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Research Note

Elucidation of genetic variability and inter-relationship studies for seed yield and quality traits in Indian mustard [*Brassica juncea* (L.) Czern and Coss]

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Abstract
Forty five genotypes of Indian mustard [*Brassica juncea* (L.) Czern and Coss] were evaluated for seed yield and quality traits in Randomized Block Design with four replications during the *Rabi*, 2019-2020. The analysis of variance revealed that the mean sum of squares due to genotypes was significant for all the eighteen characters studied indicating the presence of variability for all the traits among the genotypes under study. Low difference between genotypic and phenotypic variances revealed that the contribution of genotypic variance to total variance was more for all the traits except days to maturity and plant height. The high values of genotypic and phenotypic coefficient of variation for the number of branches per plant, seed yield per plant , myristic acid, palmitic acid and stearic acid which indicated the potential variability available for these traits. The high heritability estimates obtained in conjunction with high genetic advance were observed for the number of branches per plant, the number of siliquae per plant, seeds per siliqua, length of siliqua , 1000-seed weight , seed yield per plant , myristic acid , palmitic acid, stearic acid , linoleic acid , linolenic acid and glucosinolate suggesting the predominant role of additive gene action for their expression. Association analysis between seed yield per plant and other seventeen characters revealed significantly positive correlation of seed yield per plant with the number of siliquae per plant, seeds per siliqua, length of siliquam, myristic acid and erucic acid. Path analysis revealed positive direct effects of the number of siliquae per plant and seeds per siliqua towards seed yield per plant while myristic acid, the number of branches per plant had a positive indirect effect on seed yield per plant *via* the number of siliquae per plant suggesting that the selection for such traits would be more effective for improving seed yield in Indian mustard.

Key words
Indian mustard, genetic variability, heritability, genetic advance, correlation and path analysis

Indian mustard [*Brassica juncea* (L.) Czern and Coss] is one of the prime oilseed crops of the country occupying largest area among the *Brassica* group of oil seed crops. Indian mustard is a natural amphidiploids of *Brassica campestris* (2n=20) and *Brassica nigra* (2n=16). It is predominantly self-pollinated crop. However, a certain amount of cross pollination of 2 to 15 per cent may take place by honey bees carrying pollen and wind. Indian mustard is predominantly cultivated in the States of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat. Indian mustard seed contains about 38 to 42 per cent oil and 24 per cent protein. Oil is predominantly triglyceride composed of fatty acid and also consists of unsaponifiable hydrocarbon like terpenes, sterol,

tocopherol, glycolipids and phospholipids. Erucic acid and glucosinolate are the anti-nutritional components present in the oil. Erucic acid constitutes of more than fifty per cent and glucosinolate more than 20 µmoles/g.

The success of any breeding programme depends upon the genetic variability present in the breeding material. For making an effective selection, the assessment of parameters including phenotypic and genotypic coefficients of variation, heritability in the broad sense and genetic advance as per cent of mean is a pre-requisite. Yield is a complex trait, polygenic in inheritance, more prone to environmental fluctuations than ancillary traits such as the number of branches per plant, seeds per siliqua, main shoot length and 1000 seed weight. The association between yield and its components is of great importance for making the best use of these relationships in selection (Sarawgi *et al*., 1997). The path analysis helps breeders to exploit the direct and indirect effect of different traits on seed yield for future breeding programme. Therefore, the present investigation was carried out to study the genetic variability, character associations and path analysis in Indian mustard.

The experimental material comprising of forty five genotypes of Indian mustard were grown in Randomized Block Design with four replications at Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during the *Rabi,* 2019-2020. The observations were recorded on five randomly selected plants from each genotypes in each replications for eighteen characters *viz.,* days to flowering, days to maturity, plant height (cm), the number of branches per plant, the number of siliquae per plant, seeds per siliqua, length of siliqua (cm), 1000-seed weight (g), seed yield per plant (g), oil content (%), myristic acid (%), palmitic acid (%), stearic acid (%), oleic acid (%), linoleic acid (%), linolenic acid (%), erucic acid (%) and glucosinolate (µmole/g). Oil content was determined in percentage through Nuclear Magnetic Resonance (NMR) technique (Tiwari *et al*., 1974). Fatty acid profile was analyzed by gas liquid chromatography (GC Thermo-Trace ultra-Al 3000 Auto sampler model). The glucosinolate content in Indian mustard genotypes was determined by the nondestructive method suggested by Kumar *et al*. (2010) using FT-NIRs (Fourier Transform Near Infrared Reflectance Spectroscopy) model MPA make by Bucker. The mean over replication of each character was subjected to statistical analysis. Genotypic and phenotypic variances were computed according to method suggested by Johnson *et al*. (1955). Analysis of variance to test the significance for each character was carried out as per the methodology given by Panse and Sukhatme (1978). The genotypic and phenotypic coefficient of variation (GCV and PCV) were estimated based on the formulae given by Burton (1952) and heritability and genetic advance

