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Variability, trait relationship and path analysis for seed yield and seed quality parameters in Indian mustard (*Brassica juncea* L.)

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Abstract

Forty accessions of Indian mustard (*Brassica juncea* L.) germplasm evaluated for yield as well as quality traits revealed significant differences among the accessions for seed yield contributing traits and seed quality parameters. The highest estimate of phenotypic and genotypic coefficient of variation was found for secondary branches per plant, harvest index. Higher estimates of heritability coupled with higher genetic advance was observed in harvest index and secondary branches per plant. The seed yield per plant, the most important economic trait, was positively and significantly correlated with 1000-seed weight, harvest index, number of seeds per at both genotypic and phenotypic levels. The characters showing significant positive correlation among yield and important characters would be highly effective and efficient in improving respective traits. Path coefficient analysis identified as plant height and 1000-seed weight important component having high order of direct effect and seedling dry weight via vigour index-II and seedling length via vigour index-II important component having high order of indirect effect on seed yield per plant. The characters identified above as important direct and indirect yield components merit due to consideration in formulating effective selection strategy for developing high yielding mustard genotypes. These components plays an important role in a crop for best selecting of genotypes for making rapid improvement in yield and other desirable characters as well as to select the potential parent for hybridization programmes.

Keywords: *Brassica juncea, coefficient of variation, correlation, genetic advance, heritability, path coefficient, variance*

Introduction

Rapeseed- mustard group of oil seed crops is the second most important crop after groundnut. The production of rapeseed-mustard in 2017-18 was about 6.31 million tonnes with productivity of 1089 kg/ha. This has been largely due to the new integrated oilseed policy of Govt. Of India is the form of Technology Mission on oilseeds and resulted in yellow revolution. However, in Uttar Pradesh, it was grown on 6.26 lakh ha area with production of 5.82 lakh Million tonnes and productivity of 930 Kg/ha and had ranks third in area after Rajasthan and MP and third in production after Rajasthan and Haryana, India (Anonymous, 2017).

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is one of the most important oilseed crops of India. In order to incorporate desirable characters to maximize economic yields, the information nature and extent of genetic variability present in a population for desirable characters, their association and relative contribution to yield constitutes the basic requirement. The present study was under taken to find out genetic variability available, heritability and genetic advance, the association of different characters and their contribution to define seed yield.

Materials and Methods

The material of the present study consisted 40 genotypes including three checks *viz.,* Vardan, Kranti and Narendra Rai- I of Indian mustard. There were grown in Randomized Block Design were conducted at Research Farm of Department of Genetics & Plant Breeding, Narendra Deva University of Agriculture and Technology, Narendra Nagar, Ayodhya (UP) during *Rabi*, 2017-18. Crop was grown in single row of 3 meter spaced at 30 cm apart. The distance between plant to plant 15 cm was maintained by thinning. All the recommended cultural practices were adopted and the observations were recorded on five competitive plants from each replication *viz.,* days to 50 per cent flowering, days to maturity, number of primary branches per plant, number of secondary branches per plant, plant height (cm), length of main raceme (cm), siliqua on main raceme (cm), number of seeds per siliqua, 1000-seed weight (g), harvest index (%), biological yield per plant (g), speed of germination, germination per cent, root length (cm), shoot length (cm), seedling length (cm), seedling dry weight (g), vigour index-I, vigour index-II and seed yield per plant (g). The data collected for all quantitative characters were subjected to analysis of variance according to the method recommended by Panse and Sukhatme (1967), coefficient of variation by Burton and De Vane (1953), estimation of heritability by Hanson *et al.* (1956), genetic advance by Johnson *et al.* (1955), correlation coefficient by Searle (1961) and path coefficient analysis by Deway and Lu (1965).

Results and Discussion

The result of analysis of variance showed that mean squares due to treatments were highly significant for all the seed yield contributing traits and seed quality parameters of all the traits for 40 genotypes is presented in Table 1. The analysis of variance showed highly significant differences for all the characters indicating the presences of variability which can be exploited through selection.

