

Correlation and path analysis for seed yield in Indian mustard (*Brassica juncea* L. Czern and Coss.)

Abstract

A study of 17 agronomic traits Indian mustard was conducted to evaluate correlation and path analysis of (*Brassica juncea* L. Czern and Coss.). Ten lines with diverse genetic makeup and their crosses were evaluated in half diallel fashion and were grown in Randomized Block Design in three replications during rabi season (2021-22). At phenotypic and genotypic levels, seed yield per plant exhibited a significant and positive correlation with plant height, total siliqua per plant and biological yield per plant in both F_1 and F_2 generations. High direct positive impact on seed yield per plant at genotypic and phenotypic levels was exhibited by plant height, total siliqua per plant, and biological yield per plant in both F_1 and F_2 generations respectively, while number of primary branches, seeds per siliqua, and oil content showed a negative direct correlation with seeds yield per plant at genotypic and phenotypic level in both F_1 and F_2 generations. The results of the study concluded that plant height, total siliqua per plant, and biological yield per plant exerted a high correlation and direct effect on seed yield per plant generation. Hence, these characters might be considered for the selection and in the improvement of seed yield of mustard genotypes.

Keywords: Indian mustard, correlation coefficient, genotype, path analysis, phenotype

Introduction

Indian mustard [*Brassica juncea* (L.) Czern and Coss] ranks second in oilseed crops around the world as well as India. It is an allopolyploid species having 36 chromosomes ($2n=36$) and amphidiploid ($2n=36$) of *Brassica campestris* ($2n=20$) and *Brassica nigra* ($2n=16$). It is a largely self-pollinated crop (85-90%) and self-compatible. Afghanistan and its adjoining regions (Central Asia) has been recognized as the primary Centre of its origin, while central and western China, Eastern India, and Asia Minor comprising Iran are considered as the secondary centers of origin according to Vavilov (1949). Although it is widespread in Europe, Africa, North America, and Asia, several authors believe that Eastern India, the Caucasus, and China are the main genetic centres for *Brassica juncea*.

Among the seven edible oilseeds cultivated in India, rapeseed-mustard contributes 27% of the total oilseeds production. *Brassica juncea* contributes to about 80 percent of the total rapeseed-mustard production in the country. Globally, India is the largest grower of the rapeseed-mustard, occupying the first position in area and second position in production after China. India has witnessed increasing trends in both, the area and production of rapeseed and mustard during last 5-6 years, and whereas in Uttar Pradesh area and production (DES, 2023). Rapeseed and mustard production 128.18 lakh tonnes, productivity 1447 kg/ha and 88.58 lakh ha in 2022-23 (PIB, 2023).

Material and method

In the present investigation the basic material comprised ten varieties/ strains of Indian mustard namely, Varuna, Urvashi, Azad Mahak, RH-749, Maya, IJ-31, KMR 17-3, KMR 17-4, RH-406 and NRC-DR-2 were taken from the germplasm maintained at Oilseed Section, Department of Genetics and Plant Breeding, C.S. Azad University of Agriculture and Technology, Kanpur. The experimental material consisting of 100 treatments (10 parents + 45 F_1 's and 45 F_2 's) was evaluated in Randomized Block Design with three replications during Rabi 2020-2021. Each parent and F_1 's planted in one row, and F_2 's in two rows 5m long and 45 cm apart, appropriate plant-to-

plant distance was maintained at 15 cm by thinning. All the recommended agronomic practices were adopted for raising a good crop. Ten plants in parents and F_1 's and 20 plants in F_2 's were taken randomly for each treatment in each replication and tagged for recording observations for days to 50% flowering, days to reproductive maturity, plant height (cm), length of main axis (cm), leaf area index, chlorophyll content, number of primary branches per plant, number of secondary branches per plant, number of siliqua on main axis, number of siliquae per plant, siliqua length (cm), number of seeds per siliqua, biological yield per plant (g), 1000-seed weight (g), harvest index (%), oil content (%) and seed yield per plant (g).

Result and discussion

Correlation coefficient analysis

Correlation studies provides association estimates between various characters. The prime objective for the breeder is yield, which is a complex and polygenic trait and is highly environment-influenced. So direct selection through yield only would not be effective. The selection criteria to be adopted is decided by the correlation studies of yield and its component characters. The formula of calculation of the genotypic and phenotypic coefficients of correlation were used as suggested by A. L. Jibouri et al., (1958). The data available to the plant breeder immensely helps in estimating the degree of association between two or more plant characteristics of a sample or a group of strains of a particular crop (table 1a and 1b).

