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Genetic variability and character association analysis for seed yield and its attributes in Indian mustard (*Brassica juncea* (L.) Czern and Coss.)

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Abstract
Sixty diverse genotypes of Indian mustard (*Brassica juncea* L.) were evaluated for seed yield and its attributes to determine the genetic variability and association of yield and its components. The analysis of variance revealed highly significant differences among the genotypes for all the traits which indicated the presence of wide genetic variability in the genetic material under study. Phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the observed characters. The moderate genotypic coefficient of variation was observed for seed yield per plant, whereas all other characters showed lower magnitude of genotypic coefficient of variation. Characters such as seed yield per plant and total number of branches per plant were exhibited moderate phenotypic coefficient of variation. A high heritability value was recorded for 1000 seed weight, oil content, days to flowering and seed yield per plant. The highest value of genetic advance (per cent mean) was observed for seed yield per plant. The seed yield per plant showed significant and positive correlation with days to flowering, days to maturity, plant height, length of main branch, number of siliquae per plant, 1000 seed weight at phenotypic levels. The path coefficient analysis revealed that days to flowering had the highest direct effect on seed yield per plant followed by number of siliquae on main branch, length of siliqua, 1000 seed weight, plant height and oil content. The direct effect of plant height and oil content on seed yield were positive but low, therefore, direct selection for these traits may not help in yield improvement. Hence, it was suggested that greater emphasis should be laid on selection for number of siliquae on main branch, number of siliquae per plant, length of siliqua and 1000 seed weight to achieve further improvement in seed yield of Indian mustard.

Keywords: Genetic variability, correlation, path analysis, seed yield and Indian mustard

1. Introduction

Oilseed *Brassicas* also referred to as rapeseed-mustard, an important group of oilseed crops in the world, comprise eight cultivated crops of tribe *Brassiceae* within the family *Brassicaceae* (Cruciferae). Among the four oleiferous *Brassica* species, major area is under *Brassica juncea* which contributes about 80% of the total rapeseed-mustard production in the country. It is grown for oil as well as condiment and for medicinal use. However, the largest cultivation of the crop is for edible vegetable oil production. It is the cheapest source of oil in human diet. It is also used in preparations of hair oils, soap making, in mixtures with mineral oils for lubrication and in the tanning and softening leather. Recently in laboratory base mustard oil has proven as oxidation fuel.

Germplasm, which is a prerequisite for any breeding programme, serves as a valuable source material as it provides scope for building of genetic variability. Understanding of the nature and magnitude of genetic variability present in the breeding material is important before initiating breeding programme. Improvement in yield and its components depend on the nature and magnitude of genetic variability present in the population. It becomes therefore difficult for plant breeder to evaluate and select for complex polygenic character like yield directly. Hence, to judge whether the observed variability is heritable or not, the primary parameters like genotypic and phenotypic variance, heritability and genetic advance are useful in understanding the nature of inheritance of traits.

The knowledge of genetic correlation, which occurs between the characters, can help the breeder to improve the efficiency of selection by using favorable combinations of traits and to minimize the retarding effect of negative correlations. Path coefficient analysis is the most effective mean to find out direct and indirect causes of association among the different variables. Path coefficient analysis can discriminate between the realistic (genetic effects) and inflated (environmental effects) correlations. Hence, the knowledge of direct and indirect effects of different components on yield is of prime importance in selection of high yielding genotypes. Keeping in view the above aspects, the present investigation was undertaken with an objective to study genetic variability, correlation and path analysis for seed yield and its attributes in Indian mustard.

2. Materials and Methods

The experiment was conducted with 60 genotypes during *rabi* season of the year 2016-17 at Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The material was grown in a Randomized Complete Block Design with three replications. Each plot consisted of a single row of 5.0 m length. Inter and intra row spacing was kept 45 cm and 15 cm, respectively. All the recommended package of practices was followed for successful raising of the crop. Five competitive plants were selected randomly from each replication. The observation were recorded for 12 characters *viz*., days to flowering, days to maturity, plant height (cm), length of main branch (cm), total number of branches per plant, number of siliquae on main branch, number of siliquae per plant, length of siliqua (cm), seeds per siliqua, 1000 seed weight (g), oil content (%) and seed yield per plant (g). The mean over replication of each character was subjected to statistical analysis. Analysis of variance was performed following the standard procedures. The phenotypic and genotypic coefficients of variation (PCV, GCV) were computed as per method described by Burton (1952) [1] and the correlation coefficients at genotypic and phenotypic level were computed according to Johnson *et al.* (1955) [5]. Path coefficient analysis was done by using correlation coefficients as suggested by Dewey and Lu (1959) [2].

