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V. K. Tiwari

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Research Article

Morphological parameters in breeding for higher seed yield in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]

V. K. Tiwari
Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya, Zonal Agricultural Research Station, A B Road, Morena (M.P) 476001
E-Mail: vkt786@rediffmail.com

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Abstract
Highest genotypic coefficient of variation was recorded for number of secondary branches per plant. High genetic variation was found in length of siliqua, seed yield per plant, number of siliqua per plant and 1000 seed weight (g). Where number of secondary branches per plant, number of siliqua per plant, length of siliqua, 1000 seed weight (g), oil content and seed yield per plant possessing high G.C.V. and heritability. High estimates of genetic advance were observed for number of siliqua per plant. High heritability coupled with high genetic advance; it was inferred that additive gene action was in operation for control of length of siliqua, seed yield per plant, 1000 seed weight, number of secondary branches per plant and number of siliqua per plant. The genotypic correlation coefficients were higher than phenotypic and environmental correlation coefficients. This indicated that there is strong inherent association between the various characters studied. Number of siliqua per plant and number of seeds per siliqua were the major characters which had highest direct contribution towards yield per plant.

Key words
Genotypic coefficient of variation, Phenotypic coefficient of variation, Heritability, Genetic advance, Correlation, Path analysis.

Introduction

Indian mustard (*Brassica juncea* L. Czern & Coss) is an important crop among the crops of oilseeds in the world. This is a major crop of rabi season of Chambal as well as other parts of MP and adjoining states of Haryana, Rajasthan and UP. In India, the area (6.5 m h), production (7.8 m tones) and productivity (1208 kg/h) of rapeseed and mustard have been estimated. In M.P, the area of mustard production was targeted 0.76 m h hectares with productivity of 989 Kg/h and production of 0.75 m tones during 2013-14 (Anonymous, 2014). The productivity of Indian genotypes is low and there is an urgent need to breed high seed yielding and high oil content varieties. Crop improvement in Indian mustard depends upon the presence of genetic variability, heritability, correlation as well as genetic gain in selection (Khan *et al*., 2006). Heritability is a key of transmissibility of traits and as such partition the total variance into genetic and environmental components (Marwede *et al*. 2004). Correlations are important in determining the degree to which various yield contributing characters are associated. Plant traits having satisfactory variability, high heritability and genetic advance would be an effective tool for crop improvement (Aytac and Kinaci, 2009). Development of high yielding varieties need critical evaluation of existing genetic variability, heritability and genetic advance (Mahmood *et al*., 2003; Pant and Singh, 2001; Akbar *et al*., 2003). Meena *et al.* (2014) suggesting that seed yield components in Indian mustard had greater importance in selection of genotypes.

Materials and Methods

Twenty-five genotypes namely; RKL-09-2, BIO-322-93, NPJ-140, Vardan (NC), DRMR 906, RRN-660, UBUS-1, HUJM 08-01, RMWR-09-1, PRL-2007-3, DRMR 283, BAUSM 2002, Kranti (NC), BBM 10-1, DRMR 447, RGN-252, RGN-145 (ZC), RH 0623, RKL-09-1, PBR 381, RH 0655, RRN-683, PRL-2006-37, RGN-247 and RVM-2 were used. Seeds are sown in randomized block design with three replications. The gross plot size was 5.00 M x 1.50 M. Seeds of each genotype were sown in five rows with row to row and plant to plant distance 30 cm and 10 cm respectively under AICRP-R&M [ICAR] net work at the RVSKVV, ZARS Research Farm, Morena during 2010. The correlation coefficient values were calculated as described by AJ-Jibouri *et al.* (1958).

At maturity three central rows were harvested to assess seed yield and five plants were randomly selected to record the observations at maturity. Data were recorded for days to 50% flowering, days to maturity, plant height, number of primary branches, number of secondary branches, number of siliqua per plant, number of seeds per siliqua, length of siliqua, 1000-seed weight and seed yield per plant except days to 50% flowering. All recommended package of practices were followed to experimental crop in order to get optimum population in the experiment. Threshed seeds were cleaned and dried; such seeds were analyzed for oil contents (%) by the methods of NMR as described by Madson (1976).

Mean and analysis of variance were calculated as described by Panse and Sukhatme (1954). The genotypic (GCV) and phenotypic coefficients of variation (PCV), heritability in broad-sense and genetic advance were calculated by the formulae given by Johnson *et al*. (1955). The correlation coefficient values were calculated as described by Al-Jibouri *et al* (1958). Direct and indirect contribution of various characters of seed yield/plant was calculated through path coefficient analysis as per Dewey and Lu (1959).