The concept of correlation originally was presented and elaborated by Fisher (1918) and Wright (1921). Dewey and Lu (1959) recognized the nature of population under consideration as the magnitude of correlation coefficient. In the present investigation, the association study was taken up amongst F_1 's and F_2 's derived from half-diallel design. In general, the magnitude of the phenotypic correlation is in the same direction but lower in revealing the pleiotropic effects rather than linkage for association.

Genotypic correlation coefficient

Seed yield/plant exhibited positive highly significant association at phenotypic level with biological yield per plant (0.977), seeds per siliqua (0.396), days to reproductive maturity (0.366), plant height (0.361), siliqua length (0.346), days to 50% flowering (0.345), total siliqua (0.287), siliqua on main axis (0.220) and harvest index (0.243). Positively significant correlation with number of secondary branches (0.181) and a non-significant positive correlation with number of primary branches (0.064), 1000 seed weight (0.036), and main axis height (0.030). Significant negative correlation with oil content (-0.173), leaf area index (-0.109), and chlorophyll content (-0.097) in F_1 's.

Seed yield/plant exhibited a positive highly significant association at the phenotypic level with biological yield per plant (0.780), chlorophyll content (0.427), total siliqua (0.323), and plant height (0.224). Positively significant correlation with 1000 seed weight (0.177) and a non-significant correlation with harvest index (0.160), oil content (0.113), days to reproductive maturity (0.036), number of primary branches (0.034), and main axis height (0.031). Non-significant and negative correlation with leaf area index (-0.103), siliqua length (-0.030), seeds per siliqua (-0.025), siliqua on main axis (0.008), number of secondary branches (-0.006) and days to 50% flowering (-0.003) in F_2 's.

phenotypic correlation coefficient

Seed yield/plant exhibited a positive highly significant association at the phenotypic level with biological yield per plant (0.957), seeds per siliqua (0.315), plant height (0.299), total siliqua (0.284), days to 50% flowering (0.232) and days to reproductive maturity (0.229). Positively significant correlation with siliqua length (0.216), harvest index (0.205), and number of secondary branches (0.181). Non-significant positive correlation with

siliqua on main axis (0.137), number of primary branches (0.062), main axis height (0.037), and 1000 seed weight (0.034). Significant negative correlation with oil content (-0.173) and non-significant negative correlation with leaf area index (-0.109) and chlorophyll content (-0.097) in F_1 's.

Seed yield/plant exhibited a positive highly significant association at the phenotypic level with biological yield per plant (0.780), chlorophyll content (0.364), and total siliqua (0.308). Positively significant correlation with plant height (0.186) and non-significant positive correlation with 1000 seed weight (0.155), harvest index (0.124), oil content (0.106), number of primary branches (0.038), days to reproductive maturity (0.019), siliqua length (0.016), main axis height (0.008) and siliqua on main axis (0.007). Non-significant and negative correlation with leaf area index (-0.099), seeds per siliqua (-0.026), days to reproductive maturity (-0.024), and number of secondary branches (-0.001) in F_2 's

Path coefficient analysis

Path analysis partitions the correlation coefficient into direct and indirect effects of component characters (independent variables) on yield (dependent variable). It gives an understanding of the cause-and-effect relationship between different character combinations (table 2a and 2b). Path coefficient analysis was proposed by **Wright (1921)** and later more lucidly explained by **Dewey and Lu (1959)**.

Genotypic correlation coefficient

In F_1 's highest positive direct effect on seed yield/plant was exerted by biological yield per plant (0.8617) followed by harvest index (0.2212), siliqua length (0.1834), days to 50% flowering (0.1436), plant height (0.0493), main axis height (0.0258) while highest negative direct effect on seed yield/plant was exerted by number of secondary branches (-0.1828) followed by chlorophyll content (-0.1342), day to 100% flowering (-0.0817), leaf area index (-0.709) and 1000 seed weight (-0.0587). In this generation, high indirect positive effect on seed yield per plant at genotypic level was exhibited by days to 50% flowering via days to reproductive maturity (0.1450), biological yield per plant (0.0496); plant height via siliqua length (0.2120); chlorophyll content via number of secondary branches (0.0803), number of primary branches per plant (0.0640); number of secondary branches via chlorophyll content (0.1094), harvest index (0.0502); siliqua length via siliqua length (0.1002), seeds per siliqua (0.0985), number of primary branches (0.0601); biological yield per plant via number of seeds per siliqua (0.3994), days to reproductive maturity (0.3133), days to 50% flowering (0.2977), siliqua length (0.2910), plant height (0.2800), number of siliquae per plant (0.2759), number of siliqua on main axis (0.2284), number of secondary branches per plant (0.2125), number of primary branches per plant (0.0959), harvest index (0.0799); harvest index via chlorophyll content (0.0800), 1000 seed weight (0.0522) While, high indirect negative impact on seed yield per plant at genotypic level was exhibited by genotypic estimate of residual effect via chlorophyll content via harvest index (-0.0485); number of secondary branches via number of siliquae per plant (-0.1158), length of main axis (-0.0919), number of siliquae on main axis (-0.0900), siliqua length (-0.0875) and number of seeds per siliqua (-0.0591); siliqua length via days to reproductive maturity (-0.0599) and days to 50% flowering (-0.0513); oil content (-0.1803), biological yield per plant via chlorophyll content (-0.1439), leaf area index (-0.1420); Harvest index via seeds per siliqua (-0.0789), number of secondary branches (-0.0607). In the F_1 's generation genotypic estimate of residual effect was 0.0080. Similar findings were reported by Ray *et al.* (2019) and Tripathi *et al.* (2020).

