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RESEARCH ARTICLE

Studies on correlation and path analysis in germplasm of Indian mustard [*Brassica juncea* (L.) Czern and Coss.]

Dinesh Awasthi, V. K. Tiwari and V. S. Kandalkar

SUMMARY

Studies on correlation revealed that seed yield per plant and harvest index exhibited significant positive correlation and both traits also demonstrated significant positive correlation with days to 50 per cent flowering and number of secondary branches per plant at both genotypic and phenotypic level. This indicated the strong association of seed yield per plant, harvest index, days to 50 per cent flowering and number of secondary branches per plant. Both genotypic and phenotypic correlation co-efficient for seed yield per plant was found significant positive correlation with days to 50 per cent flowering, number of secondary branches per plant, number of siliqua per plant and harvest index. Number of siliqua per plant was found significant positive correlation with number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant and seed yield per plant. Number of secondary branches per plant was found significant positive correlation with days to 50 per cent flowering, number of primary branches per plant, number of siliqua per plant, number of seeds per siliqua, seed yield per plant and harvest index. Further, the path co-efficient analysis showed low residual effect (0.00482, 0.00304 and 0.00167) during *Rabi* 2016-17 and 2017-18 indicating that most of the major yield components were included in the study. Harvest index percentage had the highest direct positive effects on seed yield per plant, number of siliqua per plant, number of seeds per siliqua, number of secondary branches per plant and days to maturity. Based on result it has been concluded that two traits namely seed yield per plant and harvest index exhibited significant positive correlation as well as direct effect on seed yield may be considered for selection and to improve the seed yield of the mustard germplasm.

Key Words : Correlation, Path analysis, Indian mustard (*Brassica juncea* L.)

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Rapeseed-mustard is a major oilseed crop of India mainly constituted by *Brassica rapa* (Syn. *B. campestris* L.), *B. napus* (L.), *B. juncea* (L.) and *B. carinata* Braun. In India, rapeseed-mustard is grown over in diverse agro-climatic conditions ranging from north-eastern/north-western hills to down south. It is the second largest indigenous oilseed crop, contributing 32 per cent of total oilseed production in India.

Indian mustard (*Brassica juncea* L.) is an important *Rabi* season crop it is grown under irrigated as well as rain-fed conditions. The average productivity of Indian mustard is low, therefore, breeders are trying their best to improve the productivity of Indian mustard. The seed yield is a complex character which is largely depends on its contributing characters. These characters are polygenic in nature. Therefore, it is necessary to work out the correlation between seed yield and its attributing characters for establishing the selection criteria for Indian mustard improvement more efficiently. Correlation does not identify the characters having indirect effects on seed yield. In this case, path analysis projected by Wright (1921) would give the actual significance of a traits separating into correlation co-efficient into direct and indirect effects. The correlation between two characters can be partitioned into a portion that is due to genetic cause (genetic) and the other due to environmental factors. Thus, this study was planned to identify the magnitude of yield attributing traits for its improvement.

MATERIAL AND METHODS

Experimental material:

168 germplasm lines including 07 checks namely: Rohini, Maya, RVM-1, RVM-2 JM-1, JM-2 and JM-3 of Indian mustard were sown in the Randomized Block Design with row to row 30 (cm) and plant to plant 10 (cm) distance with 2 replications at research farm of Department of Plant Breeding and Genetics, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) during 2016-17 and 2017-18.

Observations:

Five plants were randomly selected from each replication in order to record observations on days to 50 per cent flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliqua, seed weight (g), harvest index, seed yield per plant (g) and seed oil content (%). Harvest index was calculated by following formula proposed by Donald and Hamblin (1976).

Statistical procedures:

The data collected on the 10 quantitative characters and their mean values were subjected for the correlation and path analysis. Two year data were separately computed for correlation and path analysis study.