3. Results and Discussion

The analysis of variance (Table 1) revealed highly significant differences among the genotypes for all the traits. The differences between genotypes were significant for all the characters indicating presence of wide genetic variation for different characters in the genetic material studied (Table 1). Significant variation in one or more characters studied in the present investigation have also been reported by several workers *viz*., Kumar and Misra (2007) [6], Misra *et al.* (2008) [8] and Yadava *et al.* (2011) [16] for different characters like days to flowering, days to maturity, plant height, number of siliquae per plant and seed yield per plant. The reason for high magnitude of variability in the present study may be due the fact that the genotypes selected were developed in different breeding programmes representing different agro-climatic conditions of the country.

The phenotypic and genotypic components of variances were calculated for all the twelve characters under study are presented in Table 2. The results revealed that magnitude of phenotypic component of variance was higher than genotypic component of variance for all the characters. The highest value of σ^2g and σ^2p were found for number of siliquae per plant *i.e.* (798.519 and 1005.938), respectively. The lowest value of σ^2g and σ^2p were recorded for length of siliqua *i.e.* (0.066 and 0.102), which were followed by 1000 seed weight *i.e.* (0.222 and 0.232) and oil content *i.e.* (0.596 and 0.647), respectively. Thus, the result suggested that these three characters were less affected by environment as compared to other characters.

3.1 Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV)

Phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the observed characters (Table 2). The moderate genotypic coefficient of variation was observed for seed yield per plant (15.59), whereas all other characters showed lower magnitude of genotypic coefficient of variation.

The estimates of phenotypic coefficient of variation was ranged from 2.12 (oil content) to 16.42 (seed yield per plant). Characters such as seed yield per plant (16.42) and total number of branches per plant (11.58) were exhibited moderate phenotypic coefficient of variation. While phenotypic coefficient of variation was low for the remaining characters. Results revealed presence of high amount of genetic variability in the evaluated genotypes for the major yield contributing characters along with seed yield per plant which indicated that further improvement for these traits is possible. Similar findings pertaining to occurrence of high genetic variability has also been reported by Singh (2004) [12] for different traits including seed yield.

3.2 Heritability and Genetic advance

The estimates of broad sense heritability for all the characters under study are presented in Table 2. A high heritability value was recorded for 1000 seed weight (95.65), oil content (92.18), days to flowering (90.28) and seed yield per plant (90.18). However, plant height (89.72), days to maturity (87.70), number of siliquae per plant (79.38) exhibited moderate heritability, while remaining characters showed lower heritability. In the present study, high broad sense heritability was recorded for 1000 seed weight, oil content, days to flowering and seed yield per plant. Similar results were also observed by Ghosh and Gulati (2001) [3], Mahla *et al.* (2003) [7], Singh (2004) [12] and Yadava *et al.* (2011) [16]. The high estimates of heritability values indicate that a large proportion of phenotypic variability for concerned character was heritable. Hence simple selection would be effective for improvement of these traits.

The expected genetic advances with respect to twelve characters at 5.00 per cent selection intensity were calculated. Since, these values were not comparable; they were expressed as expected genetic advance in percentage and are presented in Table 2. Genetic advance expressed as per cent of mean of different characters ranged from 4.03 to 30.39. The highest value of genetic advance (per cent mean) observed for seed yield per plant (30.49). The lowest value of genetic advance (per cent mean) was observed for oil content (4.03) followed by days to maturity (4.78), seeds per siliqua (5.65), number of siliquae on main branch (6.09) and length of siliqua (9.18). The remaining characters recorded moderate values of genetic advance (per cent mean). Thus in the present study, high heritability along with high genetic advance was observed for seed yield per plant. These results are in conformity with the findings of Singh (2004) [12], Kumar and Misra (2007) [6], Yadava *et al.* (2011) [16] and Gupta and Dwivedi (2016) [4].

3.3 Correlation

The correlation coefficients between seed yield per plant and its eleven component characters as well as among themselves were estimated at genotypic and phenotypic levels (Table 3).

In general, the values of genotypic correlation were slightly higher than their phenotypic counterpart. Higher genotypic correlations than phenotypic ones might be due to modifying or masking effect of environment in the expression of these characters under study. Johnson *et al.* (1955) [5] also reported that higher genotypic correlation than phenotypic correlation indicated an inherent association between various characters. In few cases, the phenotypic correlation was slightly higher than their genotypic counterpart, which implied that the non-genetic causes inflated the values of genotypic correlation because of the influence of the environmental factors.

