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Variability and Association Studies in Indian Mustards (*Brassica juncea* L. Czern and Coss)

Runa Singh[1*], Alok Kumar Maurya[2], S. P. Mishra[1] and G. P. Dixit[2]

[1]Dept. of Crop Sciences, Faculty of Agriculture, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna, Madhya Pradesh (485 334), India

[2]ICAR- Indian Institute of Pulses Research, Kanpur, Uttar Pradesh (208 024), India

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Corresponding Author

Runa Singh

e-mail: runasingh0710@gmail.com

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Abstract

A collection of 25 Indian mustard genotypes/ varieties were evaluated during Rabi 2017-18 to study the extent of variation and interrelationship between the yield characters. The analysis of variance indicated highly significance among treatments for all the characters expect silique length, day to 50% flowering and days to 80% maturity. Phenotypic coefficients of variability (PCV) were higher than genotypic coefficients of variability (GCV) for all the characters. Estimates of heritability (broad sense) ranged from 22.59% for days to 50% flowering and 66.79 for seed yield/plant. The expected genetic advance in percent of mean ranged between 2.45% for days to 80% maturity to 28.43% for seed yield per plant. The high heritability coupled with high genetic advance was found for total no. of siliqua per plant, plant height and seed yield/plant. In general, genotypic correlations were higher than phenotypic ones in magnitude for all the characters. The seed yield/plant (g) showed highly significant and positive correlation with total no. of siliquae per plant while significant and negative correlation with days to 80% maturity, number of seeds/siliqua, number of primary branch and siliqua length, at genotypic level. Path coefficient analysis revealed that the highest positive direct effect on seed yield (g) was exhibited by plant height, 1000 seed weight and siliqua length while negative direct effect was recorded with days to 80% maturity, number of seed per siliqua and plant height on seed yield at phenotypic level. Considering the high estimates of different genetic parameters, the present study suggested that Patna Mustard, RH-30, Gujarat Mustard and Varuna are the important varieties and plant height, seed yield/plant and total no. of siliqua/plant to be considered for selecting high yielding mustard genotypes.

1. Introduction

Indian mustard [*B. juneca* (Linn) Czern and Coss] popularly known as rai, raya or laha is one of the most important oil seed crops of the country and occupies considerably large acreage among the *Brassica* group of oil seed crops. It is estimated that total production of mustard seed in India is around 86.93 lakh MT. India is the fourth producer of mustard seed contributing to around 11% of world's ..... total area, production and yield of rapeseed-mustard in world during 2018-19 was 36.59 million hectares (mha), 72.37 million tonnes (mt) and 1980 kg/ha, respectively. Globally, India continues to be at rank 4th after Canada, China and European Union in acreage (17.19%) and after European Union, Canada and China in production (8.54%). Backed by good monsoon, India has attained a record acreage increased from 5.98 mha (2017-18) to 6.12 mha (2018-19) and production got increased from 8.43 mt (2017-18) to 9.26 mt (2018-19). In India, mustard and rapeseed are grown largely in Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana, West Bengal, and Assam, states accounted for 86.29% of area and 88.46% of production in the country. Rajasthan alone contributed 40.74% to the total area and 44.97% to the production (Anonymous, 2020).

Information on the nature and magnitude of variability present in the exiting material and association among the various morphological characters is a pre-requisite for any breeding programme to be initiated for high yields. However, seed yield a complex character usually controlled by non-additive gene actions and it is not only influenced by a number of other morphological characters which are governed by a large numbers of gene, but also environment to a great extent. Thereby, the heritable variation creates difficulty in a selection programme. Therefore, it is necessary to partition

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the overall variability into heritable components which enable the breeders to adopt suitable breeding procedure for further improvement of genetic stocks.