Table 1. Analysis of variance for different characters in Indian mustard

S. No.	Characters	Mean Sum of Squares		
		Replications	Genotypes	Error
		df = 3	df = 44	df = 132
1	Days to flowering	3.2796	88.8896**	8.7758
2	Days to maturity	10.9389	84.3659**	26.1018
3	Plant height	10.0320	2355.0462**	475.4773
4	Number of branches per plant	1.9884	76.4872**	3.0808
5	Number of siliquae per plant	249.9548	8917.8400**	1002.8375
6	Seeds per siliqua	0.1928	16.6534**	0.5745
7	Length of siliqua	0.0048	1.7675**	0.0586
8	1000-seed weight	0.0036	2.5532**	0.0107
9	Seed yield per plant	1.3656	98.1220**	3.2788
10	Oil content	0.0484	18.2384**	0.6405
11	Myristic acid	0.0008	0.2366**	0.0009
12	Palmitic acid	0.0002	1.2926**	0.0011
13	Stearic acid	0.0117	9.8516**	0.0052
14	Oleic acid	0.1927	12.8343**	0.1222
15	Linoleic acid	0.0119	18.7839**	0.1081
16	Linolenic acid	0.0505	3.5669**	0.0510
17	Erucic acid	2.7121	21.6572**	2.7910
18	Glucosinolate	9.6784	461.3689**	4.1684

** significant at 0.01% level. df = Degree of freedom

as per cent mean were calculated according to Allard (1960). Heritability percentage was categorized as (<30% = Low, 30-60% = Moderate, >60% = High) demonstrated by Robinson *et al*. (1949). The genetic advance as per cent of mean was categorized as (<10% = Low, 10-20 % = Moderate, >20% = High) demonstrated by Johnson *et al*. (1955). Correlation coefficient and path coefficient was worked out as suggested by Al-Jibouri *et al.* (1958) and Dewey and Lu (1959), respectively.

The analysis of variance revealed that the mean sum of square due to genotype was significant for all the eighteen traits under study, which indicated the presence of considerable variability among the genotypes study (**Table 1**). The difference between genotypic and phenotypic variances was low indicating more contribution of genotypic variance to the total variance for all the traits except day to maturity and plant height (**Table 2**). Similar results were also observed by Akabari and Niranjana (2015), Iqbal *et al.* (2019), Patel *et al.* (2019) and Saiyad *et al.* (2020a). The estimates of GCV and PCV were very high for the various traits like the number of branches per plant, seed yield per plant, myristic acid, palmitic acid and stearic acid, whereas the moderate estimates of GCV and PCV were observed for plant height, the number of siliquae per plant, seeds per siliqua, length of siliqua, 1000-seed weight, linoleic acid and linolenic acid and low for days to maturity, oil content and erucic acid (**Table 1**). Similar findings were earlier reported by Raliya *et al.* (2018), Chaurasiya *et al.* (2019), Kumar *et al.* (2019), Tripathi *et al.* (2019), Pandey *et al.* (2020) and Saiyad *et al.* (2020a). The GCV and PCV do not confirm the full scope of heritable variation in genotype under study. It can be determined with more accuracy when heritability with genetic advance is studied. Therefore, heritability and genetic advance plays important role in the improvement of various characters through selection. The magnitude of heritability was high for all the characters under study *viz.,* days to flowering, the number of branches per plant, the number of siliquae per plant, seeds per siliqua, length of siliqua, 1000-seed weight, seed yield per plant, oil content, myristic acid, palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, erucic acid and glucosinolate while, days to maturity, plant height and erucic acid had moderate heritability. The high heritability coupled with high genetic advance was found for the number of branches per plant, the number of siliquae per plant, seeds per siliqua, length of siliqua, 1000-seed weight, seed yield per plant, myristic acid, palmitic acid, stearic acid, linoleic acid, linolenic acid and glucosinolate. This indicated the major role of additive gene action for the expression of these traits and improvement in these traits could be made by selection in Indian mustard. The present findings are in accordance with Shekhawat *et al*. (2014), Raliya *et al.* (2018), Gupta *et al.* (2019), Tripathi *et al.* (2019) and Pandey *et al.* (2020). Seed yield, being a complex quantitative trait, is