In F_2 's highest positive direct effect on seed yield/plant was exerted by biological yield per plant (0.7557) followed by chlorophyll content (0.3502), plant height (0.3995), number of secondary branches (0.2904), leaf area index (0.0807) and total siliqua (0.0789) while highest negative direct effect on seed yield/plant was exerted by siliqua length (-0.2290) followed by harvest index (-0.1184), days to 50% flowering (-0.1000), main axis height (-0.0841), oil content (-0.0699), siliqua on main axis (-0.0504), number of primary branches (-0.0337) and 1000

seed weight (-0.0334). In this generation, high indirect positive effect on seed yield per plant at genotypic level was exhibited by siliqua length (0.2120), number of primary branches per plant (0.1286), days to 50% flowering (0.1250), harvest index plant height via (0.1246), days to reproductive maturity (0.1087), chlorophyll content (0.0852), oil content (0.0789); chlorophyll content via harvest index (0.1281), days to 50% flowering (0.1063), days to reproductive maturity (0.1045), oil content (0.0781), plant height (0.0747); number of secondary branches via number of seeds per siliqua (0.0625); seeds per siliqua via main axis height (0.0614); biological yield per plant via number of siliquae per plant (0.2229), number of primary branches per plant (0.1813), 1000-seed weight (0.1489), chlorophyll content (0.1300), oil content (0.1002), length of main axis (0.0898), days to 50% flowering (0.0838), plant height (0.0833); While, high indirect negative impact on seed yield per plant at genotypic level was exhibited by days to 50% flowering via days to reproductive maturity (-0.943); days to reproductive maturity via days to 50% flowering (-0.0825); plant height via number of secondary branches per plant (-0.1788), number of seeds per siliqua (-0.0809); chlorophyll content via number of primary branches per plant (-0.0672), biological yield per plant (0.0603), leaf area index (-0.0576); number of primary branches via days to reproductive maturity (-0.1300), days to 50% flowering (-0.0581), number of primary branches (-0.0625); siliqua length via oil content (-0.0914), days to 50% flowering (-0.0754); biological yield per plant via leaf area index (-0.1431), harvest index (-0.1035), number of secondary branches (-0.0825); harvest index via leaf area index (-0.0598). In the F₂'s generation genotypic estimate of residual effect was 0.0158. Similar findings were reported by Yadav *et al.* (2021) and Lavanya *et al.* (2022).

Phenotypic correlation coefficient

In F₁'s highest positive direct effect on seed yield/plant was exerted by biological yield per plant (0.9585) followed by harvest index (0.1165), plant height (cm) (0.0515) and main axis height (0.0391) leaf area index (0.0226) and days to reproductive maturity (0.0221) while highest negative direct effect on seed yield/plant was exerted by siliqua on main axis (-0.0479) followed by seeds per siliqua (-0.0369), days to reproductive maturity (-0.0246), number of primary branches (-0.0245), oil content (-0.0220) and number of secondary branches (-0.0209). In this generation, high indirect positive effect on seed yield per plant at genotypic level was exhibited by days to 50% flowering via days to reproductive maturity (0.0215); biological yield per plant via number of siliquae per plant (0.2948), plant height (0.2545), days to 50% flowering (0.2346), number of secondary branches per plant (0.2327), siliqua length (0.2365), days to reproductive maturity (0.2282), number of siliqua on main axis (0.1888), number of primary branches per plant (0.1028); While, high indirect negative impact on seed yield per plant at genotypic level was exhibited by biological yield per plant via leaf area index (-0.1521), oil content (-0.1479), chlorophyll content (-0.1433); harvest index via seeds per siliqua (-0.0273), number of secondary branches per plant (-0.0205); oil content via seeds per siliqua (-0.0273), number of secondary branches per plant (-0.0252). In the F₁'s generation genotypic estimate of residual effect was 0.0459. Similar finding were reported by Nur-E-Nabi *et al.* (2019) and Tripathi *et al.* (2020).