The success of any breeding programme depends upon the genetic variability engraved in the breeding material. The assessment of parameters including phenotypic and genotypic coefficients of variations, heritability in broad sense, and genetic advance is a pre-requisite for making effective selection. Yield is a complex trait, polygenic in inheritance, more prone to environmental fluctuations than ancillary traits polygenic in inheritance, more prone to environmental fluctuations than ancillary traits such as branches/plant, seeds/siliqua, main shoot length and 1000 seed weight. Understanding the association between yield and its components is of paramount importance for making the best use of these relationships in selection. The path coefficient analysis helps breeder to explain direct and indirect effects, and hence been extensively used in breeding experiments in different crop species (Akbar *et al*., 2003). The extent of diversity available in the crop decides the success of any crop improvement programme with manifested objectives. Assemblage and assessment of divergence in the mustard germplasm is essential to know the spectrum of diversity studies. Thus, the present investigation was planned to fetch the related information with the objectives to study the genetic variability, heritability and genetic advance of yield and its components, and association among the traits, through path coefficient analysis.

2. Materials and Methods

The experiment was conducted during Rabi 2017-18 at Agriculture Farm, NanaJi Deshmukh New Agriculture Campus Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya Chitrakoot, Satna (M.P). The place of experiment in Chitrakoot is situated at 25°10' North latitude and 80°85' East longitude. The altitude is about 200 m above mean sea level. 25 diverse varieties/ genotypes of Indian Mustards constituted the experimental materials for the present study. The experiment was conducted to evaluate the genotypes/ varieties under normal soil and rainfed condition. The experiment was laid out following Randomised Block Design (RBD) with three replications. Each treatment was grown in 3 m long single row plot spaced 45 cm apart. The plant to plant distance was maintained 30 cm by thinning. Recommended agronomic practices and plant protection measures were adopted to raise a good crop. Five competitive plants from each plot were randomly selected for recording of observation on nine characters. Average of the data from the sampled plants of each plot in respect of different characters was used for various statistical analysis. The analysis of variance for the design of the experiment was carried out according to Panse and Sukhatme (1978) and analyzed with windostat 9.3 software. The simple correlation between different characters at genotypic and phenotypic levels was worked out between characters.

3. Results and Discussion

Analysis of variance for the design of experiment indicated highly significant differences for all the characters *viz*., no. of primary branches, silique, length, total no. of silique per plant, no. of seed per silique, plant height, 1000 seed weight (g) and seed yield per plant (g) expect silique length, days to 50% flowering and days to 80% maturity which showed significant differences (Table 1). The results on range and coefficient of variation are presented character wise. In general, phenotype

Table 1: Analysis of variance for various yield traits in mustards

Source of Variation	d.f.	Days to 50% flowering	No. of primary Branchs/ plant	Silique length (cm)	Total no. of silique/ plant	No. of seeds/ silique	Plant height (cm)	Days to 80% maturity	1000 seed weight (g)	Seed yield/ plant (g)
Replication	2	2.68	0.14	0.59*	386.13	0.25	1015.41*	20.25	1.93	2
Treatments	24	10.73*	1.12**	0.30*	2905.34	0.73**	72.48**	37.09*	2.30	20.07
Error	48	5.72	0.49	0.15	540.69	0.29	300.96	18.4	0.74	2.85

*Significant at 5% Probablity level; **Significant at 1% Probablity level.

coefficients of variation were higher than genotyping coefficient of variation for all the characters. The perusal of the data revealed that days to 50% flowering ranged from 41.67 days (RLM-619) to 49.33 days (RNG-73) and the grand mean was 45.92 days (Table 2). The phenotypic and genotypic coefficients of variation were 5.92 and 2.81, respectively for this character. Number of primary branches per plant showed moderate values of phenotypic and genotypic coefficient of variation indicating that environment has played significant role in the expression of this character. The silique length showed low values of phenotypic and genotypic coefficients of variation indicating that environment has played significant role in the expression. The phenotypic and genotypic coefficients of variation exhibited high values which were recorded 18.69 and 14.39, respectively for this character indicating that environment has played significant role in the expression of this character. The number of seeds per siliqua showed low values of phenotypic and genotypic coefficients

of variation indicating that environment has played significant role in the expression. Plant height exhibited high values of phenotypic and genotypic coefficient of variation indicating that environment has played significant role in the expression of this character. Days to 80% maturity varied from 100.67 days (Patna mustard) to 114.67 (MCN-7) and the grand mean was 105.75 (Table 2). The phenotypic and genotypic coefficient variation was very low for this character. The bolder size of seeds was found for 1000-seed weight in variety Pusa Bold (9.90) and small size Rohini and RLM-619 (6.67) and the grand mean was 8.20. Seed yield per plant ranged from 83.95 g (MNC-7) to 19.89 g (Patna Mustard) while the grand mean was 14.19 g. Seed yield per plant exhibited of highest values of phenotypic and genotypic coefficient of variation, respectively indicating that environment has played significant role in the expression of this character, where as CV% among all characters ranged from 4.06% (days to 80% maturity) to 12.95% (plant height) (Table 2).