The seed yield per plant showed significant and positive correlation with days to flowering, days to maturity, plant height, length of main branch, number of siliquae per plant, 1000 seed weight at phenotypic levels. Similar results were also reported earlier by Singh *et al.* (2010) [13], Yadava *et al.* (2011) [16] and Singh *et al.* (2013) [14]. While remaining characters showed positive and non-significant correlation with seed yield per plant at both the levels. Length of main branch showed significant positive correlation with all the characters except oil content at phenotypic level only. Number of siliquae on main branch exhibited significant positive correlation with all the characters except 1000 seed weight and seed yield per plant at phenotypic level. The number of siliquae per plant showed positive and significant correlation with plant height, length of main branch, total number of branches per plant, number of siliquae on main branch at phenotypic level. The length of siliqua exhibited significant and positive correlation with days to flowering, days to maturity, plant height, length of main branch, total number of branches per plant, seed per siliqua and oil content at phenotypic level. 1000 seed weight was positively and significantly correlated with length of main branch, number of siliquae per plant, length of siliqua and seeds per siliqua at phenotypic level. Similar results for different traits in rapeseed-mustard were also reported by Singh (2004) [12], Rai *et al.* (2005) [10], Yadava *et al.* (2011) [16] and Singh *et al.* (2013) [14].

3.4 Path coefficient analysis

Seed yield per plant is the result of direct and indirect effects of several yield contributing characters. To know the contribution of various characters towards seed yield, the significant genotypic correlation of different traits with seed yield were partitioned into their direct and indirect effects (Table 4). The perusal of results revealed that days to flowering had the highest direct effect on seed yield per plant followed by number of siliquae on main branch, length of siliqua, 1000 seed weight, plant height and oil content. The direct effect of plant height and oil content were positive but low, therefore, direct selection for these traits may not help in yield improvement. These results are in agreement with the reports of Shalini *et al.* (2000) [11], Pandey and Singh (2005) [9] and Verma *et al.* (2008) [15]. On the contrary days to maturity had negative direct effect (-1.170) on seed yield per plant.

From the above discussion, it can be concluded that due weightage should be given to the characters *viz.*, seed yield per plant, number of siliquae per plant, length of siliqua and 1000 seed weight while selection for improving seed yield in Indian mustard.

Table 1: Analysis of variance for twelve characters in Indian mustard

Sr. No.	Source	Mean squares		
		Replications	Genotypes	Error
	d.f.	2	59	118
1	Days to flowering	0.017	44.48**	1.54
2	Days to maturity	0.68	25.10**	1.11
3	Plant height (cm)	29.21	547.41**	20.12
4	Length of main branch (cm)	80.33	115.80**	14.78
5	Total number of branches per plant	7.00	11.89**	2.70
6	Number of siliquae on main branch	49.61	19.38**	6.22
7	Number of siliquae per plant	837.95	2602.97**	207.41
8	Length of siliqua (cm)	0.068	0.233**	0.035
9	Seeds per siliqua	1.68	1.79**	0.61
10	1000 seed weight (g)	0.0004	0.67**	0.009
11	Oil content (%)	0.059	1.839**	0.050
12	Seed yield per plant (g)	34.71	199.31**	6.98

*, ** Significant at 5% and 1% levels, respectively.

Table 2: The estimates of genotypic and phenotypic variance and other genetic parameters for twelve characters in Indian mustard

Sr. No.	Character	Mean	Range	σ^2g	σ^2p	GCV	PCV	H^2(b) (%)	GA (% of mean)
1	Days to flowering	42.75	35.33 - 49.00	14.315	15.852	8.85	9.31	90.28	17.32
2	Days to maturity	114.01	108.00 - 119.33	7.998	9.111	2.48	2.65	87.70	4.78
3	Plant height (cm)	176.85	148.00 - 206.00	175.764	195.89	7.50	7.91	89.72	14.62
4	Length of main branch (cm)	83.58	70.67 - 93.33	33.674	48.459	6.94	8.33	69.49	11.92
5	Total number of branches per plant	20.74	16.67 - 25.00	3.066	5.767	8.44	11.58	53.12	12.68
6	Number of siliquae on main branch	43.57	38.33 - 48.67	4.253	10.876	4.73	7.57	39.09	6.09
7	Number of siliquae per plant	341.52	274.67 - 399.33	798.519	1005.938	8.27	9.29	79.38	15.18
8	Length of siliqua (cm)	4.35	3.77 - 5.03	0.066	0.102	5.91	7.34	65.34	9.18
9	Seeds per siliqua	14.31	12.67 - 15.67	0.395	1.010	4.39	7.03	38.61	5.65
10	1000 seed weight (g)	5.10	4.13 - 5.97	0.222	0.232	9.24	9.44	95.65	18.61
11	Oil content (%)	37.88	36.21 - 39.72	0.596	0.647	2.04	2.12	92.18	4.03
12	Seed yield per plant (g)	51.36	36.80 - 69.13	64.111	71.093	15.59	16.42	90.18	30.49

GCV: Genotypic coefficients of variation; PCV: Phenotypic coefficients of variation; H^2(b): Heritability in broad sense; GA: Genetic advance

