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Seed Yield Improvement in Mustard [*Brassica juncea* (L.) Czern & Coss] via Genetic Parameters; Heritability, Genetic Advance, Correlation and Path Coefficient Analysis

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***Abstract* – Twenty advanced lines along with check varieties of mustard were evaluated under the environmental conditions of Islamabad by utilizing heritability, correlation and path coefficient analysis for seed yield and yield contributing traits. The statistical analysis showed significant differences among all the traits studied. Genotypic and phenotypic variances and coefficients of variation revealed considerable genetic variability in the population. Both genotypic and phenotypic coefficients of variability were high for seed yield. Additive gene effects were evident from high heritability accompanied by high values of genetic advance for seed yield. For further confirmation correlation and path analysis were employed. The genetic correlation of seed yield was positive and significant with days to flower; seeds pod^{-1}, pod length and oil percentage. Path analysis revealed direct positive contribution of seeds pod^{-1} and oil %age toward seed yield. The indirect effect of pod length on seed yield was positive. So seeds pod^{-1}, pod length and oil percentage would be of great use for indirect selection for improvement in seed yield.**

***Keywords* – Genetic Parameters, High Yielding Varieties, Selection Criteria, Mustard in Pakistan.**

I. Introduction

Brassica crop is the traditional oilseed crops of Pakistan and is grown on an area of 236,000 hectares with a production of 178,900 tons with an average yield of kg ha^{-1}. As a whole, these crops contribute about 10 percent of the local edible oil production in the country and 70 percent of its domestic requirements are fulfilled through imports. This trend will not only continue but will further worsen in future with increase in population and per capita consumption.

Due to its relatively greater drought and heat tolerance, *Brassica juncea* (L.) Czern & Coss is considered as an important oilseed crop for dryer regions of Pakistan (Oram et al., 1999). It also possesses biotic stress tolerance. Different genes for blackleg (*Leptosphaeria maculans* (Desm.) Ces. & de Not.) resistance are reported in *Brassica juncea* (L.) Czern & Coss but are not observed in *Brassica napus* L./ *Brassica rapa* L.(Burton et al., 1999). This is why the farmers of southern Punjab prefer to grow mustard as oilseed crop in their crop rotation. The average yield of this crop at farmer's field is very low. This is due to the adoption of low yielding cultivars. Thus, increases in mustard production can be done by selecting and developing new yielder and adapted cultivars that can replace the old varieties. National Agricultural Research Centre, Islamabad is continuously doing research on this aspect.

Yield in mustard is a complex character to study. Use of simple correlation analysis could not fully explain the relationships among the characters. Therefore, the path coefficient analysis has been used by many researchers to determine the impact of independent variables (yield components) on the dependent one (grain yield). Path analysis has also been used to develop selection criteria for complex traits in several crop species of economic importance. Correlations between seed yield and related traits could be partitioned through path analysis into direct and indirect effects to identify characters most responsible for the increase of seed yield. (Chaudhri. 1986).So the breeder(s) has extensively used this analysis in explaining the direct and indirect effects in different crop species (Marinkovic, 1992; Punia and Gill, 1994, Pant and Singh, 2001., Aycicek and Telat, 2006). The present investigation was planned to access heritability, association between traits and defines suitable selection criteria for mustard yield improvement.

II. Material and Methods

The experiment was carried out at experimental area of Oilseeds Research Program, NARC, Islamabad in a randomized complete block design with four replications. Experimental material for the present study consisted of twenty entries of *Brassica juncea* (L.) Czern & Coss. Seed were sown in 13 October 2011. Three weeks after sowing the distance of 10-15 centimeter between the plants was kept by thinning. Each genotype was planted in four rows of 5 meter length by 30 centimeters between rows. Fertilizers, N with 90 kg/ha and P_2O_5 with 60 kg/ha were applied during seed bed preparation. Irrigation, weed and pest control measures were taken whenever required.

Observations for different eight characters viz; days to flowering, days to maturity, plant height (cm), branches plant^{-1}, pod length (cm), seeds pod^{-1}, oil contents (%) and seed yield kgha^{-1} were recorded for each entry and replication. Genotypic and phenotypic coefficients of variability were worked out as proposed by Burton (1952). Heritability estimates were determined by the formula given by Falconer (1989). The genetic advance was computed according to Allard (1960).The genotypic and

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phenotypic correlation coefficients were estimated as described by Kwon and Torrie (1964). The path coefficients were obtained according to Dewey and Lu (1959).