Table 2: Mean, range, genotype and phenotypic of variation for nine quantitative characters

Sl. No.	Characters	Grand mean (X) + SE	Range		Coefficient of Variation		CV%
			Min.	Max.	Genotypic	Phenotypic	
1	Days to 50% flowering	45.92 ± 1.38	41.67	49.33	2.81	5.92	5.21
2	No. of primary Branches/plant	7.10 ± 0.22	5.97	8.40	6.46	11.75	9.81
3	Silique length (cm)	5.40 ± 0.22	4.84	5.95	4.23	8.26	7.10
4	Total no. of silique/plant	195.05 ± 13.42	110.67	230.83	14.39	18.69	11.92
5	No. of seeds/silique	12.42 ± 0.31	1.23	13.63	3.09	5.35	4.37
6	Plant height (cm)	134.00 ± 10.02	100.53	167.20	8.85	15.68	12.95
7	Days to 80% maturity	105.75 ± 2.48	10.67	14.67	2.36	4.69	4.06
8	1000 seed weight (g)	8.20 ± 0.50	6.67	9.90	8.78	13.69	10.51
9	Seed yield/plant (g)	14.19 ± 0.98	8.95	19.89	16.89	20.66	11.91

Heritability in broad sense was computed for all the characters and been presented in (Table 3). In general, moderate estimates of broad sense heritability were observed for all the characters. The heritability values ranged from 22.59% for days to 50% flowering to 66.79% for seed yield/plant. The moderate estimate heritability were found for seed yield/plant (66.79) and total no. of silique per plant (59.31) while low heritability estimates were showed for 1000 seed weight (41.10), no. of seeds per silique (33.33), plant height (31.83%), no. of primary branches (30.21), siliqua length (26.25), days to 80% maturity (25.30%) and lowest by days to 50% flowering (22.59%).

The expected genetic advance in percent of mean ranged from 2.45% for days to 80% maturity to 28.43% for seed yield per plant. The high heritability coupled with high genetic advance was found with total no. of siliqua per plant, plant height and seed yield/plant, while high heritability coupled with low genetic advance were found in remaining characters (Table 3).

The seed yield plant (g) showed highly significant and positive correlation with total no. of siliquae per plant (0.386) while significant and negative correlation with days to 80% maturity (-0.951), number of seed/siliqua (-0.406), number of primary branch (-0.262) and siliqua length (-0.209) at genotypic level. Among other correlation, 1000 seed weight showed significant and positive with days to 50% flowering (0.274) while significant and negative correlation with plant height (-0.315) at genotypic level where as it showed negative correlation with days to 50% flowering (0.170) at phenotypic level. At genotype level, days to 80% maturity exhibited significant and

Table 3: Heritibility (%) in board sense, genetic advance and genetic advance in percent of mean for nine quantitative characters in Indian Mustards

Sl. No.	Characters	Heritability (broad sense)	Genetic advance	Genetic advance in percent of mean
1	Days to 50% flowering	22.59	1.26	2.75
2	No. of primary Branches/plant	30.21	0.52	7.31
3	Silique length (cm)	26.25	0.24	4.47
4	Total no. of silique/plant	59.31	44.54	22.84
5	No. of seeds/ silique	33.33	0.46	3.67
6	Plant height (cm)	31.83	13.78	10.28
7	Days to 80% maturity	25.30	2.59	2.45
8	1000 seed weight (g)	41.10	0.95	11.59
9	Seed yield/ plant (g)	66.79	4.03	28.43

