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

Durga Prasad, RK Yadav, Mahak Singh, Shweta, CP Sachan and RK Singh

Abstract
A study was conducted to evaluate correlation and path analysis of 16 yield and quality traits in Indian mustard (*Brassica juncea* L. Czern and Coss.). Ten diverse genotype and there crosses was evaluated in half diallel fashion during *Rabi* 2020-21 in a randomized block design with three replications. At phenotypic and genotypic level, seed yield per plant exhibit significant and positive correlation with 1000-seed weight (F_1) and harvest index (F_2). High direct positive impact on seed yield per plant at genotypic and phenotypic level was exhibited by no. of primary branches per plant (F_1) and protein content (F_2) respectively, while harvest index showed direct impact on seed yield at genotypic and phenotypic level in F_2's generations. Hence, these characters should be given more weightage in selection programme of high yielding genotypes.

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

Introduction
Indian mustard [*Brassica juncea* (L.) Czern and Coss] is the second most important oilseed crop of the world as well as India after groundnut. It is a natural amphidiploid (2n=36) of *Brassica compestris* (2n=20) and *Brassica nigra* (2n=16). It is self-compatible and largely self pollinated crop (85-90%). Indian mustard is popularly known as rai, raya or laha and it occupies considerably large acreage among the Brassica group of oil seed crops accounting for about 75-80% of the 6.6 million hectare under rapeseed-mustard in the country.
Brassica are economically most important genus consisting of oilseeds, vegetables and forage crops. *Brassica juncea* L. commonly known as Indian mustard, is the second most important oilseed crops of India next to groundnut, sharing 27.8 percent in the India's oilseed economy (Akanksha, 2017) [1]. Cytologically Indian mustard is an amphidiploid (2n=36), derived from interspecific cross of *Brassica compestris* L. (2n=20) and *Brassica nigra* L. (2n=16) followed by natural chromosome doubling.
India is third largest producer of mustard in the world after china and Canada with 12 percent of world's total production. India hold premier position in rapeseed- mustard in the world with 2ndand 3r^{d} rank in area and production, respectively. The demand of edible oils has been estimated to be increased upto 11.12 million tonnes by 2030. This is equal to production of 32.35 million tonnes of edible oilseeds in the year 2030.

Material and methods
The basic material in the present investigation comprised of ten varieties/ strains of Indian mustard namely, Aashirwad, NDR 501-26, Rohini, Basanti, KMR 17-5-23, KMR 17-5-22, KMR 17-5-21, Narendra Rai 8501, PR 21 and PR-20 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 comprising of 100 treatment *viz*., (10 parents + 45 F1's and 45 F2's) was evaluated in Randomized Block Design with three replications during *Rabi* 2020-2021. Each parent and F1's planted in one row, and F2's in two rows of 5m long 45 cm apart, 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 F1's and 20 plants in F2's were taken randomly for each treatment in each replication and tagged for recording observations for days to 50% flowering, Total

glucosinolate, leaf area index, days to maturity, plant height, seed yield per plants, no. of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, no. of seed per siliqua, 1000-seed weight, harvest index, oil content, protein content and erucic acid.

Result and discussion

Correlation coefficient analysis

The study of correlation provides an estimate of association between various characters. The yield, prime object for breeder, is a complex and polygenic character and highly influenced by environment. So direct selection only through yield would not be effective. Correlation studies of yield and its component characters decide the selection criteria to be adopted. The data available to the plant breeder on two or more plant characteristics of a sample or a group of strains of a particular crop helps immensely in estimating the degree of association among them (table 1a and 1b).

The original (primary) concept of correlation was presented and elaborated by Fisher (1918) and Wright (1921) [10]. De-Varies stated that correlation between botanical markers and breeding qualities are to be considered as reliable guide lines in the work of association. Duwey and Lu (1959) [4] emphasized to recognized to nature o population under consideration as the magnitude o correlation coefficient. In the present investigation, the association study was taken up amongs F1 and F2 derived from half diallel design. In general, the phenotypic correlation are in same direction but lower in magnitude revealing the pleiotropic effects rather than linkage for these association.