The highest estimates of PCV and GCV were found for secondary branches per plant (48.7%, 43.6 %), harvest index (41.9%, 41.2%), root length (33.4%, 28.7%), 1000-seed weight (24.4%, 19.9%), vigour index-I (23.9%, 20.5%), seedling length (23.4%, 19.8%), shoot length (23.2%, 16.5%) and primary branches per plant (20.6 %, 19.1%). The PCV and GCV were computed to assess the nature and magnitude of existing variability in the genotype. The result showed a close correspondence between the phenotypic and genotypic variance for all the characters indicating stable expression of attributes and absence of high environmental influence. Hence, these characters are more suitable for direct selection procedure. Similar result were reported by Shekhawat *et al.* (2014), Akabari and Niranjana (2015), Dilip *et al.* (2016), Srivastava *et al.* (2016), Rai *et al.* (2017), Kumar et al. (2017) and Raliya *et al.* (2018). The moderate estimates of PCV and GCV were recorded for biological yield per plant (19.3%, 18.9%), number of seeds per siliqua (17.8%, 16.8%), vigour index-II (16.7%, 16.3%), seedling dry weight (16.4%, 16.1%), siliqua on main raceme (14.5%, 13.5%), seed yield per plant (12.0%, 10.3%), plant height (11.8%, 11.5%). Similar result reported by Tripathi *et al.* (2013) and Dilip *et al.* (2016).

The genotypes under study showed high heritability values for all the characters under study. The estimates of heritability in broad sense showed considerable variation for different characters (Table 2). Highest heritability was recorded for harvest index (96.6%)

Table 1: Analysis of variance for 20 characters in Indian mustard (*Brassica juncea* L.)

Characters / Source of variation	Source of variation		
	Replication	Treatment	Error
d.f.	2	39**	78
Days to 50% flowering	1.430	6.823**	0.645
Days to maturity	3.185	53.120**	1.715
Primary branches/ plant	0.492	3.246**	0.175
Secondary branches/plant	3.418	21.651**	1.664
Plant height (cm)	52.942	1278.294**	24.227
Length of main raceme (cm)	18.216	121.585**	7.565
Siliqua on main raceme (cm)	13.012	123.693**	6.496
Number of seeds/siliqua	0.484	16.220**	0.590
1000-seed weight (g)	0.122	2.129**	0.301
Harvest index (%)	2.175	193.658**	2.261
Biological yield/ plant (g)	1.432	481.774**	7.982
Speed of germination	0.741	3.706**	0.523
Germination (%)	1.481	7.683**	1.308
Root length (cm)	0.593	5.085**	0.529
Shoot length (cm)	1.326	3.558**	0.871
Seedling length (cm)	1.617	13.227**	1.551
Seedling dry weight (g)	0.005	0.392**	0.005
Vigour index-I	14023.12	111514.4**	12012.25
Vigour index-II	62.972	3217.109**	53.256
Seed yield/ plant (g)	1.189	8.452**	0.914

*significant at 0.5% level; **significant at 0.1% level

Table 2: Estimates of range, grand mean phenotypic (PCV) and genotypic (GCV) coefficients of variation, heritability (h^2bs) and genetic advance for twenty characters in Indian mustard.