In F₂'s, highest positive direct effect on seed yield/plant was exerted by biological yield per plant (0.7426) followed by chlorophyll content (0.2201), harvest index (0.1443), plant height (0.1218), total siliqua (0.937), 1000 seed weight (0.0725), number of secondary branches/plant (0.0676), siliqua length (0.0519) and days to maturity (0.0473) while highest negative direct effect on seed yield/plant was exerted by days to 50% flowering (-0.1940) followed by main axis height (-0.0750), leaf area index (-0.0691), oil content % (-0.0369), siliqua on main axis (-0.0274). In this generation, high indirect positive effect on seed yield per plant at genotypic level was exhibited by days to 50% flowering via days to reproductive maturity (0.0215); biological yield per plant via number of siliquae per plant (0.2948), plant height (0.2545), days to 50% flowering (0.2346), number of secondary branches per plant (0.2327), siliqua length (0.2365), days to reproductive maturity (0.2282), number of siliqua on main axis (0.1888), number of primary branches per plant (0.1028); harvest index via leaf area index (0.0238), chlorophyll content (0.0270) and 1000 seed weight (0.0205) while leaf area index (0.0676), chlorophyll content (0.0475), plant height

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

DFF=days to 50% flowering, DRM= days to reproductive maturity,PH= plant height (cm),MAH= length of main axis (cm),LAI= leaf area index, CC= chlorophyll content, PB= number of primary branches, SB= number of secondary branches, SOMA=siliqua on main axis, TS= number of siliquae per plant,SL=siliqua length, S/S=seeds per siliqua, BY= biological yield per plant, TSW=1000-seed weight, HI=harvest index, OC= oil content, SY/P =seed yield per plant.

Table 1b: Phenotypic (P) and Genotypic (G) correlation coefficient analysis of F₂ for seed yield and its component traits in Indian mustard.

Hybrid		DFF	DRM	PH	MAH	LAI	CC	PB	SB	SOMA	TS	SL	S/S	BY	TSW	HI (%)	OC (%)	SY/P (g)
DFF	GC	1.000	0.942**	0.313**	0.233**	-0.370**	0.303**	0.081	-0.200*	0.073	-0.116	0.329**	0.270**	0.111	0.239**	-0.136	0.153	-0.003
	PC	1.000	0.779**	0.190*	0.183*	-0.315**	0.228**	0.039	-0.108	0.013	-0.093	0.186*	0.227**	0.092	0.216*	-0.112	0.121	-0.024
DRM	GC			0.272**	0.285**	-0.426**	0.298**	-0.012	-0.042	0.161	-0.036	0.13	0.270**	0.064	0.217*	-0.115	0.119	0.036
	PC			0.181*	0.253**	-0.407**	0.261**	-0.013	-0.052	0.144	-0.039	0.111	0.187*	0.060	0.216*	-0.095	0.102	0.019
PH	GC				-0.066	0.086	0.213*	0.322**	-0.448**	0.048	0.038	0.531**	-0.202*	0.11	0.031	0.312**	0.198*	0.224**
	PC				-0.020	0.077	0.134	0.229**	-0.187*	0.056	0.010	0.083	-0.149	0.073	0.024	0.188*	0.138	0.186*
MAH	GC					-0.189*	0.126	0.262**	0.098	0.446**	-0.024	-0.268**	0.092	0.119	0.149	-0.014	0.031	0.031
	PC					-0.174*	0.111	0.156	0.119	0.329**	-0.027	-0.154	0.048	0.108	0.152	-0.006	0.048	0.008
LAI	GC						-0.164	0.084	-0.086	-0.104	0.127	0.071	-0.105	-0.189*	-0.098	0.505**	-0.112	-0.103
	PC						-0.148	0.033	-0.058	-0.088	0.120	0.029	-0.091	-0.186*	-0.092	0.469**	-0.106	-0.099
CC	GC							-0.192*	-0.068	0.117	0.067	0.011	0.036	0.172*	0.126	0.366**	0.223**	0.427**
	PC							-0.124	-0.068	0.069	0.046	0.026	0.030	0.148	0.095	0.329**	0.196*	0.364**
PB	GC								0.251**	-0.088	-0.388**	0.317**	-0.479**	0.240**	-0.092	0.063	-0.116	0.034
	PC								-0.047	-0.051	-0.180*	0.049	-0.154	0.121	-0.048	0.034	-0.031	0.038
SB	GC									-0.059	0.079	0.071	0.214*	-0.109	-0.025	0.083	0.069	-0.006
	PC									-0.076	0.051	-0.012	0.092	-0.078	-0.038	0.082	0.037	-0.001
SOMA	GC										0.242**	-0.09	0.015	0.035	-0.007	0.013	0.182*	-0.008
	PC										0.182*	-0.119	-0.041	0.031	-0.004	0.000	0.108	0.007
TS	GC											0.251**	0.199*	0.295**	-0.088	-0.044	0.203*	0.323**
	PC											0.100	0.124	0.279**	-0.092	-0.041	0.188*	0.308**
SL	GC												0.210*	-0.05	-0.182*	-0.148	0.399**	-0.03
	PC												0.219*	-0.028	-0.065	-0.045	0.150	0.016
S/S	GC													0.057	0.200*	-0.272**	0.145	-0.025
	PC													0.032	0.157	-0.201*	0.104	-0.026
BY	GC														0.197*	-0.137	0.133	0.815**
	PC														0.186*	-0.126	0.126	0.780**
TSW	GC															-0.212*	0.011	0.177*
	PC															-0.191*	-0.015	0.155
HI (%)	GC																-0.143	0.16
	PC																-0.125	0.124
OC (%)	GC																	0.113
	PC																	0.106
SY/P (g)	GC																	1
	PC																	1