Results and Discussion

A wide range of variability had been noticed among 25 genotypes of Indian mustard for different characters under study (Table 1). Highly significant differences among genotypes for nine characters *viz*. days to 50% flowering, days to maturity, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, length of siliqua, 1000 seed weight, oil content and seed yield per plant exhibited abundant variability for these traits. Non-significant differences among the genotypes were observed for plant height and number of seeds per siliqua showing least variability for the trait [Labana *et al.* (1980) and Singh *et al.* (2003)]. The highest genotypic coefficient of variation was observed for length of siliqua (28.81%), followed by number of secondary branches per plant (28.33%), seed yield per plant (25.70%), number of siliqua per plant (25.49%) and 1000 seed weight (17.93%) and the lowest genotypic coefficient of variation was recorded for the days to maturity (1.99%) followed by plant height (3.10%), oil content (3.70%) and number of seeds per siliqua (5.61%). The highest phenotypic coefficient of variation was recorded for number of secondary branches per plant (36.0%) followed by length of siliqua (30.15%), seed yield per plant (27.35%), number of siliqua per plant (25.93%) and 1000 seed weight (20.04%). The lowest phenotypic coefficient of variation was recorded for the days to maturity (2.25%) followed by oil content (3.70%), plant height (6.07%) and number of seeds per siliqua (12.47%). The number of secondary branches per plant, length of siliqua, seed yield per plant, number of siliqua per plant and 1000 seed weight showed high PCV and GCV estimates. High degree of variability for these characters has also been reported by Choudhary *et al.* (2003), Singh *et al.* (2004), Rai *et al.* (2005) and Muhammad *et al.* (2007). Selection based on these characters, which have recorded maximum GCV, would facilitate successful isolation of desirable genotypes for these characters. PCV and GCV of characters namely; days to maturity, plant height and oil content that had indicated limited scope for improvement.

A comparison of differences between PCV and GCV showed a wide difference in respect of number of seeds per siliqua, number of secondary branches per plant and number of primary branches per plant. This might have been due to larger influence of environment on these traits. Oil content, days to maturity and days to 50% flowering showed the least differences, indicating the greater role of genetic factors influencing the expression of these characters. This indicated the utility of such of those characters that show the least difference between PCV and GCV, which is estimated in the selection programme. Selection based on a particular character will be effective when its heritability estimate is high. Burton (1952) suggested that GCV together with heritability estimates would give the best picture of the extent of advance to be expected by selection. High heritability estimates were found for oil content (99.5%) followed by days to 50% flowering (90.0%) and seed yield per plant (89.3%). Moderate heritability values were observed for the characters number of primary branches per plant (47.8%), while low heritability estimates were recorded for number of seeds per siliqua (20.4%) followed by plant height (18.3%).

The high estimates of heritability in broad sense were recorded for oil content, days to 50% flowering, number of siliqua per plant, length of siliqua, seed yield per plant, days to maturity, 1000 seed weight and number of secondary branches per plant [Singh *et al.* (2003a) and Acharya and Pati (2008)]. High heritability estimates was recorded in characters namely; number of secondary branches per plant, length of siliqua, seed yield per plant and number of siliqua per plant showed high GCV estimates thereby pointing to the improvement of these characters through simple mass selection. The highest genetic advance was observed for number of siliqua per plant and lowest for number of seeds per siliqua. The estimates of expected genetic advance expressed as percentage of mean was highest for length of siliqua (53.95%) followed by seed yield per plant (49.35%), number of secondary branches per plant (48.50%), number of siliqua per plant (46.50%) and 1000 seed weight (30.02%) and lowest for plant height (2.80%), days to maturity (6.51%) and number of seeds per siliqua (5.00%) (Table 2).