III. Results and Discussion

Table 1: Average performance of mustard lines/varieties at NARC during 2011-12

Entry Name	Days to flower	Days to maturity	Plant height (cm)	Branches plant^{-1}	Pod length (cm)	Seeds pod^{-1}	Oil content	Seed Yield	
								Yield (kgha^{-1})	Percent ± over Khanpur Raya
AGM-14	67	178	224	7	4.1	14	39.94	3163	22.2
AGM-13	65	176	228	7	3.9	13	**40.03**	2875	11.1
SPS-417	82	178	233	7	3.4	12	37.89	2740	5.9
AGM-15	66	176	238	7	4.0	15	39.31	2669	3.1
SPS-161	78	179	231	7	3.4	11	37.07	2611	0.9
AGM-2	67	176	229	8	4.1	13	39.66	2588	0.0
Khanpur Raya (C)	**70**	**175**	**219**	**8**	**4.1**	**14**	37.98	2588	0.0
SPS-425	69	178	241	6	3.9	13	38.99	2588	0.0
SPS-123	79	179	270	6	3.9	12	38.17	2347	-9.3
BARD-1	**79**	**180**	**227**	**7**	**3.7**	**11**	38.15	2203	**-14.9**
PAC-437	71	179	216	8	3.8	13	36.56	2203	-14.9
AGM-1	67	179	233	7	3.9	13	39.12	2156	-16.7
SPS-93	101	180	236	7	3.2	10	38.52	2060	-20.4
SPS-209	80	180	237	7	3.5	12	36.84	1940	-25.0
SPS-321	78	180	232	7	3.7	11	38.71	1916	-26.0
SPS-223	80	176	235	7	3.3	11	**34.90**	1820	-29.7
SPS-410	95	181	230	6	3.3	12	35.94	1796	-30.6
SPS-136	74	177	226	7	3.5	11	38.78	1772	-31.5
SPS-163	113	184	257	9	3.5	12	37.21	1772	-31.5
SPS-415	104	180	238	6	3.4	12	39.17	1581	-38.9
Average	**79**	**178**	**239**	**7**	**3.7**	**12**	**38.15**	**2269**	**-12.3**
Variety mean	766.98**	17.28**	301.6**	1.83**	0.343**	5.59**	7.5**	205425**	
LSD (0.05)	7.2	3.6	8.5	0.6	0.4	1.6	2.06	373	
CV %	6.4	1.4	2.7	5.7	7.3	9.3	3.81	11.6	

** denote significance at 1% probability level

The statistical analysis of the data (variety mean sum of square, LSD (0.05) and CV% presented in table 1 revealed large level of phenotypic variation among entries for all recorded traits .Days to 50% flowering ranged from 65 to 113 days. The minimum flowering days (65) were recorded in AGM-13 while maximum days (92) were recorded in SPS-163. Twelve entries completed 50% flowering earlier than the mean (79days) Physiological maturity ranged from 175 to 184 days. The entry Khanpur Raya matured early and took 175 days to mature while late flowering entry SPS-J163 also matured late and took 184 days to mature.

The maximum plant height of 270 cm was recorded in SPS-123. The plants of PAC-437 were relatively dwarf and had 216 cm plant height. The branches per plant ranged from 6 to 9 among the entries but most of the entries had 7 branches plant^{-1}. The SPS-J163 had maximum branches 9 plant^{-1}. The pod length ranged between 3.2 and 4.1cm. The AGM-14, AGM-2 and Khanpur Raya produced the longest (4.1cm) pods whereas the entry SPS-93 produced the smallest pods (3.2cm in length). The number of seeds ranged from 10 to 15 seeds pod^{-1}. The maximum (15) number of seeds pod^{-1} was produced by AGM-15 while SPS-93 being the shortest produce the minimum number of seeds i.e. 10 pods^{-1} .Oil contents ranged between 34.90 and 40.03%. The entry AGM-13 showed maximum oil percentage i.e.40.03 % while minimum by the entry SPS-223 (34.90 % oil contents).Seed yield ranged from 1581 to 3163 kgha^{-1}. The line AGM-14 produced maximum seed yield of 3163 kgha^{-1} followed by AGM-13 (2875 kgha^{-1}), SPS-417(2740 kgha^{-1}) and AGM-15 (2669kgha^{-1}). Over all, 6 lines produced more seed yield than check variety Khanpur Raya (2588 kgha^{-1}).

Genotypic and phenotypic coefficients of variability revealed considerable genetic variability in the population. Both genotypic and phenotypic coefficients of variability were higher for seed yield followed by days to flower and plant height.