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

DFF=days to 50% flowering, DRM= days to reproductive maturity,PH= plant height (cm),MAH= length of main axis (cm),LAI= leaf area index, CC= chlorophyll content, PB= number of primary branches, SB= number of secondary branches, SOMA=siliqua on main axis, TS= number of siliquae per plant,SL=siliqua length, S/S=seeds per siliqua, BY= biological yield per plant, TSW=1000-seed weight, HI=harvest index, OC= oil content, SY/P =seed yield per plant.

Table 2a: Genotypic (G) and Phenotypic(P) Path coefficient of F₁ for 17 characters in 10x10 Diallel cross in Indian mustard.

Hybrid		DFF	DRM	PH	MAH	LAI	CC	PB	SB	SOMA	TS	SL	S/S	BY	TSW	HI	OC	SY/P
DFF	GP	0.1436	-0.0825	-0.0031	0.0072	0.0189	0.0413	-0.0008	-0.0458	0.0012	0.0003	-0.0513	-0.0006	0.2977	0.0060	0.0098	0.0037	0.345**
	PP	0.0221	-0.0240	-0.0008	0.0106	-0.0035	-0.0028	-0.0025	-0.0035	-0.0033	0.0003	-0.0019	-0.0034	0.2346	0.0005	0.0065	0.0032	0.232**
DRM	GP	0.1450	-0.0817	-0.0027	0.0068	0.0198	0.0352	-0.0008	-0.0441	0.0011	0.0003	-0.0599	-0.0008	0.3133	0.0083	0.0228	0.0040	0.366**
	PP	0.0215	-0.0246	-0.0005	0.0097	-0.0036	-0.0023	-0.0025	-0.0032	-0.0036	0.0004	-0.0018	-0.0031	0.2282	0.0006	0.0105	0.0028	0.229**
PH	GP	-0.0090	0.0045	0.0493	0.0071	0.0041	-0.0004	-0.0014	-0.0379	0.0042	0.0038	0.0433	-0.0020	0.2800	0.0000	0.0179	-0.0026	0.361**
	PP	-0.0004	0.0003	0.0515	0.0084	-0.0013	-0.0001	-0.0040	-0.0036	-0.0058	0.0042	0.0020	-0.0080	0.2545	-0.0001	0.0031	-0.0020	0.299**
MAH	GP	0.0398	-0.0215	0.0135	0.0258	0.0052	0.0402	-0.0021	-0.0919	0.0095	0.0046	0.0016	-0.0009	0.0398	-0.0065	-0.0254	-0.0020	0.030
	PP	0.0060	-0.0061	0.0111	0.0391	-0.0019	-0.0027	-0.0072	-0.0097	-0.0203	0.0052	0.0001	-0.0044	0.0440	-0.0007	-0.0130	-0.0029	0.037