Estimation of correlations:

Phenotypic and genotypic correlation co-efficient between characters were computed utilizing respective components of variances and co-variances, by following formula suggested by Miller *et al.* (1958).

$$r_{XY} = \frac{Cov.X.Y}{\sqrt{V_X + V_Y}}$$

where, r_{xy}= Correlation co-efficient between character X and Y,

cov_{xy} = Covariance of character X and Y

v_x = Variance of character X

v_y= Variance of character Y

The significance of phenotypic and genotypes correlation co-efficients was tested with estimated values compared with the tabulated values of Fisher and Yates (1938) at n-2 d.f. at two levels of probability, *viz.*, 5 per cent and 1 per cent.

Path co-efficient analysis:

Path co-efficient is a standardized partial regression, which measures the direct influence of one variable upon another and allows partition of correlation co-efficient into components of direct and indirect effects. The proportion of direct and indirect contributions of various characteristics to the total correlation co-efficients with grain yield per plant was estimated through path co-efficient analysis as suggested by Wright (1921 and 1934) and elaborated by Dewey and Lu (1959).

To estimate various direct and indirect effects, the following set of simultaneous equations were formed and solved.

$$r_{1y} = P_{1y} + r_{12}P_{2y} + r_{13}P_{3y} + \ldots + r_{1I}P_{Iy}.$$
$$r_{2y} = r_{2y}P_{1y} + P_{2y} + r_{23}P_{3y} + \ldots + r_{2I}P_{Iy}.$$
$$r_{Iy} = r_{I1}P_{1y} + r_{I2}P_{2y} + r_{I3}P_{3y} + \ldots + P_{Iy}.$$

where,

r_{1y} to r_{Iy}= Co-efficient of correlation between causal factor 1 to I and dependent y,

r_{12} to $r_{I-1,I}$= Co-efficient of correlation among causal factors themselves

P_{1y} to P_{Iy} = Direct effects of characters 1 to I on character y.

Residual effect, which measures the contribution of the characters not considered in the causal scheme, was obtained as:

$$\text{Residual effect } (P_{RY}) = \sqrt{1-R^2}$$

where,

$$R^2 = \sum_{iy} P_{iy}^2 + 2\sum_{\substack{i\neq j \\ i>j}} P_{iy}P_{jy}r_{ij}$$

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Estimates of correlation co-efficients:

Genotypic and phenotypic correlation co-efficients between yield and its contributing characters and among themselves were calculated and are presented in Table 1 and 2.

Genotypic correlation among traits:

Out of the 45 correlation co-efficients among the ten traits, 21 and 19 correlation co-efficients were significant at genotypic level during the year 2016-17 and 2017-18, respectively.

Seed yield per plant was found significant positive correlation with days to 50 per cent flowering, number of secondary branches per plant, harvest index and number of siliqua per plant; whereas harvest index also had significant positive correlation with seed yield per plant during the year 2017-18. Number of seeds per siliqua was found significant positive correlation with days to 50 per cent flowering, number of primary branches per plant, number of secondary branches per plant and number of siliqua per plant, while significant negative correlation with days to maturity and plant height. During 2017-18, 1000 seed weight was found significant positive correlation with days to 50 per cent flowering and plant height. Number of seeds per siliqua was found significant positive correlation with days to 50 per cent flowering, number of primary branches per plant, number of

Table 1 : Genotypic correlation co-efficients among 10 characters in 168 genotypes of Indian mustard (2016-17 and 2017-18)