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

Characters		DFF	DM	LAE	PH	PBPP	SBPP	SPP	SPS	LMR	SI	HI	OC	PC	EA	TG	SYPP
Days to 50% flowering	P	1.00	0.186*	0.088	-0.009	0.081	0.006	-0.027	-0.021	-0.051	-0.139	0.024	-0.142	-0.181*	-0.013	0.091	0.040
	G	1.00	0.338**	0.114	-0.110	0.285**	0.020	-0.054	-0.058	-0.200**	-0.240**	0.006	-0.260**	-0.337**	-0.038	0.110	0.112
Days to maturity	P		1.000	0.188*	0.069	0.088	0.151	0.048	-0.021	-0.173*	-0.047	-0.162*	0.056	-0.148	0.186*	0.085	-0.077
	G		1.000	0.232**	0.076	0.119	0.177*	0.077	-0.155*	-0.344**	-0.084	-0.221**	0.106	-0.183*	0.237**	0.093	-0.094
Leaf Area Index	P			1.000	-0.065	0.518**	0.242**	0.313**	-0.061	0.159*	0.169*	0.121	0.116	0.056	-0.146	0.028	0.181*
	G			1.000	-0.065	0.874**	0.286**	0.365**	-0.089	0.246**	0.202**	0.152	0.127	0.079	-0.150	0.026	0.187*
Plant Height	P				1.000	-0.211**	-0.285**	-0.226**	-0.092	0.127	-0.242**	-0.106	-0.093	0.122	0.084	-0.216**	-0.075
	G				1.000	-0.432**	-0.340**	-0.262**	-0.202**	0.147	-0.260**	-0.127	-0.139	0.155*	0.087	-0.241**	-0.090
No. of Primary branches per plant	P					1.000	0.322**	0.329**	0.029	0.003	0.127	0.134	0.125	-0.063	-0.170*	0.068	0.126
	G					1.000	0.417**	0.621**	0.135	0.046	0.363**	0.198*	0.077	-0.064	-0.293**	0.100	0.156*
No. of Secondary branches per plant	P						1.000	0.638**	0.055	0.003	0.594**	0.227**	0.028	0.085	-0.196*	-0.123	0.257**
	G						1.000	0.777**	0.067	0.079	0.838**	0.307**	0.044	0.169*	-0.249**	-0.172*	0.346**
No. of siliqua per plant	P							1.000	0.036	0.069	0.625**	0.323**	-0.056	0.136	-0.269**	-0.125	0.334**
	G							1.000	0.098	0.128	0.749**	0.383**	-0.061	0.128	-0.305**	-0.143	0.416**
No. of seed per siliqua	P								1.000	0.275**	0.152	-0.044	0.034	-0.009	-0.075	-0.137	0.144
	G								1.000	0.391**	0.214**	-0.094	-0.018	-0.081	-0.124	-0.175*	0.253**
Length of Main Raceme	P									1.000	0.186*	-0.061	0.005	0.179*	-0.205**	-0.069	0.138
	G									1.000	0.311**	-0.014	-0.049	0.209**	-0.305**	-0.089	0.189*
1000-seed weight	P										1.000	0.220**	-0.154*	0.208**	-0.168*	-0.092	0.349**
	G										1.000	0.304**	-0.121	0.236**	-0.202**	-0.101	0.469**
Harvest Index	P											1.000	-0.062	0.078	-0.212**	0.051	0.225**
	G											1.000	-0.148	0.085	-0.239**	0.047	0.338**
Oil Content	P												1.000	0.155*	-0.075	0.101	-0.492**
	G												1.000	0.215**	-0.080	0.125	-0.710**
Protein content	P													1.000	0.059	0.100	0.098
	G													1.000	0.054	0.127	0.114
Erucic acid	P														1.000	0.259**	-0.049
	G														1.000	0.269**	-0.060
Total Glucosinolates	P															1.000	-0.222**
	G															1.000	-0.238**

Significance Levels * = <.05, ** = <.01 respectively.

Table 1b: Phenotypic (P) and Genotypic (G) correlation coefficient analysis of F_2 for seed yield and its component traits in Indian mustard.