Table 3: Genotypic and phenotypic correlation coefficients for various characters in Indian mustard

Character		Days to maturity	Plant height (cm)	Length of main branch (cm)	Total number of branches per plant	Number of siliquae on main branch	Number of siliquae per plant	Length of siliqua (cm)	Seeds per siliqua	1000 seed weight (g)	Oil content (%)	Seed yield per plant (g)
Days to flowering	r_g	0.918	0.378	0.330	0.064	0.386	0.147	0.261	0.293	-0.022	-0.120	0.244
	r_p	0.905 **	0.346 **	0.273 **	0.058	0.251 **	0.122	0.180 *	0.187 *	-0.020	-0.096	0.214 **
Days to maturity	r_g		0.476	0.400	0.053	0.501	0.042	0.339	0.376	-0.022	-0.235	0.169
	r_p		0.428 **	0.327 **	0.027	0.314 **	0.049	0.219 **	0.227 **	-0.019	-0.202 **	0.153 *
Plant height (cm)	r_g			0.881	0.240	0.322	0.215	0.295	0.279	0.137	-0.100	0.233
	r_p			0.770 **	0.143	0.283 **	0.159 *	0.212 **	0.165 *	0.122	-0.102	0.197 **
Length of main branch (cm)	r_g				0.360	0.326	0.322	0.456	0.479	0.221	-0.129	0.207
	r_p				0.149 *	0.482 **	0.231 **	0.318 **	0.267 **	0.172 *	-0.085	0.163 *
Total number of branches per plant	r_g					0.699	0.578	0.249	0.363	0.106	0.373	0.043
	r_p					0.211 **	0.427 **	0.193 **	0.216 **	0.099	0.237**	0.069
Number of siliquae on main branch	r_g						0.542	0.197	0.460	0.204	0.022	0.124
	r_p						0.278 **	0.057	0.145	0.102	0.023	0.061
Number of siliquae per plant	r_g							0.203	0.227	0.329	0.486	0.316
	r_p							0.136	0.143	0.326 **	0.413 **	0.389 **
Length of siliqua (cm)	r_g								0.927	0.205	-0.220	0.168
	r_p								0.774 **	0.153 *	-0.177 *	0.136
Seeds per siliqua	r_g									0.302	-0.154	0.25
	r_p									0.165 *	-0.086	0.140
1000 seed weight (g)	r_g										0.072	0.561
	r_p										0.077	0.548 **
Oil content (%)	r_g											0.056
	r_p											0.051

Table 4: Path coefficient analysis showing direct and indirect effects of eleven causal on seed yield per plant in Indian mustard

Character	Days to flowering	Days to maturity	Plant height (cm)	Length of main branch (cm)	Total number of branches per plant	Number of siliquae on main branch	Number of siliquae per plant	Length of siliqua (cm)	Seeds per siliqua	1000 seed weight (g)	Oil content (%)	Genotypic correlation with seed yield per plant (g)
Days to flowering	1.056	0.970	0.400	0.349	0.068	0.408	0.156	0.276	0.311	-0.024	-0.128	0.245
Days to maturity	-1.075	-1.170	-0.557	-0.468	-0.063	-0.587	-0.050	-0.397	-0.441	0.027	0.275	0.169
Plant height (cm)	0.118	0.149	0.313	0.276	0.075	0.101	0.067	0.093	0.087	0.043	-0.031	0.233
Length of main branch (cm)	-0.028	-0.034	-0.074	-0.084	-0.030	-0.027	-0.027	-0.038	-0.040	-0.019	0.011	0.207
Total number of branches per plant	-0.029	-0.024	-0.107	-0.160	-0.445	-0.311	-0.257	-0.111	-0.162	-0.047	-0.166	0.043
Number of siliquae on main branch	0.226	0.293	0.188	0.191	0.409	0.584	0.317	0.115	0.269	0.119	0.013	0.124
Number of siliquae per plant	-0.027	-0.008	-0.039	-0.058	-0.104	-0.097	-0.179	-0.036	-0.041	-0.059	-0.087	0.316
Length of siliqua (cm)	0.136	0.177	0.154	0.238	0.130	0.103	0.106	0.522	0.484	0.107	-0.115	0.169
Seeds per siliqua	-0.100	-0.128	-0.095	-0.163	-0.123	-0.156	-0.077	-0.315	-0.339	-0.103	0.052	0.250
1000 seed weight (g)	-0.011	-0.012	0.069	0.111	0.053	0.103	0.165	0.103	0.152	0.502	0.036	0.562
Oil content (%)	-0.024	-0.046	-0.020	-0.025	0.073	0.004	0.095	-0.043	-0.030	0.014	0.195	0.056

Note: Diagonal values are direct effects
Residual effect = 0.769

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