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

Abstract

A study for 17 agronomic traits was conducted 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 inhalf diallel fashion were grown in Randomized Block Design in three replications during rabi season (2021-22). Atphenotypic and genotypic level, seed yield per plant exhibited significant and positive correlation withplant 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 atgenotypic and phenotypic level was exhibited by plant height, total siliqua per plant and biological yield per plant in both $F_1$and F_2generations respectively, while number of primary branches, seeds per siliqua and oil content showed 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 plantexerted high correlation and direct effect on seed yield per plant generations. Hence, Thesecharactersmight be considered for selection and in improvementof seed yield of mustard genotypes.

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

Introduction

Indian mustard [Brassica juncea (L.) Czern and Coss] is the ranks second in oilseedcrops around the world as well as India.It is an allopolyploid species having 36 chromosomes (2n=36) and amphidiploid (2n=36) of Brassica compestris (2n=20) and Brassica nigra (2n=16). It is 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% in the total oilseeds production. Brassica juncea contributes to about 80 per cent 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, 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 of 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

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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 viz., (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 of 5m long 45 cm apart, appropriate plant to plant distance was maintained 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 fordays to 100% 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).

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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).

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The concept of correlation originally was presented and elaborated by Fisher (1918) and Wright (1921). Dewey and Lu (1959) recognizedthe nature of population under consideration as the magnitude of correlation coefficient. In the present investigation, the association study was taken up amongstF_1's and F_2's derived from half diallel design. In general, the magnitude of phenotypic correlation is in same direction but lower in revealing the pleiotropic effects rather than linkage for these 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 100% flowering (0.345),total siliqua (0.287),siliqua on main axis (0.220) andharvest index (0.243). Positively significant correlation with number of secondary branches (0.181) and non-significant positive correlation with number of primary branches (0.064),1000 seed weight (0.036) andmain 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.

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Seed yield/plant exhibited positive highly significant association at 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 non-significant correlation with harvest index (0.160), oil content (0.113), days to reproductive maturity (0.036), number of primary branches (0.034) andmain axis height (0.031). Non-significant and negative correlation withleaf 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) anddays to 100% flowering (-0.003) in F_2's.

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phenotypic correlation coefficient

Seed yield/plant exhibited positive highly significant association at phenotypic level with biological yield per plant (0.957), seeds per siliqua (0.315), plant height (0.299), total siliqua (0.284), days to 100% 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 positive highly significant association at 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), seedsper siliqua (-0.026), days to reproductive maturity (-0.024) and number of secondary branches (-0.001) in F_2's

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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 the understanding of 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

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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 100% 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 bydays to 100% 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 vianumber of seeds per siliqua (0.3994), days to reproductive maturity (0.3133), days to 100% 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 bygenotypic estimate ofresidual effect waschlorophyll content viaharvest 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 100% 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 generationgenotypic estimate ofresidual effect was 0.0080.Similar finding were reported byRay et al (2019) and Tripathi et al (2020).

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In F_2's highest positive direct effect on seed yield/plant was exerted bybiological 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 100% 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 100% 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 100% 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 100% 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 100% flowering via days to reproductive maturity (-0.943); days to reproductive maturity via days to 100% 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 100% flowering (-0.0581), number of primary branches (-0.0625); siliqua length via oil content (-0.0914), days to 100% 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 F_2's generation genotypic estimate of residual effect was 0.0158.Similar finding were reported byYadav et al (2021) and Lavanya et al(2022).

Phenotypic correlation coefficient

In F_1'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 bydays to 100% flowering viadays to reproductive maturity (0.0215);biological yield per plant vianumber of siliquae per plant (0.2948), plant height (0.2545), days to 100% 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 bybiological yield per plant vialeaf 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). Inthe F_1's generation genotypic estimate ofresidual effect was0.0459.Similar finding were reported byNur-E-Nabi 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 (0.7426) 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 100% 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

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days to 100% flowering via days to reproductive maturity (0.0215); biological yield per plant vianumber of siliquae per plant (0.2948), plant height (0.2545), days to 100% 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 (0.0272); While, high indirect negative impact on seed yield per plant at genotypic level was exhibited bydays to 100% flowering via days to maturity (-0.1511),chlorophyll content (-0.0443), seed/siliqua (-0.0441), 1000 seed weight (-0.0421);plant height via number of primary branches (-0.0228); main axis height viapods on main axis in (-0.0247); leaf area index via 1000-seed weight (-0.1927) and biological yield per plant (-0.1309), oil content (-0.324);biological yield per plants via leaf area index (-0.1383), harvest index (-0.0935);harvest index via seeds per siliqua (-0.0291), 1000 seed weight (-0.0275).Inthe F_2's generation genotypic estimate ofresidual effect was0.0251.Similar finding were reported bySingh et al(2017) and Rauf and Rahim (2018) The residual effect determine how the best factor accountfor the variability of the dependent variable t.e. seed yield perplant. The low estimate of residual effect suggest that most ofthe important traits contributing to yield have been includedin the study

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Table 1a: Phenotypic (P) and Genotypic (G) correlation coefficient analysis of F_1 for seed yield and its component traits in Indian mustard.