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches / plant	No. of secondary branches / plant	No. of siliqua per plant	No. of seeds per siliqua	1000 seed weight (g)	Seed yield per plant (g)	Harvest index
Days to 50% flowering		0.096	0.085	0.194**	0.276**	0.079	0.229**	0.230**	0.130*	0.136*
Days to maturity	0.085		0.228**	-0.075	-0.084	-0.044	-0.075	0.087	-0.057	-0.051
Plant height (cm)	0.057	0.222**		0.392**	-0.075	0.006	-0.151**	0.184**	-0.003	-0.001
No. of primary branches/plant	0.134*	-0.081	0.404**		0.431**	0.530**	0.435**	-0.01	-0.001	-0.004
No. of secondary branches/plant	0.270**	-0.086	-0.080	0.560**		0.636**	0.461**	0.015	0.206**	0.212**
No. of siliqua per plant	0.066	-0.035	-0.010	0.558**	0.653**		0.512**	-0.067	0.077	0.181**
No. of seeds per siliqua	0.186**	-0.109*	-0.162**	0.423**	0.498**	0.492**		-0.024	-0.01	-0.018
1000 seed weight (g)	0.215**	0.101	0.183**	-0.042	0.026	-0.047	-0.063		0.071	0.081
Seed yield per plant (g)	0.132*	-0.059	-0.011	-0.009	0.188**	0.177**	-0.038	0.074		0.898**
Harvest index	0.140*	-0.054	-0.009	-0.018	0.193**	0.079	-0.044	0.087	0.897**	

Upper diagonal indicated year 2017-18 and lower diagonal year 2016-17; * and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 2: Phenotypic correlation co-efficients among ten characters in 168 genotypes of Indian mustard (2016-17and 2017-18)

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches / plant	No. of secondary branches / plant	No. of siliqua per plant	No. of seeds per siliqua	1000 seed weight (g)	Seed yield per plant(g)	Harvest index
Days to 50% flowering		0.095	0.072	0.071	0.180**	0.071	0.142**	0.220**	0.128*	0.134*
Days to maturity	0.083		0.198**	-0.023	-0.054	-0.04	-0.045	0.081	-0.057	-0.051
Plant height (cm)	0.045	0.190**		0.165**	-0.008	0.019	-0.113*	0.150**	-0.002	-0.002
No. of primary branches/plant	0.053	-0.030	0.193**		0.284**	0.221**	0.049	0.019	-0.002	-0.003
No. of secondary branches/plant	0.165**	-0.056	-0.010	0.296**		0.523**	0.188**	-0.019	0.127*	0.131*
No. of siliqua per plant	0.056	-0.033	0.010	0.213**	0.532**		0.210**	-0.075	0.164**	0.069
No. of seeds per siliqua	0.117*	-0.064	-0.120*	0.048	0.168**	0.166**		-0.065	-0.005	-0.011
1000 seed weight (g)	0.200**	0.088	0.134*	0.035	-0.028	-0.071	-0.086		0.063	0.072
Seed yield per plant (g)	0.129*	-0.059	-0.010	-0.006	0.111*	0.159**	-0.021	0.063		0.898**
Harvest index	0.138*	-0.053	-0.009	-0.006	0.116*	0.063	-0.026	0.074	0.897**	

Upper diagonal indicated year 2017-18 and lower diagonal year 2016-17; * and ** indicate significance of values at P=0.05 and 0.01, respectively secondary branches per plant, number of siliqua per plant and number of seeds per siliqua, while significant negative correlation with plant height (Table 1).

Plant height was found significant positive correlation with days to maturity, number of primary branches per plant and 1000 seed weight (g), while significant negative correlation with number of seeds per siliqua. Days to 50 per cent flowering was found significant positive correlation with number of primary branches per plant, number of secondary branches per plant, number of seeds per siliqua, 1000 seed weight (g), seed yield per plant (g) and harvest index. During 2017-18, number of siliqua per plant was found significant positive correlation with number of primary branches per plant, number of secondary branches per plant and number of seeds per siliqua (Table 1). This suggests the high degree of association between these traits; Nasim *et al*. (2013) reported positive correlation between pod length and 1000- seed weight. Malik *et al*. (2000) and Jeromela *et al*. (2007) reported positive correlation between siliqua per plant and seed yield. Labana *et al.* (1980) reported that plant height was negatively correlated with seed yield in *B. juncea*.