positive correlation with days to 50% flowering (0.376), plant height with number of seeds/siliqua (0.767), number of seed/siliqua length (0.329) while days to 80% maturity exhibited significant and negative correlation with plant height (-0.382), siliqua length with days to 50% flowering (-0.258) and number of primary branches with days to 50% flowering (-0.420) at genotypic level. Path coefficient analysis revealed that the highest positive direct effect on seed yield (g) was exhibited by plant height (0.734), 1000 seed weight (0.313) and siliqua length (0.143). The negative direct effect was recorded in no. of seeds/siliqua (-1.430), days to 50% flowering (-0.718), number of primary branches (-0.527), days to 80% maturity (-0.298) and total no. of siliqua per plant (-0.082) contributed substantial negative direct effects on seed yield at genotypic level. At phenotypic level, path coefficient analysis revealed the highest positive direct effect on seed yield(g) and was exhibited by total no of siliqua per plant (0.202), siliqua length (0.122), days to 50% flowering (0.057) and number of primary branches (0.035) and 1000 seed weight (0.034) while negative direct effect was recorded with days to 80% maturity (-0.343), no. of seed per siliqua (-0.039) and plant height (-0.035) contributed substantial negative direct effects on seed yield (Table 4).

Table 4: Estimates of Genotypic Correlations for different quantitative characters in Indian Mustards

Sl. No.	Characters	Days to 50% flowering	No. of primary Branches/plant	Silique length (cm)	Total no. of silique/plant	No. of seeds/silique	Plant height (cm)	Days to 80% maturity	1000 seed weight (g)	Seed yield/plant (g)
1	Days to 50% flowering	1.000	-0.420	-0.258	-0.117	-0.728	-0.627	0.306	-0.170	0.033
2	No. of primary Branches/plant	-0.042	1.000	0.099	-0.092	0.160	0.120	-0.243	0.028	-0.262
3	Silique length (cm)	-0.0258	-0.099	1.000	-0.075	-0.329	-0.009	0.059	0.060	-0.209
4	Total no. of silique/plant	0.117	-0.092	-0.075	1.000	-0.382	-0.009	-0.417	-0.024	0.386
5	No. of seeds/silique	-0.728	0.160	0.329	-0.382	1.000	0.767	-0.119	-0.043	-0.406
6	Plant height (cm)	-0.627	0.120	-0.009	-0.009	0.767	1.000	-0.600	-0.140	0.105
7	Days to 80% maturity	0.306	-0.243	-0.059	-0.417	-0.119	-0.600	1.000	-0.022	-0.951
8	1000 seed weight (g)	-0.274	0.082	-0.103	-0.169	-0.067	-0.315	-0.077	1.000	0.086
9	Seed yield/plant (g)	0.033	-0.262	0.209	0.386	-0.406	-0.105	-0.951	-0.086	1.000

A perusal of phenotypic (PCV) and genotype (GCV) coefficient of variability further indicate that in general PCV was higher than GCV for all the characters. Coefficients of variability were high for all the characters. The existence of considerable higher variability for seed yield and its major indicates sample opportunities for improvement through selection. These observations are in agreement with the findings of Ali *et al.* (2003), Agrawal *et al.* (2003), Chaudhary *et al.* (2004), Chauhan *et al.* (2010) and Misra (2012) reported the maximum PCV for character seed yield per plant followed by seed per siliqua and Rashid *et al.* (2014) for seed yield per plant. Genetic advance expressed in percent of mean (GA %) also varied considerably from character to character. Considering heritability in broad sense and genetic advance together, it was noted that higher heritability (> 50%) was associated with high genetic advance (> 20%) for all character suggesting moderate and low estimates of expected genetic advance for this characters.

The parameter genetic advance in percent of mean (GA) is a more reliable index for understanding the effectiveness of selection in improving the traits because its estimates is derived by involvement of heritability, phenotypic standard deviation and intensity of selection. Thus, heritability and genetic advance in percent of mean combination provide clear picture regarding the effectiveness of selection for improving the plant characters.