The genetic gain that can be expected by selection for a character is given by the estimates of genetic advance. The genetic advance ranged from 0.62 (number of seeds per siliqua) to 76.44 (number of siliqua per plant). The genetic advance as per cent of mean was found maximum for length of siliqua followed by seed yield per plant, number of secondary branches per plant, number of siliqua per plant and 1000 seed weight. These characters also showed high heritability estimates. Such a high heritability coupled with high genetic advance has been reported for number of secondary branches/plant [Mahla *et al.* (2003) and Acharya and Pati (2008)]; for number of siliqua per plant [Choudhary *et al.* (2003) and Acharya and Pati (2008)]; for seed yield per plant [Choudhary *et al.* (2003), Mahla *et al.* (2003) and Singh *et al.* (2003a)] and for 1000 seed weight [Mahla *et al.* (2003) and Acharya and Pati (2008)] (Table 2). Such high heritability coupled with high genetic advance for the characters mentioned above indicates the predominance of additive gene action on these traits. High heritability with moderate genetic advance was recorded for days to 50% flowering indicating that the character were less influenced by environment but governed by both additive and non-additive gene action. High heritability coupled with low genetic advance as per cent of mean was recorded for days to maturity and oil content indicating less influence of environment but prevalence of non-additive gene action for which simple selection will be less effective. Moderate heritability with moderate genetic advance was recorded for number of primary branches per plant revealing lesser influence of environment but governed by non-additive and additive gene action. Hence, limited improvement is expected through selection in later generations.

Genotypic and phenotypic correlations among seed yield per plant and various characters namely days to 50% flowering number of siliqua per plant, length of siliqua and oil were at par which showed that there is least environmental influence on the appearance of genotypes. Seed yield per plant was found to be highly significant and positively associated with number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, Similar results were reported by Patra *et al.* (2006), Muhammad *et al.* (2007), Ramanjaneyulu and Giri (2007), Verma *et al.* (2008) and Shekhawat *et al.* (2014). Interestingly, significant and negative correlation was found with days to 50 % flowering at phenotypic level. Days to 50% flowering were recorded highly significant and positive association with length of siliqua. Contrary to it, Shekhawat *et al.* (2014) reported significant and positive correlation with test weight while significant negative correlation between days to maturity and number of seeds per siliqua was observed. Whereas, highly significant and negative association with number of secondary branches per plant, number of siliqua per plant and number of seeds per siliqua. Other characters namely; number of primary and secondary branches per plant had highest positive correlation with number of sliliqua per plant. On the other hand, number of seeds per siliqua had highest positive association with oil content (Table 3). The observed correlation coefficients between yield and various yield components were partitioned into direct and indirect effects (Table 4). The highest positive direct effect on seed yield was obtained by number of siliqua per plant (1.708) followed by 1000 seed weight (0.950) and number of seeds per siliqua (0.553). This is supported by the finding of Shekhawat *et al.* (2014). This shows true relationship with seed yield per plant. Kardam and Singh (2005), Verma and Mahto (2005), Patra *et al.* (2006) and Muhammad *et al.* (2007) also reported highest positive direct effect of number of siliqua per plant on seed yield. Similarly, Patra *et al.* (2006) and Verma *et al.* (2008) had reported high positive direct effect of number of seeds per siliqua, which support the present results. Number of secondary branches per plant recorded the highest negative effect (-1.050) followed by oil content (-0.765) and plant height (-0.485). The indirect effect of days to 50% flowering *via.* number of secondary branches per plant (0.435) and oil content (0.225) were found to be positive; whereas, indirect effect of this character *via.* number of siliqua per plant (-0.838) and number of seeds per plant (-0.120) were recorded negative. Days to maturity *via.* oil content had only positive indirect effect (-0.219); While other characters had shown negative effect. Plant height *via.* number of secondary branches per plant (0.536) and oil content (0.428) had positive indirect effect. The negative indirect effect was noticed *via.* number of seeds per siliqua (-0.069). The most important traits like number of primary branches per plant and secondary branches per plant had highest positive indirect *via.* number of siliqua per plant (1.145) and length of siliqua (0.015). The indirect positive effects of number of siliqua per plant, number of seeds per siliqua and length of siliqua *via.* length of siliqua (0.015), 1000 seed weight (0.283) and oil content (0.280 were noticed. The negative direct contribution was converted into positive mainly due to its positive indirect effects *via.* most of characters especially number of secondary branches per plant and number of siliqua per plant. The genotypic correlation and path coefficient analysis indicated that the characters namely number of siliqua per plant and number of seeds per siliqua had strong positive correlation and high magnitude of positive direct effects on seed yield. Further, the indirect effects of most of the other characters *via.* number of siliqua per plant was positive. It is therefore suggested that preference should be given to these characters in selection programme to isolate superior lines with genetic potentiality for higher seed yield.

Plant height and number of seeds per siliqua had low values for heritability and genetic advance, Hence, it may not respond favorably to selection. Therefore, it is evident that length of siliqua, seed yield per plant, number of secondary branches per plant, number of siliqua per plant and 1000 seed weight recorded high GCV value, heritability estimate and genetic advance. Hence, the improvement in these traits could be achieved through direct selection. Further, the findings pertaining to correlation and path analysis, it is evident that the two traits *viz*., number of siliqua per plant and number of seeds per siliqua are undisputedly most important components for further yield improvement in mustard.