Heritability and genetic advance are important selection parameters as they provide an idea about the effectiveness of the selection of a genotype based on phenotypic performance. Genetic advance estimates are normally more helpful in predicting the gain under selection than heritability estimates alone. A trait having high heritability and high genetic advance is considered under the control of additive genes thus highlighting the usefulness of plant selection on the basis of phenotypic performance (Mondal and Khajuria, 2000; Shalini *etal* 2000 and Ghosh and Gulati, 2001)

Table 2: Genotypic / phenotypic coefficients of variability, heritability and genetic advance in mustard lines

S. #	**Character**	**Mean value**	**Genotypic coefficient of variability**	**Phenotypic coefficient of variability**	h^2_{BS} **(%)**	**Genetic advance (% mean)**
1	Days to flower	79	17.21	18.37	87.7	22.4[2nd]
2	Days to maturity	178	0.92	1.71	28.9	1.54
3	Plant height(cm)	232	3.50	4.40	63.2	11.3[3rd]
4	Branches $Plant^{-1}$	7	9.19	10.78	72.6	0.97
5	Seeds Pod^{-1}	12	8.60	12.64	46.3	1.24
6	Pod length(cm)	3.7	7.06	10.14	48.5	0.32
7	Oil %age	38	3.05	4.88	39.1	1.28
8	Seed Yield($kgha^{-1}$)	1182	18.27	21.66	71.2	319[1st]

In our study, seed yield and days to flowering had high heritability (71.2% and 87.7%, respectively) accompanied by high genetic advance (319% and 22.4%, respectively) indicating that the heritability is due to additive gene effects and selection is effective. Similar results had been reported by Chandra and Singh (2001). Among the other traits studied plant height and branches per plant had high $h^2_{B.S}$ along with low genetic advance showing that the non additive gene effects were involved in the genetic control of these traits. Thus explaining that high heritability for these two traits may be due to favorable environment rather than genotype selection. So selection based on theses two traits may not be rewarding .The traits days to maturity, seeds per pod length and oil % showed low heritability as well as low genetics advance. This result indicated that these traits were highly influenced by the environment and selection of genotypes through these traits would be ineffective. These results are in agreement with the findings of (Khulbe etal .2000; Pant, and Singh, 2001)

Correlation coefficient is a statistical measure which is used to find out the degree and direction of relationship between two or more variables. In our study both genotypic and phenotypic correlations were determined. Table 3 revealed that the genotypic correlation coefficients were higher than their respective phenotypic ones. These values indicated that these traits were strongly associated genetically and the phenotypic expression of these traits was less influenced by the environment. The same signs of phenotypic and genotypic correlation coefficients indicated that the association was in the same direction. So, only the results of genotypic correlation was discussed as below

Table 3: Genotypic / phenotypic correlation coefficients among seed yield & its components in mustard lines

Parameters		**Days to flower**	**Days to maturity**	**Plant height**	**Branches $plant^{-1}$**	**Seeds pod^{-1}**	**Pod length**	**Oil %age**	**Seed yield**
Days to flower	r_g	1	**0.9544***	**0.6466***	-0.0513	-0.6263*	-0.823*	-0.3865	**0.715***
	r_p	1	0.5645**	0.4903**	-0.0483	-0.3809**	-0.5235**	-0.3054*	0.5429**
Days to maturity	r_g		1	**0.7284***	-0.1437	-0.6679*	-0.7406*	-0.3785	-0.7941*
	r_p		1	0.22	-0.0766	-0.1716	-0.2727*	-0.2915*	-0.3212*
Plant height	r_g			1	**0.0288**	-0.2096	-0.4298	-0.0714	-0.3986
	r_p			1	0.0485	-0.0225	-0.2505	-0.034	-0.2402
Branche $plant^{-1}$	r_g				1	**0.3719**	**0.3239**	-0.1521	**0.2527**
	r_p				1	0.2607*	0.2048	-0.024	0.2105
Seeds pod^{-1}	r_g					1	**0.7858***	**0.4352**	**0.6614***
	r_p					1	0.7127**	0.2007	0.3591**
Pod length	r_g						1	**0.766***	**0.7607***
	r_p						1	0.3654**	0.4257**
Oil %age	r_g							1	**0.5797***
	r_p							1	0.3472**
Seed yield	r_g								1
	r_p								1

*, ** denote significance at the 5% and 1% probability level respectively.

Genotypic correlation of days to flower with days to maturity (0.9544), plant height (0.6466) and seed yield (0.715) was significant and positive whereas correlation between days to flowering, branches per plant, seeds per pod, pod length and oil percentage was negative. Similarly days to maturity showed significant positive correlation with plant height (0.7284) while significant but negative with seeds per pod (0.6679), pod length (0.7406) and seed yield (0.7941).However the non significant negative correlation of days to maturity was observed with branches per plant and oil percentage. Correlation of plant height with branches per plat was positive whereas correlation between plant height and seeds per pods, pod length, oil percentage and seed yield was negative though it was insignificant. Branches per plant showed positive but non significant correlation with seeds per pod (0.3719), pod length (0.3239) and seed yield (0.2527) showing no or very little contribution of this trait toward the increase in seeds per pod, pod length and ultimately to seed yield. These results are contradictory to those of Basalma (2008) and Khan and Rashid (1999).

