	F1	0.0006	0.0032	-0.0027	0.0020	0.0009	-0.0012	-0.0020	-0.0186	0.0024	0.0002	0.2552	0.3618	0.0016	0.604**
	F2	0.0005	-0.0001	-0.0003	0.0015	0.0027	0.0017	-0.0055	-0.0147	-0.0005	0.0018	0.2169	0.3769	0.0025	0.583**
Number of seeds/siliqua	F1	0.0001	-0.0004	-0.0004	0.0043	0.0008	-0.0022	-0.0035	-0.0066	0.0067	0.0002	0.1978	0.2402	0.0019	0.439**
	F2	0.0001	0.0000	0.0000	0.0027	0.0029	0.0027	-0.0083	-0.0064	-0.0012	0.0021	0.2053	0.1984	0.0024	0.401**
1000-seed weight (g)	F1	0.0002	0.0007	0.0000	0.0048	0.0006	-0.0021	-0.0026	-0.0091	0.0038	0.0004	0.1763	0.1656	0.0029	0.342**
	F2	0.0002	-0.0001	0.0000	0.0021	0.0020	0.0024	-0.0066	-0.0073	-0.0007	0.0036	0.1497	0.1856	0.0036	0.334**
Biological yield/plant (g)	F1	-0.0003	-0.0009	-0.0011	-0.0010	0.0007	-0.0011	-0.0021	-0.0086	0.0024	0.0001	0.5493	-0.0177	-0.0009	0.519**
	F2	0.0000	0.0000	-0.0001	0.0012	0.0033	0.0021	-0.0076	-0.0075	-0.0006	0.0013	0.4246	0.1280	0.0002	0.545**
Harvest index (%)	F1	0.0004	0.0010	-0.0011	0.0016	0.0007	-0.0001	-0.0011	-0.0078	0.0019	0.0001	-0.0114	0.8562	0.0024	0.843**
	F2	0.0002	-0.0001	-0.0001	0.0008	0.0018	0.0001	-0.0024	-0.0065	-0.0003	0.0008	0.0640	0.8498	0.0023	0.910**
Oil Content%	F1	-0.0004	-0.0005	0.0001	-0.0057	-0.0004	0.0011	0.0015	0.0037	-0.0016	-0.0002	0.0592	-0.2559	-0.0081	-0.207**
	F2	-0.0001	0.0001	0.0000	-0.0028	-0.0010	-0.0016	0.0051	0.0039	0.0003	-0.0014	-0.0072	-0.2086	-0.0094	-0.223**

Residuals effects: 0.00172 (F1): 0.00099 (F2)

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