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Table 1. Variability among genotypes of Indian mustard with respect to different character in Indian Mustard

S. No.	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliqua /plant	No. of seeds /siliqua	Length of siliqua (cm)	1000 seed weight (g)	Oil content (%)	Seed yield per plant (g)
1	59.00	128.00	181.00	5.60	6.80	178.60	13.00	4.00	6.00	41.00	10.50
2	57.00	126.00	189.66	4.50	3.40	108.70	13.50	3.24	6.10	39.00	6.20
3	59.00	128.00	190.99	4.23	4.80	174.30	12.60	4.50	5.10	42.00	9.15
4	62.00	122.00	170.55	4.70	6.25	180.00	11.00	3.00	4.78	41.25	4.50
5	55.00	127.00	185.55	4.25	7.20	137.00	12.00	3.75	5.39	39.83	6.50
6	58.00	127.00	185.00	5.60	7.25	180.78	11.20	3.89	5.20	40.10	8.26
7	63.00	128.00	170.66	5.25	3.50	110.00	12.00	3.80	4.50	40.81	4.50
8	59.00	125.67	180.00	5.88	7.55	169.22	11.00	3.80	5.30	40.09	8.00
9	62.00	128.00	185.44	5.25	5.66	150.00	12.00	5.20	3.90	37.50	7.00
10	63.00	127.00	182.88	5.70	6.00	168.00	13.00	3.80	5.00	42.30	7.00
11	51.00	124.00	182.33	6.20	10.00	280.00	12.50	3.95	3.20	41.00	12.00
12	53.00	123.00	171.33	5.50	7.00	190.50	12.00	3.30	3.60	41.10	6.30
13	58.00	126.00	188.44	4.60	5.00	170.25	11.03	3.60	3.40	40.20	7.00
14	54.00	124.00	186.77	4.60	4.00	190.89	12.25	3.70	3.70	41.20	6.89
15	50.00	123.00	189.00	4.25	7.00	180.40	11.00	3.90	4.70	41.70	7.25
16	61.00	124.00	190.77	5.50	6.10	190.00	11.11	8.75	4.32	39.20	7.32
17	55.00	125.00	170.40	4.25	5.25	158.10	13.25	4.60	5.32	40.25	8.85
18	65.00	126.00	185.11	4.00	3.65	130.55	12.00	4.15	5.30	38.18	5.69
19	59.88	125.00	190.11	4.20	3.50	140.80	14.80	4.60	5.50	40.00	9.91
20	60.00	127.00	182.00	4.30	5.30	141.30	12.50	3.60	5.76	40.00	7.63
21	62.00	128.00	190.00	4.40	5.25	144.30	11.00	5.40	4.40	38.00	6.53
22	55.00	125.00	180.00	4.40	3.50	85.00	11.25	3.90	5.70	39.00	4.60
23	61.00	124.00	182.30	4.20	6.35	155.50	12.22	5.50	3.80	40.37	6.13
24	55.00	120.00	195.00	4.70	5.25	180.10	13.11	3.75	4.20	40.00	8.04
25	55.00	125.00	190.25	8.22	13.00	289.22	15.23	4.56	4.32	44.65	13.00
C.D. at 5%	2.68	2.10	NS	0.98	2.10	20.52	NS	0.88	0.99	0.55	1.58

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Table 2. Mean, range, coefficient of variation and heritability of different characters in Indian Mustard

S. No.	Characters	Range	Grand Mean	PCV (%)	GCV (%)	Heritability(%)	Genetic advance	GA as per cent of mean
1	Days to 50% flowering	50.00-65.00	58.08	8.40	7.50	90.0	9.19	15.66
2	Days to maturity	1120.00-128.00	125.43	2.25	1.99	82.8	4.45	6.51
3	Plant height (cm)	1170.40-195.00	188.04	6.07	3.10	18.3	4.35	2.80
4	Number of primary branches per plant	4.00-8.22	4.95	17.38	12.52	47.8	0.79	16.80
5	Number of secondary branches per plant	3.40-13.00	6.71	36.0	28.33	70.4	3.69	48.50
6	Number of siliqua per plant	85.00-289.22	165.11	25.93	25.49	85.8	76.44	46.50
7	Number of seeds per siliqua	11.00-15.23	13.39	12.47	5.61	20.4	0.62	5.00
8	Length of siliqua (cm)	3.00-8.75	5.00	30.15	28.81	86.5	3.18	53.95
9	1000 seed weight (g)	3.20-6.10	4.65	20.04	17.93	80.0	1.51	30.02
10	Oil content (%)	39.58-43.90	42.50	3.70	3.70	99.5	3.32	6.82
11	Seed yield per plant (g)	4.5-13.00	7.55	27.35	25.70	89.3	4.45	49.35