LAI	GP	-0.0383	0.0228	-0.0029	-0.0019	-0.0709	0.0356	-0.0009	-0.0052	0.0007	0.0008	0.0310	0.0010	-0.1420	-0.0061	0.0536	0.0026	-0.120
	PP	-0.0034	0.0039	-0.0029	-0.0032	0.0226	-0.0031	-0.0035	-0.0006	-0.0003	0.0010	0.0019	0.0039	-0.1521	-0.0007	0.0238	0.0036	-0.109
CC	GP	-0.0441	0.0214	0.0002	-0.0077	0.0188	-0.1342	0.0030	0.1094	-0.0054	-0.0028	-0.0075	0.0002	-0.1439	0.0074	0.0800	-0.0020	-0.107
	PP	-0.0051	0.0048	-0.0005	-0.0087	-0.0058	0.0120	0.0104	0.0112	0.0073	-0.0035	-0.0008	0.0005	-0.1433	0.0008	0.0270	-0.0032	-0.097
PB	GP	0.0186	-0.0105	0.0111	0.0085	-0.0097	0.0640	-0.0063	-0.1311	0.0057	0.0070	0.0601	-0.0008	0.0959	-0.0037	-0.0441	-0.0003	0.064
	PP	0.0023	-0.0025	0.0083	0.0116	0.0032	-0.0051	-0.0245	-0.0144	-0.0109	0.0083	0.0035	-0.0038	0.1028	-0.0004	-0.0167	-0.0001	0.062
SB	GP	0.0360	-0.0197	0.0102	0.0130	-0.0020	0.0803	-0.0045	-0.1828	0.0083	0.0090	0.0877	-0.0021	0.2125	-0.0042	-0.0607	0.0001	0.181*
	PP	0.0037	-0.0037	0.0089	0.0182	0.0006	-0.0064	-0.0169	-0.0209	-0.0160	0.0107	0.0051	-0.0095	0.2327	-0.0005	-0.0252	0.0003	0.181*
SOMA	GP	0.0099	-0.0052	0.0122	0.0144	-0.0029	0.0428	-0.0021	-0.0900	0.0169	0.0044	0.0396	-0.0017	0.2284	-0.0072	-0.0381	-0.0010	0.220**
	PP	0.0015	-0.0019	0.0062	0.0166	0.0001	-0.0018	-0.0056	-0.0070	-0.0479	0.0036	0.0030	-0.0071	0.1888	-0.0007	-0.0070	-0.0035	0.137
TS	GP	0.0027	-0.0016	0.0131	0.0085	-0.0042	0.0266	-0.0031	-0.1158	0.0053	0.0142	0.1002	-0.0024	0.2759	-0.0008	-0.0326	0.0014	0.287**
	PP	0.0003	-0.0006	0.0125	0.0116	0.0012	-0.0024	-0.0117	-0.0128	-0.0097	0.0175	0.0057	-0.0109	0.2948	-0.0001	-0.0133	0.0020	0.284**
SL	GP	-0.0401	0.0267	0.0117	0.0002	-0.0120	0.0055	-0.0021	-0.0875	0.0037	0.0077	0.1834	-0.0036	0.2910	-0.0073	-0.0315	-0.0002	0.346**
	PP	-0.0029	0.0031	0.0070	0.0004	0.0029	-0.0007	-0.0060	-0.0074	-0.0098	0.0069	0.0145	-0.0165	0.2365	-0.0006	-0.0114	-0.0004	0.216*
S/S	GP	0.0135	-0.0099	0.0149	0.0036	0.0102	0.0040	-0.0007	-0.0591	0.0044	0.0052	0.0985	-0.0066	0.3994	-0.0022	-0.0789	-0.0003	0.396**
	PP	0.0020	-0.0021	0.0112	0.0046	-0.0024	-0.0002	-0.0025	-0.0054	-0.0093	0.0052	0.0065	-0.0369	0.3721	-0.0001	-0.0273	-0.0001	0.315**
BY	GP	0.0496	-0.0297	0.0160	0.0012	0.0117	0.0224	-0.0007	-0.0451	0.0045	0.0045	0.0619	-0.0031	0.8617	-0.0017	0.0205	0.0028	0.977**
	PP	0.0054	-0.0059	0.0137	0.0018	-0.0036	-0.0018	-0.0026	-0.0051	-0.0094	0.0054	0.0036	-0.0143	0.9585	-0.0002	0.0086	0.0034	0.957**
TSW	GP	-0.0148	0.0116	0.0000	0.0029	-0.0074	0.0169	-0.0004	-0.0130	0.0021	0.0002	0.0229	-0.0002	0.0256	-0.0587	0.0522	-0.0036	0.036
	PP	-0.0014	0.0021	0.0009	0.0040	0.0023	-0.0013	-0.0014	-0.0015	-0.0048	0.0001	0.0013	-0.0004	0.0259	-0.0069	0.0205	-0.0051	0.034
HI	GP	0.0064	-0.0084	0.0040	-0.0030	-0.0172	-0.0485	0.0013	0.0502	-0.0029	-0.0021	-0.0261	0.0024	0.0799	-0.0139	0.2212	-0.0005	0.243**
	PP	0.0012	-0.0022	0.0014	-0.0044	0.0046	0.0028	0.0035	0.0045	0.0029	-0.0020	-0.0014	0.0086	0.0704	-0.0012	0.1165	0.0000	0.205*
OC	GP	-0.0403	0.0245	0.0099	0.0038	0.0140	-0.0205	-0.0001	0.0013	0.0013	-0.0015	0.0031	-0.0001	-0.1803	-0.0159	0.0077	-0.0132	-0.206*
	PP	-0.0032	0.0032	0.0047	0.0052	-0.0037	0.0017	-0.0001	0.0003	-0.0077	-0.0016	0.0002	-0.0002	-0.1479	-0.0016	-0.0002	-0.0220	-0.173*