Character	Range	Grand mean	Coefficient of variation (%)		Genetic advance in	Heritability
			PCV (%)	GCV (%)	per cent of mean ($\overline{Ga}$ %)	(h^2bs %)
Days to 50% flowering	69.0-74.0	72.04±0.46	2.28	1.99	3.58	76.1
Days to maturity	105-126	116.12±0.756	3.74	3.57	7.00	90.9
Primary branches/ plant	3.73-8.40	5.31±0.24	20.63	19.06	36.28	85.4
Secondary branches/plant	2.07-11.93	5.92±0.74	48.74	43.59	80.33	80.0
Plant height (cm)	119.79-220.15	178.56±2.84	11.78	11.45	22.93	94.5
Length of main raceme (cm)	63.09-86.89	73.37±1.581	9.20	8.40	15.81	83.4
Siliqua on main raceme (cm)	38.27-75.60	46.45±1.47	14.53	13.46	25.67	85.7
Number of seeds/siliqua	9.20-23.07	13.56±0.44	17.76	16.83	32.87	89.8
1000-seed weight (g)	2.38-6.02	3.91±0.31	24.38	19.95	33.62	67.0
Harvest index (%)	6.65-38.27	19.41±0.86	41.88	41.16	83.33	96.6
Biological yield/ plant (g)	29.83-84.51	66.65±1.63	19.33	18.86	37.90	95.2
Speed of germination	14.61-18.55	16.75±0.41	7.52	6.15	10.37	67.0
Germination (%)	86.30-93.70	89.05±0.66	2.08	1.64	2.65	61.9
Root length (cm)	2.72-8.13	4.29±0.42	33.36	28.36	50.98	74.2
Shoot length (cm)	7.19-16.11	5.73±0.53	23.92	16.51	24.21	50.7
Seedling length (cm)	7.19-16.11	9.97±0.72	23.40	19.78	34.46	71.5
Seedling dry weight (g)	1.65-3.01	2.23±0.04	16.38	16.09	32.54	96.4
Vigour index-I	624.55-1509.18	888.56±63.27	23.92	20.50	36.18	73.4
Vigour index-II	143.63-272.19	199.01 ±4.21	16.73	16.31	32.80	95.2
Seed yield/ plant (g)	11.49-19.23	15.40±0.55	12.02	10.29	18.15	73.3

followed by seedling dry weight (96.4%), biological yield per plant (95.2%), vigour index-II (95.2%), plant height (94.5%), days to maturity (90.9%), number of seeds per siliqua (89.8%), siliqua on main raceme (85.7%), primary branches per plant (85.4%), length of main raceme (83.4%) and secondary branches per plant (80.0%) mainly due to additive effect and selection is effective for such traits. The heritability gives an idea of transmissibility of a character from parents to offspring. The result obtained under present study is in accordance with earlier reports of Mehla *et al.* (2003), Upadhyay and Kumar (2009), Goyal *et al.* (2012), Singh *et al.* (2013), Priyamedha *et al.* (2013), Shekhawat *et al.* (2014), Dilip *et al.* (2016).

Genetic advance is relative increase in mean value of population after selection. The very high estimates of genetic advance were recorded for harvest index (83.3%) followed by secondary branches per plant (80.3%) and root length (51.0%). Moderate value of genetic advance were recorded for biological yield per plant (37.9%), primary branches per plant (36.3%), vigour index-I (36.2%), seedling length (34.5%), 1000-seed weight (33.6%), number of seeds per siliqua (32.9%), vigour index II (32.8%) and seedling dry weight (32.5%), siliqua on main raceme (25.7%), shoot length (24.2%) and plant height (22.9%). The low estimates of genetic advance (<20%), were recorded for Seed yield per plant (18.2%), length of main raceme (15.8%), speed of germination (10.4%), days to maturity (7.0%), days to 50 per cent flowering (3.6%) and germination (2.7%). Higher estimates of heritability coupled with higher genetic advance for harvest index and secondary branches per plant indicated that heritability of the trait is mainly due to additive effect and selection is effective for such traits. It also predicts the gain under selection than heritability estimates alone. This indicates that improvement in these traits could be made by simple selection. Similar results were obtained by Upadhyay and Kumar (2009), Goyal *et al.* (2012), Yadav *et al.* (2011) and Lodhi *et al.* (2014).