Table 3. Estimates of phenotypic and genotypic correlation for different traits in Indian mustard

Characters		Days to maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliqua /plant	No. of seeds /siliqua	Length of siliqua (cm)	1000 seed weight (g)	Oil content (%)	Seed yield per plant (g)
Days to 50%	P	0.180	0.043	0.050	-0.311**	-0.301**	-0.100	0.315**	0.060	-0.270*	-0.512**
flowering	G	0.211	0.060	0.051	-0.376	-0.368	-0.350	0.340	0.029	-0.294	-0.487
Days to maturity	P		-0.016	0.077	-0.180	-0.312**	0.068	-0.129	0.312**	-0.261*	0.066
	G		0.090	0.160	-0.210	0.378	0.080	-0.166	0.421	-0.288	0.035
Plant height (cm)	P			0.035	0.028	0.019	0.165	0.140	0.035	-0.230*	0.190
	G			-0.542	-0.480	-0.141	-0.190	0.407	0.145	-0.564	0.419
Number of primary	P				0.620**	0.622**	-0.138	-0.056	-0.057	0.056	0.886**
branches per plant	G				0.730	0.740	-0.285	-0.016	-0.026	0.077	0.455
Number of secondary	P					0.705**	-0.065	0.010	-0.260*	0.140	0.439**
branches per plant	G					0.865	-0.350	0.008	-0.340	0.160	0.389
Number of siliqua per	P						0.010	0.030	-0.410**	0.250*	0.599**
plant	G						-0.075	0.070	-0.520	0.260	0.620
Number of seeds per	P							-0.060	0.130	0.150	0.358*
siliqua	G							-0.225	0.280	0.370	0.776
Length of siliqua (cm)	P								-0.142	-0.342**	0.071
	G								-0.180	-0.173	0.060
1000 seed weight (g)	P									0.080	0.095
	G									0.010	0.302
Oil content (%)	P										0.355
	G										0.245

* Significant at p =0.05; ** Significant at p = 0.01; P = Phenotypic level. ; G= Genotypic level

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Table 4. Genotypic path analysis, direct (diagonal) and indirect effect of different characters on seed yield per plant in Indian Mustard

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	Number of siliqua per plant	Number of seeds per siliqua	Length of siliqua (cm)	1000 seed weight (g)	Oil content (%)	Genotypic correlation coefficient with seed yield
Days to 50% flowering	**-0.240**	0.050	-0.032	-0.019	0.435	-0.838	-0.120	0.055	0.030	0.225	-0.487
Days to maturity	-0.031	**0.335**	-0.044	-0.045	-0.236	-0.938	-0.038	-0.029	-0.415	0.219	0.035
Plant height (cm)	-0.019	0.025	**-0.485**	0.163	0.536	-0.359	-0.069	0.067	0.133	0.428	0.419
Number of primary branches per plant	-0.006	0.040	0.277	**-0.287**	-0.808	1.589	-0.067	-0.022	-0.210	-0.157	0.455
Number of secondary branches per plant	0.050	-0.040	0.230	-0.210	**-1.050**	1.145	-0.125	0.003	-0.335	-0.129	0.389
Number of siliqua per plant	0.050	-0.080	0.075	-0.190	-0.955	**1.780**	-0.029	0.015	-0.532	-0.237	0.620
Number of seeds per siliqua	0.053	0.015	0.090	0.058	0.380	-0.195	**0.553**	-0.039	0.283	-0.285	0.776
Length of siliqua (cm)	-0.040	-0.035	-0.025	0.014	-0.015	0.189	-0.080	**0.263**	-0.190	0.280	0.060
1000 seed weight (g)	-0.005	0.047	-0.047	0.051	0.271	-1.325	0.100	-0.030	**0.950**	0.080	0.302
Oil content (%)	0.045	-0.064	0.285	-0.025	-0.188	0.719	0.135	-0.065	0.115	**-0.765**	0.245

Residual = 0.0465;
Note: Bold and underlined values denote direct effect

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