Characters		DFF	DM	LAE	PH	PBPP	SBPP	SPP	SPS	LMR	SI	HI	OC	PC	EA	TG	SYPP
Days to 50% flowering	P	1.000	-0.014	-0.085	0.359**	0.107	-0.022	0.018	-0.126	0.168*	0.137	0.077	0.053	-0.369**	-0.074	0.058	-0.122
	G	1.00	0.001	-0.163*	0.442**	0.134	0.027	0.092	-0.419**	0.165*	0.272**	0.058	0.169*	-0.547**	-0.123	0.090	-0.126
Days to maturity	P		1.000	0.072	-0.057	0.086	0.144	0.059	-0.056	-0.170*	0.219**	0.051	0.112	0.024	-0.009	0.016	0.048
	G		1.000	0.104	-0.075	0.027	0.188*	0.135	-0.114	-0.300**	0.343**	0.066	0.137	0.004	0.013	0.034	0.006
Leaf Area Index	P			1.000	-0.182*	-0.200*	-0.013	-0.034	0.022	-0.156*	-0.056	-0.026	-0.062	0.074	0.055	0.094	0.046
	G			1.000	-0.230**	-0.305**	-0.063	-0.031	0.040	-0.209**	-0.055	-0.055	-0.096	0.091	0.061	0.099	0.085
Plant Height	P				1.000	0.176*	-0.035	0.061	-0.191*	0.397**	-0.008	0.131	0.073	-0.194*	-0.063	0.032	0.031
	G				1.000	0.230**	0.063	0.117	-0.401**	0.490**	0.019	0.208**	0.056	-0.229**	-0.067	0.045	-0.025
No. of Primary branches per plant	P					1.000	0.289**	0.324**	-0.032	0.008	0.056	0.038	0.039	0.111	0.217**	0.130	0.069
	G					1.000	0.568**	0.546**	0.152	0.051	0.112	0.017	0.039	0.141	0.281**	0.171*	0.139
No. of Secondary branches per plant	P						1.000	0.706**	0.076	-0.001	-0.006	0.097	-0.209**	-0.180*	0.133	0.192*	0.188*
	G						1.000	1.015**	0.123	0.021	0.071	0.164*	-0.269**	-0.257**	0.214**	0.282**	0.426**
No. of siliqua per plant	P							1.000	0.073	0.091	-0.102	0.172*	-0.129	-0.207**	0.145	0.238**	0.304**
	G							1.000	0.269**	0.180*	-0.153*	0.267**	-0.215**	-0.284**	0.186*	0.291**	0.489**
No. of seed per siliqua	P								1.000	-0.077	-0.165*	0.022	-0.151	0.166*	0.043	0.007	0.216**
	G								1.000	-0.272**	-0.291**	0.040	-0.262**	0.322**	0.089	0.022	0.452**
Length of Main Raceme	P									1.000	-0.235**	0.137	0.094	-0.199*	0.185*	0.050	0.046
	G									1.000	-0.325**	0.181*	0.097	-0.246**	0.221**	0.068	0.053
1000-seed weight	P										1.000	0.006	0.277**	-0.080	-0.018	0.049	-0.241**
	G										1.000	-0.032	0.344**	-0.117	-0.013	0.044	-0.307**
Harvest Index	P											1.000	-0.276**	-0.098	0.011	-0.074	0.484**
	G											1.000	-0.405**	-0.124	0.014	-0.089	0.765**
Oil Content	P												1.000	0.045	-0.131	0.184*	-0.452**
	G												1.000	0.053	-0.154*	0.211**	-0.668**
Protein content	P													1.000	0.215**	0.179*	-0.022
	G													1.000	0.234**	0.201**	-0.042
Erucic acid	P														1.000	0.279**	0.128

	G														1.000	0.287**	0.176*
Total Glucosinolates	P															1.000	-0.026
	G															1.000	-0.036

Significance Levels * = <.05, ** = <.01 respectively.