Correlation coefficient which provides symmetrical measurement of degree of association between two variables or characters helps us in understanding the nature and magnitude of association among yield and yield components. The dependence of seed yield on various growth and yield parameters as well as interdependence among growth and yield parameters were evident from the positive and significant correlation presented in Table 3. In the present study, genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficient for most of the traits indicating the depression of phenotypic expression by environmental influence. The seed yield per plant, the most important economic trait, was positively and significantly correlated with 1000-seed weight (0.658, 0.847), harvest index (0.338, 0.403), number of seeds per siliqua (0.355, 0.447), siliqua on main raceme (0.339, 0.447) at both phenotypic and genotypic levels respectively. Such positive association of seed yield per plant with harvest index, number of seeds per siliqua, siliqua on main raceme was also observed by Shweta *et al.* (2014), Kumar and Pandey (2014), Lodhi *et al.* (2014), Singh *et al.* (2014), Sirohi *et al.* (2015), Kumar *et al.* (2016) and Kumar *et al*. (2017). The phenotypic and genotypic correlation coefficients between important yield components varied from being significantly positive to significant negative besides being non-significant for many characters pairs. This reveals a high complete situation in attaining a proper balance between yield and its components due to complexities that arise due to subsistence of strong negative and positive association between various characters in this, as well as in many other crops (Singh *et al.,* 2003; Misra *et al.,* 2008; Suryanarayana *et al.,* 2014; Negi *et al.,* 2017). The grain yield, in most of the crops, is referred to as super character which results from multiplicative interaction of several other characters that are termed as yield components.

Knowledge of correlation alone is often misleading as the correlation observed may not be always true. Two characters may show correlation just because they are correlated with a common third one. In such cases, it becomes necessary to use a method which takes in to account the casual relationship between the variables, in addition to the degree of such relationship. Path coefficient analysis measures the direct influence of one variable upon the other and permits separation of partitioning of total correlation into direct and indirect effect provide actual information on contribution of characters and thus from the basis for selection to improve the yield. In the present experiment, highest positive direct effect on seed yield per plant at phenotypic level was exerted by number of seed per siliqua (0.785) followed by plant height (0.698), days to 50 per cent flowering (0.511), 1000-seed weight (0.368), germination per cent (0.352), seedling length (0.348), harvest index (0.302), siliqua on main raceme (0.215), days to maturity (0.146), seedling dry weight (0.110), root length (0.053), length of main raceme (0.032) (Table 2). However, the highest positive direct effect on seed yield per plant at genotypic level was exhibited by plant height (0.978) followed by 1000-seed weight (0.552), number of seed per siliqua (0.490), siliqua on main raceme (0.423), vigour index-II (0.372), harvest index (0.286), vigour index- I (0.194), speed of germination (0.175), primary branches per plant (0.167) and days to 50 per cent flowering (0.009). Similar result

Table 3: Estimates of phenotypic and genotypic correlation coefficients between different characters in Indian mustard