Table 2. Mean, range, genotypic, phenotypic and environmental variance, GCV, PCV, h^2 (broad sense) and GA as per cent of mean for different characters in Indian mustard

Characters	Mean	Range	Genotypic variance	Phenotypic variance	Environmental variance	GCV (%)	PCV (%)	h^2 (broad sense) (%)	GA as % of mean
Days to flowering	46.71	37.00-55.25	20.03	28.80	8.78	9.58	11.49	69.53	16.46
Days to maturity	105.53	96.25-114.50	14.57	40.67	26.10	3.60	6.04	35.64	4.43
Plant height (cm)	191.36	142.40-247.55	469.89	945.37	475.48	11.33	16.07	49.71	16.45
Number of branches per plant	18.03	9.90-26.90	18.35	21.43	3.08	23.75	25.67	85.63	45.28
Number of siliquae per plant	286.07	181.78-399.83	1978.75	2981.59	1002.84	15.55	19.09	66.37	26.10
Seeds per siliqua	12.04	7.75-16.80	4.02	4.59	0.57	16.66	17.81	87.50	32.10
Length of siliqua (cm)	4.81	3.54-6.33	0.43	0.49	0.06	13.58	14.48	87.95	26.23
1000-seed weight (g)	5.49	3.88-7.08	0.64	0.65	0.01	14.53	14.65	98.35	29.69
Seed yield per plant (g)	18.19	12.02-33.58	23.71	26.99	3.28	26.78	28.57	87.85	51.70
Oil content (%)	38.46	32.42-41.50	4.40	5.04	0.64	5.45	5.84	87.29	10.50
Myristic acid (%)	1.02	0.44-1.40	0.06	0.06	0.00	23.89	24.08	98.44	48.82
Palmitic acid (%)	1.63	0.97-2.72	0.32	0.32	0.00	34.78	34.83	99.67	71.52
Stearic acid (%)	4.04	1.34-7.95	2.46	2.47	0.01	38.80	38.84	99.79	79.84
Oleic acid (%)	20.87	18.00-24.46	3.18	3.30	0.12	8.54	8.71	96.30	17.27
Linoleic acid (%)	15.13	11.18-19.82	4.67	4.78	0.11	14.28	14.45	97.74	29.09
Linolenic acid (%)	5.92	4.32-8.63	0.88	0.93	0.05	15.84	16.29	94.52	31.72
Erucic acid (%)	51.40	45.28-55.74	4.72	7.51	2.79	4.23	5.33	62.82	6.90
Glucosinolate (µmole/g)	107.46	80.14-130.26	114.30	118.47	4.17	9.95	10.13	96.48	20.13

Table 3. Genotypic (r_g) and phenotypic (r_p) correlation coefficient of seed yield per plant with quantitative characters in Indian mustard

Character		Days to maturity	Plant height	Number of branches per plant	Number of siliquae per plant	Seeds per siliqua	Length of siliqua	1000-seed weight	Seed yield per plant
Days to flowering	r_g	0.510**	0.378**	-0.158*	-0.172*	-0.207**	-0.347**	-0.319**	-0.275**
	r_p	0.307**	0.277**	-0.154*	-0.154*	-0.137	-0.287**	-0.268**	-0.210**
Days to maturity	r_g		0.238**	-0.070	-0.013	0.064	0.168*	-0.357**	-0.054
	r_p		0.036	-0.011	-0.012	0.037	0.104	-0.216**	-0.026
Plant height	r_g			0.145	0.041	-0.091	-0.149*	-0.544**	-0.044
	r_p			0.129	0.053	-0.097	-0.071	-0.385**	0.011
Number of branches per plant	r_g				0.389**	-0.214**	-0.132	-0.161*	0.337**
	r_p				0.297**	-0.205**	-0.114	-0.149*	0.280**
Number of siliquae per plant	r_g					0.056	-0.091	-0.201**	0.869**
	r_p					0.039	-0.088	-0.153*	0.658**
Seeds per siliqua	r_g						0.448**	0.052	0.333**
	r_p						0.392**	0.049	0.305**
Length of siliqua	r_g							0.220**	0.138
	r_p							0.201**	0.133
1000-seed weight	r_g								0.023
	r_p								0.020

* Significant at 0.05% level and ** Significant at 0.01% level.