Where,

Days to 50% flowering=DFF, Days to Maturity=DM, Leaf Area Index=LAI, Plant Height=PH, No. of Primary branches per plant=PBPP, No. of Secondary branches per plant=SBPP, No. of siliqua per plant=SPS, No. of seed per siliqua=SPS, Length of Main Raceme=LMR, 1000-seed weight=SI, Harvest Index=HI, Oil Content=OC, Protein content=PC, Erucic acid=EA, Total Glucosinolates=TG, Seed Yield Per Plant=SYPP.

Phenotypic correlation coefficient

In F_1, Seed yield per plant exhibit significant and positive correlation with 1000-seed weight (0.349) followed by no. of siliqua per plant (0.334), no. of secondary branches (0.257) harvest index (0.225) and leaf area index (0.181); non significant and positive correlation with days to 50 % flowering (0.04) followed by no. of primary branches(0.126), no. of seed per siliqua (0.144), length of main raceme(0.138), protein content (0.098).

In F2, Seed yield per plant exhibit significant and positive correlation with harvest index (0.484) followed by no. of siliqua per plant (0.304), no. of secondary branches (0.188) no. of seed per siliqua (0.216), erucic acid (0.128); non significant and positive correlation with no. of primary branches (0.069) followed by plant height (0.031), leaf area index (0.046) days to maturity (0.048) and length of main raceme (0.046) Similar finding were reported by Singh *et. al.* (2014) [9] and Akabari and Niranjan (2015) [2].

Genotypic correlation coefficient

In F_1 generation, Seed yield per plant exhibit significant and positive correlation with 1000-seed weight (0.469) followed by no. of siliqua per plant (0.416), no. of secondary branches (0.346), harvest index (0.338), no of seed per siliqua (0.253), length of main raceme (0.189), leaf area index (0.187), no. of primary branches (0.156. In F_2 generation, Seed yield per plant exhibit significant and positive correlation with harvest index (0.765) followed by no. of seed per siliqua (0.452), no. of secondary branches (0.426), erucic acid (0.176. Similar finding were reported by Singh *et. al.* (2014) [9], Akabari and Niranjan (2015) [2], Dipti *et. al.* (2016) [3] and Kumar *et. al.* (2017) [5].

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) [10] and later more lucidly explained by Dewey and Lu (1959) [4].

Table 2a: Genotypic (G) and Phenotypic(P) Path coefficient of F1 for 16 character in 10x10 Diallel cross in Indian mustard