Bold values shows direct and normal values shows indirect effects

RESIDUAL EFFECT = 0.0158 (Genotypic)

RESIDUAL EFFECT = 0.0080 (phenotypic)

Where,

DFP=days to 50% flowering, DRM= days to reproductive maturity,PH= plant height (cm),MAH= length of main axis (cm),LAI= leaf area index, CC= chlorophyll content, PB= number of primary branches, SB= number of secondary branches, SOMA=siliqua on main axis, TS= number of siliqua per plant,SL=siliqua length,S/S=seeds per siliqua, BY= biological yield per plant, TSW=1000-seed weight, HI=harvest index, OC= oil content, SY/P =seed yield per plant.

Table 2b: Genotypic (G) and Phenotypic(P) Path coefficient of F₂ for 17 characters in 10x10 Diallel cross in Indian mustard

Hybrid	DFP	DRM	PH	MAH	LAI	CC	PB	SB	SOMA	TS	SL	S/S	BY	TSW	HI	OC	SY/P	
DFP	GP	-0.1000	-0.0139	0.1250	-0.0196	-0.0299	0.1063	-0.0027	-0.0581	-0.0037	-0.0092	-0.0754	-0.0035	0.0838	-0.0080	0.0161	-0.0107	-0.003
	PP	-0.1940	0.0368	0.0232	-0.0137	0.0217	0.0503	-0.0008	-0.0073	-0.0004	-0.0087	0.0097	-0.0038	0.0680	0.0157	-0.0161	-0.0045	-0.024
DRM	GP	-0.0943	-0.0148	0.1087	-0.0240	-0.0344	0.1045	0.0004	-0.0121	-0.0081	-0.0029	-0.0298	-0.0035	0.0483	-0.0073	0.0137	-0.0083	0.036
	PP	-0.1511	0.0473	0.0221	-0.0190	0.0281	0.0574	0.0002	-0.0035	-0.0039	-0.0037	0.0058	-0.0031	0.0442	0.0156	-0.0137	-0.0038	0.019
PH	GP	-0.0313	-0.0040	0.3995	0.0056	0.0069	0.0747	-0.0108	-0.1300	-0.0024	0.0030	-0.1215	0.0026	0.0833	-0.0011	-0.0369	-0.0138	0.224**
	PP	-0.0369	0.0086	0.1218	0.0015	-0.0053	0.0295	-0.0044	-0.0126	-0.0015	0.0009	0.0043	0.0025	0.0539	0.0017	0.0272	-0.0051	0.186*
MAH	GP	-0.0233	-0.0042	-0.0265	-0.0841	-0.0153	0.0443	-0.0088	0.0285	-0.0225	-0.0019	0.0614	-0.0012	0.0898	-0.0050	0.0017	-0.0022	0.031
	PP	-0.0355	0.0120	-0.0025	-0.0750	0.0120	0.0245	-0.0030	0.0081	-0.0090	-0.0026	-0.0080	-0.0008	0.0798	0.0110	-0.0008	-0.0018	0.008
LAI	GP	0.0610	-0.0192	0.0093	0.0130	-0.0691	-0.0327	-0.0006	-0.0039	0.0024	0.0112	0.0015	-0.1384	-0.0067	0.0676	0.0039	-0.099	
	PP	-0.0034	0.0039	-0.0029	-0.0032	0.0226	-0.0031	-0.0035	-0.0006	-0.0003	0.0010	0.0019	0.0039	-0.1521	-0.0007	0.0238	0.0036	-0.109
CC	GP	-0.0304	-0.0044	0.0852	-0.0106	-0.0133	0.3503	0.0065	-0.0197	-0.0059	0.0053	-0.0026	-0.0005	0.1300	-0.0042	-0.0433	-0.0156	0.427**
	PP	-0.0443	0.0123	0.0163	-0.0084	0.0103	0.2201	0.0024	-0.0046	-0.0019	0.0043	0.0014	-0.0005	0.1096	0.0069	0.0475	-0.0073	0.364**
PB	GP	-0.0081	0.0002	0.1286	-0.0220	0.0068	-0.0672	-0.0337	-0.0625	0.0044	-0.0306	-0.0726	0.0062	0.1813	0.0031	-0.0075	0.0081	0.034
	PP	-0.0077	-0.0006	0.0279	-0.0117	-0.0023	-0.0274	-0.0192	-0.0032	0.0014	-0.0169	0.0025	0.0026	0.0901	-0.0035	0.0049	0.0011	0.038
SB	GP	0.0200	0.0006	-0.1788	-0.0083	-0.0070	-0.0238	0.0073	0.2904	0.0030	0.0063	-0.0163	-0.0028	-0.0825	0.0008	-0.0098	-0.0048	-0.006
	PP	0.0209	-0.0025	-0.0228	-0.0090	0.0040	-0.0149	0.0009	0.0676	0.0021	0.0048	-0.0006	-0.0015	-0.0580	-0.0028	0.0118	-0.0014	-0.001
SOMA	GP	-0.0073	-0.0024	0.0193	-0.0375	-0.0084	0.0411	0.0030	-0.0172	-0.0504	0.0191	0.0207	-0.0002	0.0263	0.0002	-0.0015	-0.0127	-0.008
	PP	-0.0026	0.0068	0.0068	-0.0247	0.0061	0.0152	0.0010	-0.0051	-0.0274	0.0171	-0.0062	0.0007	0.0229	-0.0003	0.0001	-0.0040	0.007
TS	GP	0.0117	0.0005	0.0151	0.0020	0.0103	0.0233	0.0131	0.0231	-0.0122	0.0789	-0.0574	-0.0026	0.2229	0.0030	0.0052	-0.0142	0.323**
	PP	0.0180	-0.0019	0.0012	0.0020	-0.0083	0.0102	0.0035	0.0035	-0.0050	0.0937	0.0052	-0.0021	0.2074	-0.0067	-0.0060	-0.0070	0.308**
SL	GP	-0.0329	-0.0019	0.2120	0.0226	0.0058	0.0039	-0.0107	0.0207	0.0046	0.0198	-0.2290	-0.0027	-0.0375	0.0061	0.0175	-0.0279	-0.030
	PP	-0.0361	0.0052	0.0101	0.0116	-0.0020	0.0057	-0.0009	-0.0008	0.0033	0.0094	0.0519	-0.0037	-0.0206	-0.0047	-0.0065	-0.0055	0.016
S/S	GP	-0.0270	-0.0040	-0.0809	-0.0077	-0.0085	0.0127	0.0161	0.0621	-0.0008	0.0157	-0.0480	-0.0129	0.0429	-0.0067	0.0322	-0.0101	-0.025
	PP	-0.0441	0.0088	-0.0181	-0.0036	0.0063	0.0066	0.0030	0.0062	0.0011	0.0116	0.0113	-0.0168	0.0235	0.0114	-0.0291	-0.0038	-0.026
BY	GP	-0.0111	-0.0009	0.0441	-0.0100	-0.0153	0.0603	-0.0081	-0.0317	-0.0018	0.0233	0.0114	-0.0007	0.7557	-0.0066	0.0162	-0.0093	0.815**
	PP	-0.0178	0.0028	0.0088	-0.0081	0.0129	0.0325	-0.0023	-0.0053	-0.0008	0.0262	-0.0014	-0.0005	0.7426	0.0135	-0.0182	-0.0047	0.780**
TSW	GP	-0.0239	-0.0032	0.0126	-0.0126	-0.0079	0.0443	0.0031	-0.0073	0.0003	-0.0070	0.0416	-0.0026	0.1489	-0.0334	0.0252	-0.0008	0.177*
	PP	-0.0420	0.0102	0.0029	-0.0114	0.0064	0.0208	0.0009	-0.0026	0.0001	-0.0086	-0.0034	-0.0026	0.1383				