Table 4. Genotypic (r_g) and phenotypic (r_p) correlation coefficient of seed yield per plant with quality characters in Indian mustard

Character		Myristic acid	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Erucic acid	Glucosinolate	Seed yield per plant
Oil content	r_g	-0.397**	-0.503**	-0.187*	0.006	-0.031	-0.379**	0.490**	0.023	0.062
	r_p	-0.378**	-0.473**	-0.179*	0.019	-0.033	-0.358**	0.399**	0.025	0.054
Myristic acid	r_g		0.579**	0.144	-0.348**	0.032	0.166*	-0.185*	0.344**	0.193**
	r_p		0.575**	0.144	-0.344**	0.031	0.168*	-0.147*	0.330**	0.179*
Palmitic acid	r_g			0.144	-0.269**	0.155*	0.523**	-0.588**	0.159*	0.036
	r_p			0.144	-0.265**	0.152*	0.507**	-0.469**	0.155*	0.033
Stearic acid	r_g				-0.243**	-0.281**	-0.134	-0.239**	0.139	-0.019
	r_p				-0.241**	-0.277**	-0.128	-0.191*	0.135	-0.020
Oleic acid	r_g					-0.446**	-0.187*	-0.022	-0.174*	-0.120
	r_p					-0.433**	-0.191*	-0.004	-0.162*	-0.104
Linoleic acid	r_g						0.193**	-0.558**	0.149*	-0.152*
	r_p						0.186*	-0.440**	0.146*	-0.146*
Linolenic acid	r_g							-0.532**	-0.095	-0.047
	r_p							-0.410**	-0.096	-0.033
Erucic acid	r_g								-0.149*	0.260**
	r_p								-0.105	0.169*
Glucosinolate	r_g									0.086
	r_p									0.070

* Significant at 0.05% level and ** Significant at 0.01% level.

dependent on several component characters. Therefore, knowledge of the association of different components together with their relative contributions has immense value in selection. The correlation coefficients were estimated for all the combinations of eighteen characters under study at genotypic (r_g) and phenotypic (r_p) levels. The perusal of the data showed that the magnitude of genotypic correlation coefficients was relatively higher than the corresponding phenotypic correlation coefficient in almost all the traits paired indicating the inherent association between various characters. The results of the correlation between different pairs of characters are described in **Table 3 and Table 4**, respectively.

The seed yield per plant had a positive and significant correlation with the number of siliquae per plant, seeds per siliqua and length of siliqua at both the levels. Days to flowering and days to maturity had a negative and significant correlation with seed yield per plant. On the other hand oil content had a negative and significant correlation with myristic acid, palmitic acid, stearic acid, linolenic acid, whereas a positive and significant correlation with erucic acid. The present findings are in agreement with those of Akabari and Niranjana (2015), Prasad and Patil (2018), Pandey *et al.* (2020) and Saiyad *et al.* (2020 b).

The estimate of correlation coefficient gives the inter-relationships of different traits, but it does not give the clear information on causes and effects. Under such condition path analysis efficiently identifies the direct and indirect effects of various traits on seed yield as well as quality traits. The estimates of direct and indirect effects of various traits on seed yield per plant are presented in **Table 5** and **Fig. 1**. The path analysis revealed that the number of siliquae per plant and seeds per siliqua showed the positive direct effects on seed yield per plant whereas, the number of branches per plant had a positive indirect effects on seed yield per plant *via* the number of siliquae per plant. Therefore, considering these characters like the number of siliquae per plant, seeds per siliqua and the number of branches per plant use as selection criteria will be helpful in improvement of seed yield in Indian mustard. Days to flowering showed a negative direct effect on seed yield per plant. Majority of the quality parameter were found negatively correlated with seed yield per plant, but improvement of quality of oil content is also valuable. A positive and high direct effect of the number of siliquae per plant on seed yield per plant was also reported by Roy *et al.* (2015), Rout *et al.* (2018) and Patel *et al.* (2019). Roy *et al.* (2015) and Pandey *et al.* (2020) also found positive and high direct effect of seeds per siliqua on seed yield per plant.