Characters		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Days to 50%	P	0.562**	0.028	-0.045	0.523**	0.009	0.137	-0.082	0.135	-0.135	0.503**	0.161	0.222	-0.012	-0.119	0.078	0.008	0.098	0.037	0.135
flowering	G	0.700**	0.024	-0.136	0.607**	0.016	0.189	-0.109	0.229	-0.165	0.579**	0.241	0.373*	0.052	-0.219	0.146	0.029	0.175	0.068	0.187
Days to	P		0.054	-0.104	0.690	0.322*	0.200	-0.149	0.383*	-0.105	0.604**	0.300	0.262	0.040	-0.214	0.141	0.136	0.166	0.169	0.306
maturity	G		0.095	-0.132	0.750**	0.392*	0.223	-0.158	0.468**	-0.105	0.660**	0.357	0.332*	0.094	-0.310	0.177	0.138	0.205	0.173	0.341*
Primary branches	P			0.611**	0.085	-0.014	0.128	0.054	-0.195	-0.092	0.032	0.023	0.127	-0.057	0.139	-0.107	-0.076	-0.097	-0.062	-0.169
/plant	G			0.715**	0.088	-0.042	0.163	0.041	-0.263	-0.102	0.004	-0.001	0.157	-0.031	0.226	-0.107	-0.069	-0.095	-0.055	-0.178
Secondary branches	P				0.007	0.017	0.007	0.147	-0.229	-0.027	-0.029	0.104	0.087	0.039	0.104	-0.005	-0.071	-5.806**	-0.060	-0.256
/plant	G				-0.012	0.032	0.016	0.141	-0.273	-0.033	-0.042	0.137	0.134	0.052	0.210	-0.051	-0.072	-0.041	-0.059	-0.336*
Plant height	P					0.400*	0.104	-0.211	0.224	-0.225	0.940**	0.213	0.233	0.306	-0.275	0.346*	0.354*	0.365*	0.380*	0.143
(cm)	G					0.438**	0.094	-0.231	0.302	-0.230	0.976**	0.264	0.312	0.354*	-0.419**	0.414**	0.366*	0.432**	0.397*	0.181
Length of main	P						0.162	0.036	0.379*	0.072	0.373*	0.299	0.121	0.279	-0.208	0.255	0.211	0.266	0.224	0.309
raceme (cm)	G						0.204	0.046	0.487**	0.079	0.417**	0.388*	0.190	0.351*	-0.380*	0.358*	0.230	0.368*	0.248	0.396*
Siliqua on main	P							0.375*	0.122	-0.209	0.118	-0.0271	0.189	-0.002	0.141	-0.061	-0.025	-0.046	-0.003	0.339*
raceme (cm)	G							0.434**	0.192	-0.230	0.129	-0.039	0.246	0.021	0.158	-0.064	-0.037	-0.047	-0.016	0.447**
Number of seeds	P								0.153	-0.018	-0.134	-0.068	0.077	-0.107	0.092	-0.092	-0.146	-0.086	-0.135	0.355*
/siliqua	G								0.192	-0.029	-0.140	-0.073	0.106	-0.118	0.092	-0.116	-0.159	-0.107	-0.148	0.447**
1000-seed weight	P									0.303	0.232	0.244	0.027	0.258	-0.247	0.304	0.359*	0.306	0.357*	0.658**
(g)	G									0.340*	0.281	0.324*	0.093	0.419**	-0.467**	0.471	0.444**	0.468**	0.449**	0.874**
Harvest index	P										-0.256	-0.007	-0.114	-0.057	0.034	-0.007	-0.010	-0.014	-0.022	0.338*
(%)	G										-0.259	-0.009	-0.108	-0.078	0.032	-0.014	-0.018	-0.020	-0.027	0.403*
Biological yield/	P											0.194	0.200	0.279	-0.219	0.293	0.314*	0.308	0.336*	0.149
plant (g)	G											0.249	0.255	0.344*	-0.329*	0.370*	0.332*	0.382*	0.356*	0.178
Speed of	P												0.189	0.127	-0.169	0.170	0.152	0.187	0.175	0.065
germination	G												0.345*	0.202	-0.349*	0.278	0.187	0.301	0.221	0.149
Germination	P													0.003	-0.141	0.102	0.069	0.193	0.196	0.031
(%)	G													0.072	-0.286	0.249	0.057	0.327*	0.158	0.104
Root length	P														-0.461**	0.827**	0.725**	0.814**	0.713**	0.175
(cm)	G														-0.594**	0.912**	0.838**	0.894**	0.836**	0.225
Shoot length	P															0.791**	0.611**	0.795**	0.622**	-0.165
(cm)	G															0.877**	0.885**	0.883**	0.911**	-0.208
Seedling length	P																0.820**	0.995**	0.821**	0.221
	G																0.970**	0.996**	0.988**	0.227
Seedling dry	P																	0.813**	0.991**	0.186
weight (g)	G																	0.946**	0.994**	0.222
Vigour index-i	P																		0.826**	0.221
	G																		0.973**	0.231
Vigour index-ii	P																			0.186
	G																			0.230

* and ** significant at 5% and 1% level of probability, respectively.

1- Days to maturity, **2**-Primary branches/ plant, **3**- Secondary branches/plant, **4**-Plant height (cm), **5** Length of main raceme (cm), **6**- Siliqua on main raceme (cm), **7**- Number of seeds/ siliqua, **8**- 1000-seed weight (g), **9**-Harvest index (%), **10**- Biological yield/ plant (g), **11**- Speed of germination, **12**- Germination (%), **13-** Root length (cm), **14**- Shoot length (cm), **15**- Seedling length (cm), **16**- Seedling dry weight (g), **17**- Vigour index-I, **18**- Vigour index-II, **19**- Seed yield/ plant (g)

Table 4. Direct and indirect effects of different characters on seed yield at phenotypic and phenotypic level in Indian mustard.