Characters		DFF	DM	LAE	PH	PBPP	SBPP	SPP	SPS	LMR	SI	HI	OC	PC	EA	TG	SYPP
Days to 50% flowering	G	-0.246	0.099	-0.059	0.011	0.231	0.007	0.018	-0.003	-0.062	0.050	0.002	0.220	-0.118	-0.005	-0.032	0.112
	P	0.010	-0.006	0.014	0.001	0.005	0.000	-0.002	-0.002	-0.004	-0.004	0.003	0.072	-0.028	-0.001	-0.019	0.040
Days to maturity	G	-0.083	0.292	-0.119	-0.007	0.096	0.062	-0.025	-0.008	-0.106	0.018	-0.065	-0.090	-0.064	0.032	-0.027	-0.094
	P	0.002	-0.031	0.029	-0.008	0.005	0.009	0.004	-0.002	-0.012	-0.001	-0.021	-0.029	-0.023	0.018	-0.017	-0.077
Leaf Area Index	G	-0.028	0.068	-0.514	0.006	0.709	0.101	-0.121	-0.004	0.076	-0.042	0.044	-0.107	0.028	-0.021	-0.007	0.187*
	P	0.001	-0.006	0.153	0.007	0.029	0.015	0.028	-0.007	0.011	0.004	0.016	-0.059	0.009	-0.014	-0.006	0.181*
Plant Height	G	0.027	0.022	0.034	-0.096	-0.351	-0.119	0.086	-0.010	0.046	0.054	-0.037	0.118	0.054	0.012	0.070	-0.090
	P	0.000	-0.002	-0.010	-0.110	-0.012	-0.018	-0.020	-0.011	0.009	-0.006	-0.014	0.047	0.019	0.008	0.044	-0.075
No. of Primary branches per plant	G	-0.070	0.035	-0.449	0.042	0.811	0.147	-0.205	0.007	0.014	-0.076	0.058	-0.065	-0.022	-0.040	-0.029	0.156*
	P	0.001	-0.003	0.079	0.023	0.056	0.020	0.029	0.003	0.000	0.003	0.017	-0.064	-0.010	-0.016	-0.014	0.126
No. of Secondary branches per plant	G	-0.005	0.052	-0.147	0.033	0.339	0.351	-0.257	0.003	0.025	-0.175	0.090	-0.037	0.059	-0.034	0.050	0.346**
	P	0.000	-0.005	0.037	0.032	0.018	0.061	0.057	0.006	0.000	0.015	0.030	-0.015	0.013	-0.019	0.025	0.257**
No. of siliqua per plant	G	0.013	0.022	-0.188	0.025	0.504	0.273	-0.330	0.005	0.040	-0.157	0.112	0.052	0.045	-0.042	0.042	0.416**
	P	0.000	-0.002	0.048	0.025	0.018	0.039	0.089	0.004	0.005	0.016	0.042	0.028	0.021	-0.026	0.026	0.334**
No. of seed per siliqua	G	0.014	-0.045	0.046	0.019	0.109	0.024	-0.032	0.049	0.121	-0.045	-0.027	0.016	-0.028	-0.017	0.051	0.253**
	P	0.000	0.001	-0.009	0.010	0.002	0.003	0.003	0.115	0.019	0.004	-0.006	-0.018	-0.001	-0.007	0.028	0.144
Length of Main Raceme	G	0.049	-0.100	-0.126	-0.014	0.037	0.028	-0.042	0.019	0.309	-0.065	-0.004	0.041	0.073	-0.042	0.026	0.189*
	P	-0.001	0.005	0.024	-0.014	0.000	0.000	0.006	0.032	0.069	0.005	-0.008	-0.003	0.028	-0.019	0.014	0.138
1000-seed weight	G	0.059	-0.025	-0.104	0.025	0.294	0.294	-0.247	0.010	0.096	-0.209	0.089	0.102	0.083	-0.028	0.029	0.469**
	P	-0.001	0.001	0.026	0.027	0.007	0.037	0.056	0.018	0.013	0.025	0.029	0.079	0.032	-0.016	0.019	0.349**
Harvest Index	G	-0.002	-0.065	-0.078	0.012	0.161	0.108	-0.126	-0.005	-0.004	-0.064	0.292	0.125	0.030	-0.033	-0.014	0.338**
	P	0.000	0.005	0.019	0.012	0.007	0.014	0.029	-0.005	-0.004	0.006	0.130	0.032	0.012	-0.020	-0.011	0.225**
Oil Content	G	0.064	0.031	-0.065	0.013	0.062	0.015	0.020	-0.001	-0.015	0.025	-0.043	-0.845	0.075	-0.011	-0.036	-0.710**
	P	-0.002	-0.002	0.018	0.010	0.007	0.002	-0.005	0.004	0.000	-0.004	-0.008	-0.509	0.024	-0.007	-0.021	-0.492**
Protein content	G	0.083	-0.053	-0.041	-0.015	-0.052	0.059	-0.042	-0.004	0.065	-0.049	0.025	-0.182	0.350	0.007	-0.037	0.114
	P	-0.002	0.005	0.009	-0.014	-0.004	0.005	0.012	-0.001	0.012	0.005	0.010	-0.079	0.154	0.006	-0.021	0.098
Erucic acid	G	0.009	0.069	0.077	-0.008	-0.238	-0.087	0.101	-0.006	-0.094	0.042	-0.070	0.067	0.019	0.137	-0.078	-0.060
	P	0.000	-0.006	-0.022	-0.009	-0.009	-0.012	-0.024	-0.009	-0.014	-0.004	-0.028	0.038	0.009	0.095	-0.053	-0.049
Total Glucosinolates	G	-0.027	0.027	-0.013	0.023	0.082	-0.060	0.047	-0.009	-0.028	0.021	0.014	-0.106	0.044	0.037	-0.290	-0.238**
	P	0.001	-0.003	0.004	0.024	0.004	-0.008	-0.011	-0.016	-0.005	-0.002	0.007	-0.051	0.015	0.024	-0.205	-0.222**