Phenotypic correlation among traits:

In both years 2016-17 and 2017-18, out of the 45 correlation co-efficients among the ten traits, 18 correlation co-efficients were significant at phenotypic level. Harvest index was found significant positive correlation with days to 50 per cent flowering and seed yield per plant (g) and with number of secondary branches per plant during 2017-18. Seed yield per plant was found significant positive correlation with days to 50 per cent flowering, number of secondary branches per plant, number of siliqua per plant and harvest index. 1000 seed weight was found significant positive correlation with days to 50 per cent flowering and plant height. Number of seeds per siliqua was found significant positive correlation with days to 50 per cent flowering; number of secondary branches per plant and number of siliqua per plant, while significant negative correlation with plant height. Number of primary branches per plant was found significant positive correlation with plant height, number of secondary branches per plant and number of siliqua per plant. Plant height was found significant positive correlation with days to maturity and 1000 seed weight, while significant negative correlation with number of seeds per siliqua; whereas, it had positive correlation with number of primary branches per plant and number of seeds per siliqua in both years 2016-17- and 2017-18 (Table 2).

Number of siliqua per plant was found significant positive correlation with number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant and seed yield per plant except number of siliqua per plant in 2017-18 but found significant position correlation with number of seed per siliqua and harvest index.Number of secondary branches per plant was found significant positive correlation with days to 50 per cent flowering, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, number of seeds per siliqua and seed yield per plant except number of secondary branches per plant in 2017-18 but had significant positive phenotypic correlation with harvest index. Days to 50 per cent flowering was found significant positive correlation with number of secondary branches per plant, number of seeds per siliqua, 1000 seed weight (g) and seed yield per plant and also had significant positive correlation harvest index during 2017-18 (Table 2). Khulbe and Pant (1999) reported positive and significant association between pod length and seed yield per plant in *B. juncea*. Masood *et al*. (1999) reported positive and significant correlation between seed yield per plant and seed yield per plot. The phenotypic correlation co-efficient was lower than genotypic correlation co-efficients; it indicated that the association of two characters is mainly due to genetic effects. Tiwari (2019) has demonstrated in his study that the genotypic correlation co-efficients were higher than phenotypic. This indicated that there is strong inherent association between the various characters which confirms the present results.

Path co-efficient analysis:

The correlation of seed yield per plant was further analyzed by the method of path co-efficient analysis. Correlation of yield with other characters were partitioned into components of direct and indirect effects to know the nature and relative importance of the components in determining seed yield per plant (Table 3 and 4).

The present path co-efficient analysis showed low residual effect (0.00482, 0.00304 and 0.00167) during *Rabi* 2016-17, 2017-18, respectively indicating that most of the major yield components were included in the study. In year 2016-17, harvest index had the highest direct positive effects on seed yield per plant followed by number of siliqua per plant, number of secondary branches per plant, number of primary branches per plant and number of seeds per siliqua. Plant height had the highest direct negative effects on seed yield per plant followed by 1000 seed weight, days to 50 per cent flowering and days to maturity. In year 2017-18, harvest index had the highest direct positive effects on seed yield per plant followed by number of siliqua per plant, number of seeds per siliqua and number of secondary branches per plant. Number of primary branches per plant had the highest direct negative effects on seed yield per plant followed by days to 50 per cent flowering, 1000 seed weight and plant height. These results indicate the correlation is mainly due to the direct effect of a character and it was realized via indirect positive and negative effects. It reveals the true relationship between them and direct selection for this trait will be rewarding for the genetic improvement of yield. Sharafi *et al*. (2015) found the number of siliqua per plant had the highest direct effect on seed yield. They also reported that number of seeds per siliqua had direct positive effect on yield per plant. On the contrary, a negative direct effect for seeds per siliqua on seed yield per plant has been reported by Basalma (2008). The value of residual effect was 0.211. It indicated that beside the component

Table 3 : Direct and indirect effects of component traits on seed yield in Indian mustard (2016-17)