Characters		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Days to 50%	P	**0.511**	0.082	0.0003	0.009	0.051	0.0003	0.029	-0.023	0.049	-0.041	-0.028	-0.007	0.078	-0.0007	0.0001	0.105	0.018	-0.615	-0.086	0.135
flowering	G	**0.009**	-0.376	0.004	0.056	0.201	-0.001	0.080	-0.042	0.849	-0.047	-0.846	0.342	-0.168	-0.006	0.010	-0.054	-0.063	0.104	0.136	0.187
Days to	P	0.006	**0.146**	0.0006	0.022	0.068	0.010	0.043	-0.042	0.141	-0.031	-0.034	-0.01	0.092	0.002	0.0003	0.190	0.288	-0.194	-0.388	0.306
maturity	G	0.006	**-0.537**	0.016	0.055	0.485	-0.041	0.094	-0.061	0.305	-0.030	-0.964	0.062	-0.149	-0.012	0.414	-0.066	-0.300	0.721	0.341	0.341
Primary	P	0.0003	0.007	**0.011**	-0.128	0.008	-0.0004	0.027	0.015	-0.071	-0.028	-0.001	-0.001	0.044	-0.003	-0.0002	-0.145	-0.162	0.113	0.142	-0.169
branches/plant	G	0.0002	-0.051	**0.167**	-0.296	0.174	0.004	0.069	0.016	-0.171	-0.029	-0.007	-0.0003	-0.071	0.004	-0.010	0.039	0.150	-0.056	-0.110	-0.178
Secondary	P	-0.0005	-0.015	0.007	**-0.210**	0.0007	0.0005	0.001	0.042	-0.084	-0.008	0.001	-0.004	0.030	0.002	-0.0002	-0.007	-0.151	6.7E-0	0.139	-0.256
branches/plant	G	-0.001	0.0714	0.120	**-0.414**	-0.024	-0.003	0.006	0.055	-0.178	-0.009	0.061	0.024	-0.060	-0.007	-0.010	0.019	0.157	-0.024	-0.117	-0.336
Plant height	P	0.006	0.100	0.001	-0.001	**0.698**	0.013	0.022	-0.060	0.082	-0.068	-0.053	-0.609	0.082	0.016	0.0004	0.466	0.748	-0.426	-0.875	0.143
(cm)	G	0.006	-0.403	0.014	0.005	**0.978**	-0.046	0.040	-0.090	0.197	-0.066	-0.427	0.046	-0.140	-0.046	0.020	-0.154	-0.793	0.257	0.784	0.181
Length of main	P	0.0001	0.047	-0.0001	-0.003	0.039	**0.032**	0.035	0.010	0.140	0.021	-0.021	-0.013	0.042	0.014	0.0003	0.344	0.445	-0.310	-0.516	0.309
raceme (cm)	G	0.0001	-0.211	-0.007	-0.013	0.867	**-0.106**	0.086	0.018	0.318	0.022	-0.610	0.068	-0.085	-0.045	0.018	-0.133	-0.499	0.218	0.490	0.396
Siliqua on main	P	0.001	0.029	0.001	-0.001	0.010	0.005	**0.215**	0.107	0.045	-0.063	-0.006	0.001	0.066	-0.0001	-0.0002	-0.082	-0.052	0.054	0.008	0.339
raceme (cm)	G	0.001	-0.119	0.027	-0.006	0.187	-0.021	**0.423**	0.169	0.125	-0.066	-0.189	-0.006	-0.110	-0.002	-0.007	0.023	0.080	-0.028	-0.032	0.447
Number of	P	-0.0009	-0.021	0.0006	-0.031	-0.020	0.001	0.081	**0.785**	0.056	-0.505	0.007	0.003	0.027	-0.005	-0.0001	-0.124	-0.308	0.100	0.311	0.355
seed/siliqua	G	-0.001	0.085	0.006	-0.058	-0.458	-0.004	0.183	**0.490**	0.125	-0.108	0.205	-0.012	-0.048	0.015	-0.004	0.043	0.344	-0.063	-0.292	0.447
1000-seed	P	0.001	0.056	-0.002	0.048	0.022	0.012	0.026	0.043	**0.368**	0.091	-0.013	-0.011	0.009	0.013	0.0003	0.410	0.758	-0.356	-0.822	0.658
weight (g)	G	0.002	-0.251	-0.044	0.113	0.599	-0.051	0.081	0.075	**0.552**	0.197	-0.410	0.056	-0.042	-0.054	0.022	-0.175	-0.962	0.278	0.887	0.874
Harvest index	P	-0.001	-0.015	-0.001	0.005	-0.022	-0.002	-0.045	-0.005	0.111	**0.302**	0.014	0.0003	-0.040	-0.003	-5E-05	-0.010	-0.022	0.017	0.051	0.338