Seeds per pod exhibited significant and positive association with pod length (0.7858) and seed yield (0.6614) while non significant and positive with oil percentage. Besides, pod length showed significant and positive correlation with oil percentage and seed yield. The significant correlation of seed yield with days to flower (0.715), seeds per pod (0.6614), pod length (0.7607 and oil percentage (0.5797) indicated that these traits would be used as selection criteria for increasing the seed yield of mustard cultivars. These results are in agreement with the earlier findings of Belete (2011).

In majority of instances, correlation alone gives confusing results when more characters are involved in the correlation study. It is understood that many of the traits are correlated with each other due to mutual association with each other. This mutual association may be positive or negative with other traits. When more variables are involved in the correlation analysis, their indirect associations become more difficult to understand. Under such circumstances, the path coefficient analysis provides an effective means of separating direct and indirect cause of association and allows crucial inspection of the specific forces acting to produce such correlation and measures the relative significance of each casual factor. Singh and Narayanan, 2000 also described the path coefficient analysis as a simply standardized partial regression coefficient which splits the correlation coefficient into direct and indirect effects. Path coefficient analysis can be computed from phenotypic correlation coefficient, genotypic correlation coefficient and environmental correlation coefficient. But being breeder we have a little interest with phenotypic and environmental path coefficients. Therefore, the path coefficient analysis presented in table 4 was worked out from genotypic correlation coefficients which split the genotypic correlation coefficients into the measures of direct and indirect effects.

Table 4: Path coefficient analysis for different traits in mustard lines/varieties

Parameters	**Days to flower**	**Days to maturity**	**Plant height**	**Branches plant^{-1}**	**Seeds pod^{-1}**	**Pod length**	**Oil %age**	**Seed yield (r_g)**
Days to flower	**-0.405**	-0.366	-2.076	-0.179	-1.999	8.477	-2.737	0.7150
Days to maturity	-0.386	**-0.384**	-2.338	-0.502	-2.131	7.628	-2.680	-0.7941
Plant height	-0.262	-0.280	**-3.210**	0.101	-0.669	4.427	-0.506	-0.3986
Branches plant^{-1}	0.021	0.055	-0.092	**3.495**	1.187	-3.336	-1.077	0.2527
Seeds pod^{-1}	0.253	0.256	0.673	1.300	**3.191**	-8.095	3.082	0.6614
Pod length	0.333	0.284	1.380	1.132	2.508	**-10.300**	5.424	0.7607
Oil %age	0.156	0.145	0.229	-0.531	1.389	-7.890	**7.081**	0.5797

The results presented in the table 4 showed the direct and indirect effects of different traits on seed yield. Branches plant^{-1}, seeds pod^{-1} and oil %age had direct positive contribution toward seed yield kgha^{-1}. Days to flower had negative direct effect on seed yield .The indirect effects of days to flower via days to maturity (-0.366), plant height (-2.076) branches plant^{-1} (-0.179), seed pod^{-1} (-1.999) and oil % (-2.737) were negative while it was positive through pod length (8.477). This suggest that the positive correlation between seed yield and days to flower was mainly contributed by the positive indirect effect via pod length , while the other indirect effects of this trait on seed yield were negative. So the indirect selection through pod length will be effective in yield improvement. The direct (-0.384) and indirect effect of days to maturity via plant height (-2.338), branches plant^{-1} (-0.502), seed pod^{-1} (-2.131) and oil percentage (-2.680) were negative on seed yield except pod length (7.628). The plant height had negative direct effects (-3.210) on seed yield while its indirect effects via seeds pod^{-1} (-0.669) and oil percentage (-0.506) were negative. Plant height exerted positive indirect effects via branches plant^{-1} (0.101) and pod length (4.427). Branches plant^{-1} had direct positive contribution toward seed yield .However its indirect effects via on seed yield through pod length (-3.336) and oil percentage (-1.077) were negative but positive via seeds pod^{-1}. This reveals true relationship between them. So the direct selection for this trait will be rewarding for seed yield improvement. Shalini *etal,* (2000) also reported the same conclusions.

The direct (3.191) and indirect effect of seeds pod^{-1} via oil percentage (3.082) were positive on seed yield but negative indirect effect was observed with pod length (-8.095).Pod length showed negative directs effects on seed yield but its indirect effects via other traits like days to flower, days to maturity, plant height and oil percentage were positive and the association between the two traits is also positive indicating that indirect selection will also attribute toward increase in seed yield. Oil percentage had direct positive effect on seed yield. A positive correlation was also observed in between these two traits. Hence Oil percentage can also be utilized as selection criteria for the development of high yielding mustard cultivars.

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IV. Conclusion

From the present studies it is concluded that seed yield is the reliable parameter for the selection of high yielding mustard lines/varieties and seeds pod^{-1}, pod length and oil percentage are the contributory traits of seed yield.

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