Hybrid		DHF	DRM	PH	MAH	LAI	CC	PB	SB	SOMA	TS	SL	S/S	BY	TSW	HI (%)	OC (%)	SY/P (g)
DHF	GC	1.000	0.979**	-0.063	0.277**	-0.267**	-0.307**	0.13	0.251**	0.069	0.019	-0.279**	0.094	0.345**	-0.103	0.044	-0.281**	0.345**
	PC	1.000	0.976**	-0.016	0.272**	-0.154	-0.230**	0.102	0.169*	0.068	0.014	-0.132	0.092	0.245**	-0.065	0.056	-0.143	0.232**
DRM	GC			-0.055	0.263**	-0.279**	-0.262**	0.129	0.241**	0.064	0.019	-0.326**	0.121	0.364**	-0.142	0.103	-0.300**	0.366**
	PC			-0.010	0.248**	-0.158	-0.195*	0.101	0.151	0.075	0.025	-0.127	0.084	0.238**	-0.087	0.090	-0.130	0.229**
PH	GC				0.274**	-0.058	0.003	0.225**	0.207*	0.246**	0.266**	0.236**	0.301**	0.325**	0.018	0.081	0.200*	0.361**
	PC				0.215*	-0.056	-0.009	0.162	0.173*	0.121	0.242**	0.136	0.217*	0.266**	0.018	0.026	0.091	0.299**
MAH	GC					-0.073	-0.300**	0.328**	0.503**	0.559**	0.328**	0.009	0.14	0.046	0.111	-0.115	0.148	0.03
	PC					-0.083	-0.223**	0.295**	0.465**	0.424**	0.295**	0.010	0.118	0.046	0.103	-0.112	0.132	0.037
LAI	GC						-0.265**	0.137	0.028	0.041	0.059	0.169*	-0.143	-0.165	0.105	0.242**	-0.197*	-0.12
	PC						-0.256**	0.142	0.026	0.006	0.054	0.130	-0.107	-0.159	0.100	0.204*	-0.163	-0.109
CC	GC							-0.476**	-0.598**	-0.319**	-0.198*	-0.041	-0.03	-0.167	-0.126	0.362**	0.153	-0.107
	PC							-0.424**	-0.535**	-0.152	-0.199*	-0.056	-0.012	-0.149	-0.108	0.232**	0.145	-0.097
PB	GC								0.717**	0.335**	0.497**	0.328**	0.113	0.111	0.062	-0.199*	0.019	0.064
	PC								0.690**	0.228**	0.476**	0.245**	0.103	0.107	0.058	-0.143	0.006	0.062
SB	GC									0.492**	0.633**	0.479**	0.323**	0.247**	0.071	-0.275**	-0.007	0.181*
	PC									0.335**	0.612**	0.351**	0.258**	0.243**	0.070	-0.216*	-0.014	0.181*
S0MA	GC										0.314**	0.216*	0.262**	0.265**	0.123	-0.172*	0.075	0.220**
	PC										0.204*	0.204*	0.194*	0.197*	0.101	-0.060	0.161	0.137
TS	GC											0.546**	0.368**	0.320**	0.014	-0.147	-0.103	0.287**
	PC											0.392**	0.296**	0.308**	0.008	-0.114	-0.089	0.284**
SL	GC												0.537**	0.338**	0.125	-0.142	0.017	0.346**
	PC												0.448**	0.247**	0.088	-0.098	0.016	0.216*
S/S	GC													0.463**	0.037	-0.357**	0.02	0.396**
	PC													0.388**	0.012	-0.234**	0.006	0.315**
BY	GC														0.03	0.093	-0.209*	0.977**
	PC														0.027	0.073	-0.154	0.957**
TSW	GC															0.236**	0.272**	0.036
	PC															0.176*	0.234**	0.034
HI (%)	GC																0.035	0.243**
	PC																-0.001	0.205*
OC (%)	GC																	-0.206*
	PC																	-0.173*
SY/P (g)	GC																	1
	PC																	1

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

DHF= days to 100% 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 F_2 for seed yield and its component traits in Indian mustard.

Hybrid		DHF	DRM	PH	MAH	LAI	CC	PB	SB	SOMA	TS	SL	S/S	BY	TSW	HI (%)	OC (%)	SY/P (g)
DHF	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
S0MA	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

DHF= days to 100% 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 F_1 for 17 characters in 10x10 Diallel cross in Indian mustard.

Hybrid		DHF	DRM	PH	MAH	LAI	CC	PB	SB	SOMA	TS	SL	S/S	BY	TSW	HI	OC	SY/P
DHF	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*

S0MA	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,

DHF= days to 100% 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 2b: Genotypic (G) and Phenotypic(P) Path coefficient of F_2 for 17 characters in 10x10 Diallel cross in Indian mustard

Hybrid		DHF	DRM	PH	MAH	LAI	CC	PB	SB	SOMA	TS	SL	S/S	BY	TSW	HI	OC	SY/P
DHF	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	0.0015	-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
S0MA	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	**0.0725**	-0.0275	0.0005	0.155
HI	GP	0.0136	0.0017	0.1246	0.0012	0.0407	0.1281	-0.0021	0.0240	-0.0007	-0.0035	0.0338	0.0035	-0.1035	0.0071	**-0.1184**	0.0100	0.160
	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,

DHF= days to 100% 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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