Bold values shows direct and normal values shows indirect effects

R SQUARE = 0.7406 RESIDUAL EFFECT = 0.5093 (Genotypic)

R SQUARE = 0.4617 RESIDUAL EFFECT = 0.7337 (phenotypic)

Where,

Days to 50% flowering=DFF, Days to Maturity=DM, Leaf Area Index=LAI, Plant Height=PH, No. of Primary branches per plant=PBPP, No. of Secondary branches per plant=SBPP, No. of siliqua per plant=SPS, No. of seed per siliqua=SPS, Length of Main Raceme=LMR, 1000-seed weight=SI, Harvest Index=HI, Oil Content=OC, Protein content=PC, Erucic acid=EA, Total Glucosinolates=TG, Seed Yield Per Plant=SYPP.

Table 2b: Genotypic (G) and Phenotypic (P) Path coefficient of F_2 for 15 character in 10x10 Diallel cross in Indian mustard

Characters		DFF	DM	LAE	PH	PBPP	SBPP	SPP	SPS	LMR	SI	HI	OC	PC	EA	TG	SYPP
Days to 50% flowering	G	**-0.005**	0.000	-0.010	-0.025	0.005	-0.007	0.039	-0.088	-0.003	-0.012	0.033	-0.056	0.008	-0.007	0.000	-0.126
	P	**-0.142**	-0.001	-0.002	0.025	0.003	0.003	0.004	-0.018	-0.004	-0.018	0.029	-0.016	0.018	-0.004	0.001	-0.122
Days to maturity	G	0.000	**0.025**	0.006	0.004	0.001	-0.047	0.058	-0.024	0.005	-0.016	0.037	-0.045	0.000	0.001	0.000	0.006
	P	0.002	**0.097**	0.002	-0.004	0.003	-0.018	0.014	-0.008	0.004	-0.028	0.019	-0.033	-0.001	-0.001	0.000	0.048
Leaf Area Index	G	0.001	0.003	**0.060**	0.013	-0.012	0.016	-0.013	0.008	0.004	0.003	-0.031	0.031	-0.001	0.004	0.000	0.085
	P	0.012	0.007	**0.028**	-0.013	-0.006	0.002	-0.008	0.003	0.003	0.007	-0.010	0.018	-0.004	0.003	0.002	0.046
Plant Height	G	-0.002	-0.002	-0.014	**-0.055**	0.009	-0.016	0.050	-0.084	-0.009	-0.001	0.117	-0.018	0.003	-0.004	0.000	-0.025
	P	-0.051	-0.006	-0.005	**0.069**	0.005	0.005	0.014	-0.027	-0.009	0.001	0.048	-0.021	0.009	-0.004	0.001	0.031
No. of Primary branches per plant	G	-0.001	0.001	-0.019	-0.013	**0.039**	-0.142	0.235	0.032	-0.001	-0.005	0.010	-0.013	-0.002	0.017	0.001	0.139
	P	-0.015	0.008	-0.006	0.012	**0.030**	-0.037	0.076	-0.005	0.000	-0.007	0.014	-0.011	-0.005	0.012	0.003	0.069
No. of Secondary branches per plant	G	0.000	0.005	-0.004	-0.004	0.022	**-0.250**	0.436	0.026	0.000	-0.003	0.093	0.088	0.004	0.013	0.001	0.426**
	P	0.003	0.014	0.000	-0.003	0.009	**-0.127**	0.165	0.011	0.000	0.001	0.036	0.061	0.009	0.007	0.004	0.188*