In the present study, the heritability values among quantitative characters ranged from 22.59% for days 50% flowering to 66.79 for seed yield/plant (Table 3). High estimates of board sense heritability (h^2b) (0.75%), moderate (50-75%) estimation of board sense heritability (h^2b) and low (< 50%) broad sense heritability (h^2b). Similar results were reported by Gupta and Singh (2001) for 1000 seed weight and yield per plant, Husain *et al.* (1996) for number of seeds per siliqua, Kumar *et al.* (2004), Mahto and Haider (2013) and Meena *et al.* (2015) for seed weight. In the present study, phenotypic and genotypic correlations were estimated. The direction of phenotypic and genotypic correlations was similar for almost all the characters. In general, genotypic correlations were higher than phenotypic ones in magnitude for all the characters. The higher genotypic correlation coefficients form a sound base for their practical implication. The character which showed negative association at genotypic level also showed negative association at phenotypic level. The seed yield per plant (g) showed highly significant and positive correlation with total no. of siliquae per plant while significant and negative correlation with days to 80% maturity, number of

Table 5: Estimates of Phenotypic Correlations for different quantitative characters in Indian Mustards

Sl. No.	Characters	Days to 50% flowering	No. of primary Branches/ plant	Silique length (cm)	Total no. of silique/ plant	No. of seeds/ silique	Plant height (cm)	Days to 80% maturity	1000 seed weight (g)	Seed yield/ plant (g)
1	Days to 50% flowering	1.000	0.048	-0.025	-0.112	-0.067	-0.068	0.054	-0.170	0.014
2	No. of primary Branches/plant	0.048	1.000	0.018	-0.059	0.199	0.248*	-0.051	0.028	0.025
3	Silique length (cm)	-0.025	-0.018	1.000	-0.156	0.122	-0.169	0.048	0.060	0.075
4	Total no. of silique/ plant	-0.112	-0.059	-0.156	1.000	-0.151	-0.076	-0.134	-0.024	0.229*
5	No. of seeds/silique	-0.067	0.199	0.122	-0.151	1.000	0.281*	-0.056	-0.043	-0.044
6	Plant height (cm)	-0.068	0.248*	-0.169	-0.076	0.281*	1.000	-0.098	-0.140	0.048
7	Days to 80% maturity	0.054	-0.051	0.048	-0.134	-0.056	-0.098	1.000	-0.022	-0.358**
8	1000 seed weight (g)	-0.170	0.028	0.060	-0.024	-0.043	-0.140	-0.022	1.000	0.042
9	Seed yield/plant (g)	0.014	-0.025	0.075	0.229*	-0.044	-0.048	-0.358**	0.042	1.000

*Significant at 5% Probablity level; **Significant at 1% Probablity level

seeds/siliqua, number of primary branch and siliqua length at genotypic level. At genotypic level, days to 80% maturity exhibited significant and positive correlation with days to 50% flowering; plant height with number of seeds/siliqua; number of seeds/siliqua length with days to 50% flowering and total no. of siliquae per plant; siliqua length with days to 50% flowering and number of primary branches with days to 50% flowering at genotypic level. Path coefficient analysis revealed that, the highest positive direct effect on seed yield (g) was exhibited by plant height, 1000 seed weight and siliqua length. The negative direct effect was recorded in character no. of seed/siliqua, days to 50% flowering, number of primary branches, days to 80% maturity and total no. of siliqua per plant contributed substantial negative direct effects on seed yield at genotypic level (Table 6). Plant height and days to 50% flowering *via* no. of seeds/siliqua *via* total number of siliqua

Table 6: Direct and indirect effects for different characters on seed yield per plant at genotypic level in Indian Mustards

Sl. No.	Characters	Days to 50% flowering	No. of primary Branches/ plant	Silique length (cm)	Total no. of silique/ plant	No. of seeds/ silique	Plant height (cm)	Days to 80% maturity	1000 seed weight (g)
1	Days to 50% flowering	-0.718	0.301	0.185	-0.084	0.523	0.450	-0.220	-0.197
2	No. of primary Branches/ plant	0.221	-0.527	-0.052	-0.049	-0.085	-0.063	0.128	-0.043
3	Silique length (cm)	-0.037	0.014	0.143	-0.011	0.047	-0.001	-0.008	-0.015
4	Total no. of silique/plant	-0.010	-0.008	0.006	-0.082	0.031	0.001	0.034	0.014
5	No. of seeds/silique	1.041	-0.229	-0.470	0.546	-1.430	-1.096	-0.170	0.096
6	Plant height (cm)	-0.460	0.088	-0.007	-0.007	0.563	0.734	-0.441	-0.231
7	Days to 80% maturity	-0.091	0.072	0.018	0.124	-0.036	0.179	-0.298	-0.023
8	1000 seed weight (g)	0.086	0.026	-0.032	-0.053	-0.021	-0.098	0.024	0.313
	Seed yield/plant (g)	0.033	-0.262	-0.209	0.386	-0.406	0.105	-0.951	-0.086
	Partial R2	-0.024	0.138	-0.030	-0.032	0.581	0.077	0.284	-0.027