Table 5. Path coefficient analysis showing direct (bold) and indirect effects of different traits on seed yield per plant in Indian mustard

Characters	DF	DM	PH	NBPP	NSPP	SPS	LS	TW	OC	MA	PA	SA	OA	LA	LLA	EA	GSL	r_g with Y
DF	**0.0020**	-0.033	0.030	-0.004	-0.154	-0.065	0.010	-0.058	-0.013	0.018	-0.011	0.001	0.008	-0.001	0.003	0.007	-0.017	-0.275**
DM	0.0010	**-0.065**	0.019	-0.002	-0.011	0.020	-0.005	-0.065	0.009	0.052	-0.017	-0.002	-0.005	0.040	0.005	-0.020	-0.009	-0.054
PH	0.0010	-0.015	**0.081**	0.004	0.036	-0.028	0.004	-0.099	-0.037	0.026	-0.007	0.002	-0.044	0.035	0.003	0.012	-0.016	-0.044
NBPP	-0.0003	0.005	0.012	**0.028**	0.346	-0.067	0.004	-0.029	0.015	0.005	0.006	0.003	0.010	0.004	-0.001	0.002	-0.004	0.337**
NSPP	-0.0003	0.001	0.003	0.011	**0.891**	0.018	0.003	-0.036	-0.018	0.023	-0.018	-0.002	-0.019	0.029	0.0001	-0.013	-0.003	0.869**
SPS	-0.0004	-0.004	-0.007	-0.006	0.050	**0.312**	-0.013	0.009	0.045	-0.043	0.002	-0.003	0.027	0.004	0.0001	-0.030	-0.010	0.333**
LS	-0.0010	-0.011	-0.012	-0.004	-0.081	0.140	**-0.028**	0.040	0.040	0.009	0.052	-0.002	0.011	0.029	-0.005	-0.044	0.005	0.138
TW	-0.0010	0.023	-0.044	-0.004	-0.179	0.016	-0.006	**0.181**	0.003	0.032	-0.032	-0.001	0.051	-0.057	0.001	0.015	0.023	0.023
OC	-0.0002	-0.004	-0.021	0.003	-0.115	0.101	-0.008	0.004	**0.139**	-0.092	0.119	-0.003	-0.001	0.005	-0.012	-0.053	0.001	0.062
MA	0.0002	-0.015	0.009	0.001	0.087	-0.057	-0.001	0.025	-0.055	**0.232**	-0.137	0.003	0.062	-0.006	0.005	0.020	0.019	0.193**
PA	0.0001	-0.005	0.002	-0.001	0.070	-0.002	0.006	0.024	-0.070	0.134	**-0.237**	0.003	0.048	-0.027	0.017	0.063	0.009	0.036
SA	0.0002	0.008	0.007	0.005	-0.097	-0.052	0.003	-0.005	-0.026	0.033	-0.034	**0.018**	0.043	0.048	-0.004	0.026	0.008	-0.019
OA	-0.0001	-0.002	0.020	-0.002	0.097	-0.047	0.002	-0.052	0.001	-0.081	0.064	-0.004	**-0.178**	0.077	-0.006	0.002	-0.010	-0.120
LA	0.00001	0.015	-0.016	-0.001	-0.151	-0.008	0.005	0.060	-0.004	0.007	-0.037	-0.005	0.079	**-0.172**	0.006	0.060	0.008	-0.152*
LLA	0.0002	-0.010	0.006	-0.001	0.004	0.001	0.004	0.004	-0.053	0.039	-0.124	-0.002	0.033	-0.033	**0.033**	0.057	-0.005	-0.047
EA	-0.0001	-0.012	-0.009	-0.001	0.104	0.088	-0.012	-0.025	0.068	-0.043	0.139	-0.004	0.004	0.096	-0.018	**-0.108**	-0.008	0.260**
GSL	-0.0010	0.010	-0.023	-0.002	-0.040	-0.053	-0.003	0.076	0.003	0.080	-0.038	0.003	0.031	-0.026	-0.003	0.016	**0.056**	0.086

* Significant at 0.05% level and ** Significant at 0.01% level, respectively. r_g= genotypic correlation. Residual effect = 0.046
DF = Days to flowering; DM = Days to maturity; PH = Plant height; NBPP = Number of branches per plant; NSPP = Number of siliquae per plant; SPS = Seeds per siliqua; LS = Length of siliqua; TW = 1000 seed weight; OC = Oil content; MA = Myristic acid; PA = Palmitic acid; SA = Stearic acid; OA = Oleic acid; LA = Linoleic acid; LLA = Linolenic acid; EA = Erucic acid; GSL = Glucosinolate and Y = Seed yield per plant.