No. of siliqua per plant	G	0.000	0.003	-0.002	-0.007	0.021	-0.253	**0.429**	0.057	-0.003	0.007	0.150	0.071	0.004	0.011	0.001	0.489**
	P	-0.003	0.006	-0.001	0.004	0.010	-0.090	**0.233**	0.010	-0.002	0.013	0.064	0.037	0.010	0.008	0.005	0.304**
No. of seed per siliqua	G	0.002	-0.003	0.002	0.022	0.006	-0.031	0.116	**0.210**	0.005	0.013	0.023	0.086	-0.005	0.005	0.000	0.452**
	P	0.018	-0.005	0.001	-0.013	-0.001	-0.010	0.017	**0.140**	0.002	0.021	0.008	0.044	-0.008	0.002	0.000	0.216**
Length of Main Raceme	G	-0.001	-0.007	-0.013	-0.027	0.002	-0.005	0.077	-0.057	**-0.018**	0.015	0.102	-0.032	0.004	0.013	0.000	0.053
	P	-0.024	-0.017	-0.004	0.028	0.000	0.000	0.021	-0.011	**-0.021**	0.030	0.051	-0.027	0.010	0.010	0.001	0.046
1000-seed weight	G	-0.001	0.008	-0.003	-0.001	0.004	-0.018	-0.066	-0.061	0.006	**-0.045**	-0.018	-0.113	0.002	-0.001	0.000	-0.307**
	P	-0.020	0.021	-0.002	-0.001	0.002	0.001	-0.024	-0.023	0.005	**-0.127**	0.002	-0.080	0.004	-0.001	0.001	-0.241**
Harvest Index	G	0.000	0.002	-0.003	-0.012	0.001	-0.041	0.115	0.008	-0.003	0.002	**0.563**	0.133	0.002	0.001	0.000	0.765**
	P	-0.011	0.005	-0.001	0.009	0.001	-0.012	0.040	0.003	-0.003	-0.001	**0.370**	0.080	0.005	0.001	-0.002	0.484**
Oil Content	G	-0.001	0.003	-0.006	-0.003	0.002	0.067	-0.092	-0.055	-0.002	-0.016	-0.228	**-0.328**	-0.001	-0.009	0.001	-0.668**
	P	-0.008	0.011	-0.002	0.005	0.001	0.027	-0.030	-0.021	-0.002	-0.035	-0.102	**-0.290**	-0.002	-0.007	0.004	-0.452**
Protein content	G	0.003	0.000	0.006	0.013	0.006	0.064	-0.122	0.068	0.004	0.005	-0.070	-0.018	**-0.015**	0.014	0.001	-0.042
	P	0.053	0.002	0.002	-0.013	0.003	0.023	-0.048	0.023	0.004	0.010	-0.036	-0.013	**-0.048**	0.012	0.004	-0.022
Erucic acid	G	0.001	0.000	0.004	0.004	0.011	-0.053	0.080	0.019	-0.004	0.001	0.008	0.051	-0.004	**0.059**	0.001	0.176*
	P	0.011	-0.001	0.002	-0.004	0.007	-0.017	0.034	0.006	-0.004	0.002	0.004	0.038	-0.010	**0.056**	0.006	0.128
Total Glucosinolates	G	0.000	0.001	0.006	-0.003	0.007	-0.070	0.125	0.005	-0.001	-0.002	-0.050	-0.069	-0.003	0.017	**0.003**	-0.036
	P	-0.008	0.002	0.003	0.002	0.004	-0.025	0.056	0.001	-0.001	-0.006	-0.027	-0.054	-0.009	0.016	**0.021**	-0.026