Residual Effect = 0.1786 Direct Effect on Main diagonal (Bold Figure)

per plant; no of seeds/siliqua and no. of primary branches *via* days to 50% flowering; days to 50% flowering *via* no. of primary branches; days to 50% flowering *via* siliqua length and no. of primary branches *via* days to 80% maturity exerted substantial positive indirect effects on seed yield, while plant height *via* days to 50% flowering; no. of seeds/siliqua *via* plant height; number of seeds per siliqua *via* siliqua length; number of seeds per siliqua *via* no. of primary branches; Plant height *via* days to 80% maturity and Plant height and days to 50% flowering *via* 1000 seed weight exerted substantial negative

indirect effects on seed yield at genotypic level. Sharma *et al*. (2010) and Bind *et al.* (2014) for biological yield per plant had the highest direct positive effect on seed yield per plant followed by harvest index,1000 seed weight, no. of seeds per siliqua and no. of primary branches. The remaining estimates of the indirect effects in the present analysis were too low to be considered important. The estimate of residual factors phenotypic (0.9030) and genotypic (0.1786) was moderate indicating that some of characters affecting seed yield have to be included in the present study.

Table 7: Direct and indirect effects for different characters on seed yield per plant at genotypic level in Indian Mustards

Sl. No.	Characters	Days to 50% flowering	No. of primary Branches/ plant	Silique length (cm)	Total no. of silique/ plant	No. of seeds/ silique	Plant height (cm)	Days to 80% maturity	1000 seed weight (g)
1	Days to 50% flowering	0.057	0.003	-0.001	-0.006	-0.004	-0.004	0.003	-0.010
2	No. of primary Branches/plant	0.002	0.035	-0.001	-0.002	0.007	0.009	-0.002	0.001
3	Silique length (cm)	-0.003	-0.002	0.122	-0.019	0.015	-0.021	0.006	0.007
4	Total no. of silique/plant	-0.023	-0.012	-0.032	0.202	-0.031	-0.015	-0.027	-0.005
5	No. of seeds/silique	0.003	-0.008	-0.005	0.006	-0.039	-0.011	0.002	0.002
6	Plant height (cm)	0.002	-0.009	0.006	0.003	-0.010	-0.035	0.003	0.005
7	Days to 80% maturity	-0.018	0.017	-0.016	0.046	0.019	0.033	-0.343	0.008
8	1000 seed weight (g)	-0.006	0.001	0.002	-0.001	-0.001	-0.005	-0.001	0.034
	Seed yield/plant (g)	0.014	0.025	0.075	0.229	-0.044	-0.048	-0.358	0.042
	Partial R2	0.001	0.001	0.009	0.046	0.002	0.002	0.123	0.001
	Residual Effect = 0.9030				Direct Effect on Main diagonal (Bold Figure)				

4. Conclusion

The extent of variation and interrelationship between the yield characters in mustard revealed higher genotypic coefficients of variability (GCV) for all the characters. The high heritability coupled with high genetic advance was found for total no. of siliqua per plant, plant height and seed yield/plant. Also, genotypic correlations were higher than phenotypic ones in magnitude for all the characters. Path coefficient analysis revealed that the highest positive direct effect on seed yield (g) was exhibited by plant height, 1000 seed weight and siliqua length. In view of above, Patna Mustard, RH-30, Gujarat Mustard and Varuna are found to be the important varieties and plant height, seed yield/plant and total no. of siliqua/ plant to be considered for selecting high yielding mustard genotypes.

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