(%)	G	-0.001	0.056	-0.017	0.013	-0.455	-0.008	-0.097	-0.011	0.222	**0.286**	0.379	-0.001	0.049	0.010	-0.001	0.005	0.039	-0.011	-0.053	0.403
Biological yield	P	0.005	0.088	0.0003	0.006	0.092	0.012	0.025	-0.038	0.085	-0.077	**-0.056**	-0.009	0.070	0.014	0.0003	0.395	0.664	-0.359	-0.772	0.149
/plant (g)	G	0.005	-0.354	0.0008	0.017	0.932	-0.044	0.054	-0.055	0.183	-0.074	**-0.460**	0.043	-0.114	-0.044	0.015	-0.137	-0.719	0.227	0.703	0.178
Speed of	P	0.001	0.043	0.0002	-0.022	0.021	0.009	-0.005	-0.019	0.090	-0.002	-0.010	**-0.046**	0.066	0.006	0.0002	0.230	0.322	-0.217	-0.403	0.065
germination	G	0.002	-0.192	-0.0003	-0.057	0.522	-0.041	-0.016	-0.028	0.211	-0.002	-0.365	**0.175**	-0.155	-0.026	0.016	-0.103	-0.405	0.179	0.437	0.149
Germination	P	0.0026	0.0383	0.001	-0.018	0.023	0.003	0.040	0.022	0.010	-0.034	-0.011	-0.008	**0.352**	0.0001	0.0002	0.138	0.145	-0.225	-0.450	0.031
(%)	G	0.003	-0.178	0.026	-0.055	0.618	-0.020	0.104	0.041	0.061	-0.031	-0.372	0.060	**-0.450**	-0.009	0.013	-0.092	-0.123	0.194	0.313	0.104
Root length	P	-0.0001	0.005	-0.0006	-0.008	0.030	0.009	-0.0004	-0.030	0.095	-0.017	-0.015	-0.005	0.001	**0.053**	0.400	0.716	0.531	-0.949	-0.639	0.175
(cm)	G	0.0005	-0.050	-0.005	-0.024	0.701	-0.037	0.008	-0.046	0.273	-0.022	-0.503	0.035	-0.032	**-0.130**	0.028	-0.339	-0.813	0.532	0.650	0.225
Shoot length	P	-0.001	-0.031	0.001	-0.022	-0.027	-0.006	0.030	0.026	-0.091	0.010	0.412	0.007	-0.049	-0.024	**-0.001**	0.667	0.290	-0.926	-0.430	-0.165
(cm)	G	-0.002	0.167	0.038	-0.087	-0.830	0.040	0.067	0.036	-0.305	0.009	0.481	-0.061	0.128	0.077	**-0.048**	-0.326	-0.916	0.525	0.797	-0.208
Seedling length	P	0.0009	0.020	-0.001	0.001	0.034	0.008	-0.013	-0.026	0.112	-0.002	-0.016	-0.007	0.036	0.043	-0.001	**0.348**	0.731	-0.159	-0.887	0.221
(cm)	G	0.001	-0.095	-0.018	0.021	0.819	-0.038	-0.027	-0.045	0.307	-0.004	-0.540	0.048	-0.112	-0.119	-0.542	**-0.372**	-0.599	0.592	0.950	0.227
Seedling dry	P	0.0001	0.019	-0.0009	0.015	0.034	0.006	-0.005	-0.041	0.132	-0.003	-0.017	-0.007	0.024	0.338	-0.0009	0.806	**0.110**	-0.947	-0.278	0.186
weight (g)	G	0.0002	-0.074	-0.011	0.030	0.725	-0.024	-0.015	-0.062	0.290	-0.305	-0.486	0.032	-0.725	-0.109	-0.042	-0.361	**-0.163**	0.562	0.961	0.222
Vigour	P	0.001	0.024	-0.001	1.2E-0	0.036	0.008	-0.010	-0.024	0.112	-0.004	-0.017	-0.008	0.068	0.043	-0.001	0.342	0.716	**-0.165**	-0.899	0.221
index-I	G	0.001	-0.510	-0.616	0.017	0.855	-0.039	-0.020	-0.041	0.706	-0.005	-0.558	0.052	-0.147	-0.116	-0.042	-0.370	-0.047	**0.194**	0.920	0.231
Vigour	P	0.0004	0.024	-0.0007	0.012	0.037	0.007	-0.0008	-0.038	0.532	-0.006	-0.018	-0.008	0.069	0.637	-0.0009	0.107	0.092	-0.962	**-0.298**	0.186
index-II	G	0.600	-0.093	-0.609	0.024	0.786	-0.026	-0.006	-0.057	0.293	-0.007	-0.520	0.038	-0.071	-0.109	-0.443	-0.367	-0.151	0.578	**0.372**	0.230