Bold values shows direct and normal values shows indirect effect
* &** Signficant at 5% & 1% respectively
R SQUARE = 0.8852 Residual Effect = 0.3388 (Genotypic)
R SQUARE = 0.4520 Residual Effect = 0.7403 (phenotypic)
Where,
Days to 50% flowering=DFF, Days to Maturity=DM, Leaf Area Index=LAI, Plant Height=PH, No. of Primary branches per plant=PBPP, No. of Secondary branches per plant=SBPP, No. of siliqua per plant=SPS, No. of seed per siliqua=SPS, Length of Main Raceme=LMR, 1000-seed weight=SI, Harvest Index=HI, Oil Content=OC, Protein content=PC, Erucic acid=EA, Total Glucosinolates=TG, Seed Yield Per Plant=SYPP.

Genotypic path coefficient

In F_1's, high direct positive impact on seed yield per plant at genotypic level was exhibited by no. of primary branches (0.8114), no of secondary branches (0.351) and protein content (0.3495) while high direct negative impact on leaf area index (-0.514), no. of siliqua per plant (-0.330), days to 50 % flowering(-0.246). In this generation, high indirect positive effect on seed yield per plant at genotypic level was exhibited by days to 50 % flowering via protein content (0.083), oil content (0.064); days to maturity via leaf area index (0.067), no. of secondary branches (0.051); leaf area index via erucic acid (0.077), no. of seed per siliqua (0.045); plant height via no. of primary branches (0.041); no. of primary branches per plant via no. of siliqua per plant (0.504), no. of secondary branches (0.338); no. of secondary branches via no. of siliqua per plant (0.272); no. of siliqua per plant via erucic acid (0.100); no. of seed per siliqua via length of main raceme (0.019); length of main raceme via 1000-seed weight (0.096); 1000-seed weight via erucic acid (0.422); oil content via erucic acid (0.067); erucic acid via glucosinolate (0.036) While, high indirect negative impact on seed yield per plant at genotypic level was exhibited by leaf area index via no. of primary branches (-0.449); no. of siliqua per plant via 1000-seed weight (-0.247), no. of primary branches per plant via erucic acid (-0.237). In F_1 generation, genotypic estimate of residual effect was 0.509.

In F_2's, high direct positive impact on seed yield per plant at genotypic level was exhibited by harvest index (0.562), no. of siliqua per plant (0.429); high direct negative impact on seed yield per plant exhibited by oil content (-0.328), no. of secondary branches (-0.249). In this generation, high indirect positive impact on seed yield per plant at genotypic level was exhibited by plant height via no of seed per siliqua (0.222); no. of primary branches per plant via no. of siliqua per plant (0.214); no. of siliqua per plant via no of seed per siliqua (0.115), harvest index (0.114) While, high indirect negative impact on seed yield per plant at genotypic level was exhibited by plant height via length of main raceme (-0.027); no. of siliqua per plant via protein content (-0.122); no. of seed per siliqua via 1000-seed weight (-0.0612), harvest index via oil content (-0.227). In F_2 generation, genotypic estimate of residual effect was 0.338. Similar finding were reported by Shekawat *et al.* (2014) [8].

Phenotypic path coefficient

In F_1's, high direct positive impact on seed yield per plant at phenotypic level was exhibited by protein content (0.1538), leaf area index (0.1532) and high direct negative impact on seed yield per plant exhibited by oil content (-0.508), total glucosinolate (-0.205). In F_1's, high indirect positive impact on seed yield per plant at phenotypic level was exhibited by plant height via no. of secondary branches (0.315); leaf area index via no. of siliqua per plant (0.048); no. of siliqua per plant via 1000-seed weight (0.0559); no of seed per siliqua

via length of main raceme (0.0316); oil content via erucic acid (0.038); erucic acid via glucosinolate content (0.0244). The rest of estimate of indirect negative impact on seed yield per plant at phenotypic level was negligible. In F_1 generation, phenotypic estimate of residual effect was 0.733.

In F_2's, high direct positive impact on seed yield per plant at phenotypic level was exhibited by harvest index (0.369) and leaf area index (0.0284); and high direct negative impact on seed yield per plant exhibited by oil content (-0.290),days to 50 % flowering (-0.1423).

In F_2's, high direct positive impact on seed yield per plant at phenotypic level was exhibited by harvest index (0.562) followed by no. of siliqua per plant (0.429), no of seed per siliqua (0.210), leaf area index (0.0604), erucic acid (0.059), no of primary branches per plan(0.039). In this generations, high indirect positive impact on seed yield per plant at genotypic level was exhibited by days to 50 % flowering via protein content (0.052); days to maturity via 1000-seed weight (0.021); plant height via length of main raceme (0.027); no. of secondary branches per plant via oil content (0.022); no. of siliqua per plant via total glucosinolate (0.055). In F_2, generation, phenotypic estimate of residual effect was 0.7403. Similar finding were reported by Lodhi *et al*. (2014) [6]. The residual effect determine how the best factor account for the variability of the dependent variable *t.e*. seed yield per plant. The low estimate of residual effect suggest that most of the important traits contributing to yield have been included in the study.

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