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches / plant	No. of secondary branches / plant	No. of siliqua per plant	No. of seeds per siliqua	1000 seed weight (g)	Harvest index	Seed yield /plant (g)	Correlation co-efficient with grain yield
Days to 50% flowering	-0.0053	-0.0005	-0.0003	-0.0007	-0.0014	-0.0004	-0.0010	-0.0012	-0.0007	-0.0050	0.132
Days to maturity	0.0000	-0.0004	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0021	
Plant height (cm)	-0.0007	-0.0026	-0.0119	-0.0048	0.0010	0.0001	0.0019	-0.0022	0.0001	-0.0120	
No. of primary branches/plant	0.0035	-0.0021	0.0106	0.0263	0.0147	0.0147	0.0111	-0.0011	-0.0005	0.0180	
No. of secondary branches/plant	-0.0048	0.0015	0.0014	-0.0100	-0.0178	-0.0116	-0.0089	-0.0005	-0.0034	0.0260	
No. of siliqua per plant	0.0005	0.0003	0.0001	0.0045	0.0053	0.0081	0.0040	0.0004	0.0006	0.1480	
No. of seeds per siliqua	0.0012	-0.0007	-0.0010	0.0027	0.0032	0.0032	0.0064	-0.0004	-0.0003	0.0060	
1000 seed weight (g)	-0.0017	-0.0008	-0.0015	0.0003	-0.0002	0.0004	0.0005	-0.0081	-0.0007	-0.0080	
Harvest index	0.1403	-0.0539	-0.0086	-0.0182	0.1936	0.0791	-0.0446	0.0874	0.8035	0.8030	

Residual effect= 0.00482, Bold values in diagonal indicates direct effects

Table 4 : Direct and indirect effects of component traits on seed yield in Indian mustard (2017-18)

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliqua per plant	No. of seeds per siliqua	1000 seed weight	Harvest index	Seed yield / plant
Days to 50% flowering	-0.0058	-0.0006	-0.0005	-0.0011	-0.0016	-0.0005	-0.0013	-0.0013	-0.0008	-0.0060
Days to maturity	-0.0004	-0.0039	-0.0009	0.0003	0.0003	0.0002	0.0003	-0.0003	0.0002	0.0040
Plant height (cm)	0.0000	0.0000	-0.0002	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0005
No. of primary branches/ plant	0.0013	-0.0005	0.0026	0.0067	0.0029	0.0035	0.0029	-0.0001	0.0000	-0.0070
No. of secondary branches/ plant	-0.0025	0.0008	0.0007	-0.0038	-0.0089	-0.0057	-0.0041	-0.0001	-0.0019	0.0090
No. of siliqua per plant	0.0008	0.0004	0.0001	0.0052	0.0062	0.0098	0.0050	0.0007	0.0008	0.1010
No. of seeds per siliqua	0.0035	-0.0012	-0.0023	0.0066	0.0070	0.0078	0.0152	-0.0004	-0.0003	0.0150
1000 seed weight (g)	-0.0020	-0.0007	-0.0016	0.0001	-0.0001	0.0006	0.0002	-0.0085	-0.0007	-0.0050
Harvest index	0.1367	-0.0514	-0.0008	-0.0045	0.2125	0.0811	-0.0178	0.0808	1.0026	0.8503

Residual effect= 0.00304; Bold values in diagonal indicates direct effects characters, there was an influence of some other attributes (approx. 21.1%) on seed yield. Similar finding were reported earlier by Singh and Singh (2010).

Tiwari (2019) reported that the positive direct effects of these traits on grain yield indicated their importance in determining this complex character and therefore, it should be kept in mind while practicing selection aimed at the improvement of seed yield. The indirect effects of these characters were found lesser than the magnitudes of this direct effect on yield which indicated that these characters were affecting the grain yield directly. Similar results were also reported by Shalini *et al*. (2000) and Mahla *et al*. (2003). Sharafi *et al*. (2015) revealed that the number of siliqua per plant had the highest direct effect on seed yield. They also reported that number of seeds per siliqua had direct positive effect on yield per plant. On the contrary, a negative direct effect for seeds per siliqua on seed yield per plant has been reported by Basalma (2008). Positive direct effects of these characters on seed yield indicated their significance in determining this complex character and therefore, should be kept in mind while; committing selection for improvement of seed yield.

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