Bold figure shows direct effect and normal value shows indirect effect

Residual effect = 0.13964

1-Days to 50% flowering, **2**- Days to maturity, **3**-Primary branches/ plant, **4**- Secondary branches/plant, **5**- Plant height (cm), **6**- Length of main raceme (cm), **7**- Siliqua on main raceme (cm), **8**- Number of seeds/siliqua, **9**- 1000-seed weight (g), **10**-Harvest index (%), **11**- Biological yield/ plant (g), **12**- Speed of germination, **13**- Germination (%), **14**- Root length (cm), **15**- Shoot length (cm), **16**-Seedling length (cm), **17**- Seedling dry weight (g), **18**- Vigour index-I, **19**- Vigour index-II, **20**- **Correlation coefficient with Seed yield/ plant (g).**

were observed by Verma *et al.* (2008), Maurya *et al.* (2013), Ikbal *et al*. (2014), Kumar *et al.* (2017), Kumar *et al.* (2018), Rout *et al.* (2018) and Vimal *et al.* (2018). Hence, direct selection for these traits would be rewarding for yield improvement, which will also reduce the undesirable effects of the component traits studied.

Conclusion

An overview of the experimental results of present investigation indicated a wide spectrum of variation with respect to yield related traits and seed quality parameter among all the forty genotypes of Indian mustard. With the help of GCV done, it may not be feasible to determine the amount of heritable variation and the relative degree to which a character is transmitted from parent to offspring is indicated by the estimates of heritability. Heritability estimates along with genetic advance are normally helpful in predicting the gain under selection than heritability estimate alone. Hence, both heritability and GA were determined to get a clear picture of the scope of improvement in various characters through seletion. Seed yield per plant was positively and significantly correlated with 1000-seed weight, harvest index, number of seeds per at both genotypic and phenotypic levels. The characters showing significant positive correlation among yield and important characters would be highly effective and efficient in improving respective traits. Path coefficient analysis identified as plant height and 1000-seed weight important component having high order of direct effect and seedling dry weight via vigour index-II and seedling length via vigour index-II important component having high order of indirect effect on seed yield per plant. The characters identified above as important direct and indirect yield components merit due to consideration in formulating effective selection strategy for developing high yielding mustard genotypes.

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