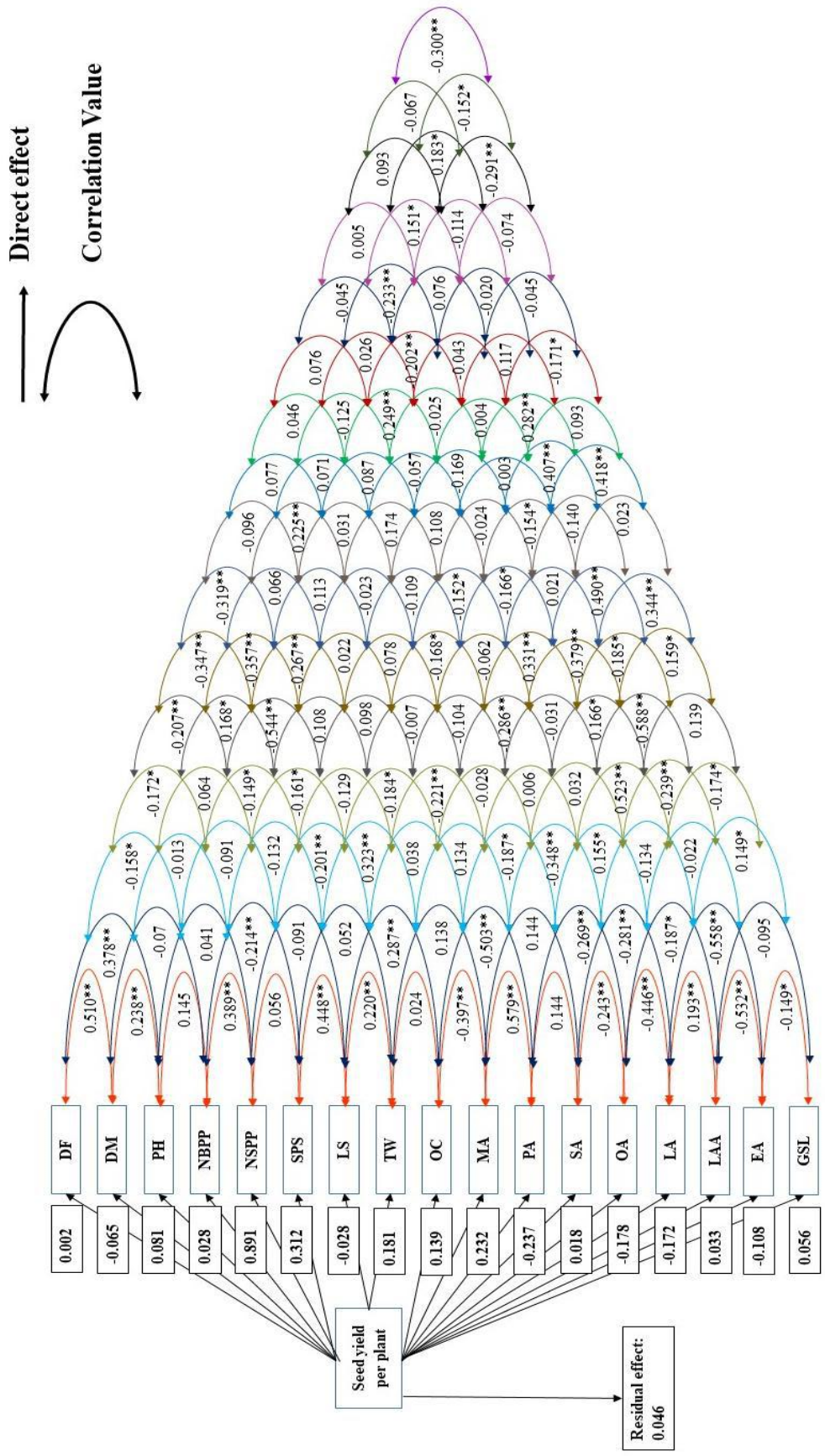

Fig. 1. Genotypic path diagram showing direct and indirect effect various traits on seed yield in Indian mustard

DF = Days to flowering; DM = Days to maturity; PH = Plant height; NBPP = Number of branches per plant; NSPP = Number of siliquae per plant; SPS = Seeds per siliqua; LS = Length of siliqua; TW = 1000 seed weight; OC = Oil content; MA = Myristic acid; PA = Palmitic acid; SA = Stearic acid; OA = Oleic acid; LA = Linoleic acid; LLA = Linolenic acid; EA = Erucic acid and GSL = Glucosinolate

Thus, based on this study, it could be concluded that, the materials under study is of diverse in nature and information generated on genetic variability, correlation and path analysis would be helpful in future breeding programme for the improvement of seed yield as well as quality in Indian mustard.

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