	PP	0.0217	-0.0045	0.0229	0.0004	-0.0324	0.0725	-0.0007	0.0055	0.0000	-0.0039	-0.0023	0.0034	-0.0935	-0.0138	0.1443	0.0046	0.124
OC	GP	-0.0153	-0.0018	0.0789	-0.0026	-0.0090	0.0781	0.0039	0.0200	-0.0092	0.0160	-0.0914	-0.0019	0.1002	-0.0004	0.0169	-0.0699	0.113
	PP	-0.0235	0.0048	0.0168	-0.0036	0.0073	0.0432	0.0006	0.0025	-0.0029	0.0176	0.0078	-0.0017	0.0935	-0.0011	-0.0180	-0.0369	0.106

Bold values shows direct and normal values shows indirect effects

RESIDUAL EFFECT = 0.0459 (Genotypic)

RESIDUAL EFFECT = 0.0251 (phenotypic)

Where,

DFP=days to 50% flowering, DRM= days to reproductive maturity,PH= plant height (cm),MAH= length of main axis (cm),LAI= leaf area index, CC= chlorophyll content, PB= number of primary branches, SB= number of secondary branches, SOMA=siliqua on main axis, TS= number of siliquae per plant,SL=siliqua length,S/S=seeds per siliqua, BY= biological yield per plant, TSW=1000-seed weight, HI=harvest index, OC= oil content, SY/P =seed yield per plant.

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