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HERITABILITY AND CORRELATION ANALYSIS FOR MORPHOLOGICAL AND BIOCHEMICAL TRAITS IN *BRASSICA CARINATA*

YASIR ALI*, FARHATULLAH, HIDAYATUR RAHMAN, ADNAN NASIM, SYED MUHAMMAD AZAM and AMANULLAH KHAN

Department of Plant Breeding and Genetics, The University of Agriculture Peshawar – Pakistan
**Correspondence author: yasirkhan.khalil@yahoo.com*

ABSTRACT

The present research was undertaken to estimate variation and heritability of some morphological and biochemical traits of introduced Ethiopian mustard genotypes. The experiment was carried out in randomized complete block design with three replications at the University of Agriculture Peshawar during 2011-2012. Analysis of variance showed highly significant differences among Brassica Carinata lines for studied parameters. Phenotypic coefficient of variation and genotypic coefficient of variation ranged from 4.92-48.24% and 3.2-38.1%, respectively. The highest heritability values were recorded for pod length (0.83) followed by pods on main raceme (0.82). Genetic advance (as percent of mean) was the highest for seed yield plant^{-1} and pods on main raceme. Highly significant positive phenotypic correlation for seed yield plant^{-1} was observed with plant height and primary branches plant^{-1} whereas significant positive phenotypic correlation was observed with seed pod^{-1}, while oil content was significantly positive correlated only with erucic acid. Carinata-29, Carinata-38, Carinata-45, Carinata-7, Carinata-47 and Carinata-83 were superior for seed yield and yield contributing traits, whereas Carinata-70 was the best for oil quality traits. On overall basis, carinata-70 and carinata-83 were the best lines hence could be used in breeding programs.

Keywords: **Ethiopian mustard, *Brassica Carinata*, Genetic Advance, heritability, Correlation coefficients**

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INTRODUCTION

Mustard belongs to the family Cruciferae (Williams, 1989; Hatam and Abbasi, 1994). It has about 338 genera and 3709 species (Warwick *et al*., 2006). About 159 species are included in the genus *Brassica* (Zhou, 2001; Zhou *et al*., 2006). The amphidiploid *Brassica carinata* (n=17) is originated from cross between *Brassica nigra* (n=8) and *Brassica oleracea* (n=9) (Morinaga, 1934).

Among oilseed crops, rapeseed and mustard rank 3rd after soybean and oil palm in production of vegetable oils. In the production of oil seed proteins it ranks 5th (Kauser *et al*., 2006). Industrial uses comprise exchange of biomass to bio-energy (Ofori and Becker, 2008). In addition it is also used for food, feed and metilester which is used in biodiesel manufacture (sabaghnia *et al*., 2010).

In Pakistan, *Brassica* rank second after cotton seed as source of vegetable oil (Khan *et al*., 2008). In 2011-2012, rapeseed and mustard were planted over 216.5 thousand hectares which produced about 191.9 thousand tons, with an average yield of 886 kg hec^{-1}. Out of this, 34% of the total edible oil was produced locally, while the remaining 66% were imported with a cost of $2.611 billion (ESOP, 2011-2012). The cause of the lower edible oil is the non availability of high yielding lines (Nassimi *et al*., 2006). In province of Khyber Pakhtunkhwa, rapeseed and mustard was grown on over 17.1 thousand hectares, which produced about 7.9 thousand tons with an average yield of 450 kg hec^{-1} during the season of 2011-2012 (Pakistan bureau of statistics, 2011-2012).

Ethiopian mustard (*Brassica carinata*) is native to Ethiopian highlands and its cultivation is thought to have been started since 4000 years B.C. (Alemayehu and Becker, 2002; Schippers, 2002). *Brassica carinata* is a conventional African vegetable, previously collected from the wild for human consumption (Schippers, 2002). In the Ethiopian highlands it is cultivated as an oil and leafy vegetable crop (Mnzava, 1986; Schippers, 2002). Ethiopian mustard (*Brassica carinata)* is cultivated as an option to the traditional mustard especially for low rainfall areas of the world. In its area of adoption, it possesses acceptable yield levels as well as resistance to diverse biotic and abiotic stresses (Getinet *et al*., 1996). Instead of these positive aspects, the oil of *Brassica*

carinata seed is not suitable for edible purpose due to numerous constraint like low oil quality i.e. high content of erucic acid (Velasco *et al*., 1998) and glucocinolate (Getinet *et al*., 1997). Overcoming these limitations, the natural variability for these particular traits has controlled by the breeding programs (Song *et al*., 1988). Therefore, one of the objective of a breeding objective in *Brassica* oil crops is the development of varieties for high content in erucic acid for industrial applications and low content for edible purpose. Other significant purpose is to increase oleic acid, linoleic acid and the decrease of linolenic acid (Robbelen, 1991).

Achievement of any crop improvement 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 (Falconer and Mackay, 1996; Marwede *et al*., 2004). Correlations are important in determining the degree to which various yield contributing characters are associated (Wright, 1921). Plant traits having satisfactory variability, high heritability and genetic advance would be an effective tool for crop improvement (Aytac and Kinaci, 2009). Additive genes are considered to control traits with high heritability and genetic advance and the phenotypic selection thus would be effective (Ghosh and Gulati, 2001; Khulbe *et al*., 2000; Akbar *et al*., 2003; Aytaç and Kinaci, 2009). Developing high yielding varieties need critical evaluation of existing genetic variability, heritability and genetic advance (Choudhary *et al*., 1999; Kakroo *et al*., 2000; Khan *et al*., 1992; Mahmood *et al*., 2003; Pant and Singh, 2001; Akbar *et al*., 2003).

Keeping in view the importance of edible oil and its shortage in the country, an experiment was conducted to screen lines derived from *Brassica carinata* L. This study was undertaken to estimate genetic variability, heritability, genetic advance and phenotypic correlation among morphological and biochemical parameters of introduced Ethiopian mustard genotypes.

MATERIALS AND METHODS

This experiment was conducted at University of Agriculture Peshawar, during the season of 2011-2012. A set of 30 *Brassica carinata* lines were used in the study. These genotypes were acquired from the University of California Davis, USA. These genotypes were grown in New Developmental Farm to determine genetic variability, heritability, genetic advance and correlation among morphological and biochemical traits. These genotypes were planted in Randomized complete block (RCB) design with three replications. Row to row distance was 0.5 m and row length was 5 m with block 1.5 m apart. Plant to plant distance of 0.3 m was maintained by thinning.

Plant height (cm), primary branches plant^{-1}, main raceme length (cm), number of pods on main raceme, pod length (cm), seeds pod^{-1}, 100 seed weight (g), seed yield plant^{-1} (g) and oil content (%) were recorded on five randomly selected plants from each plot of each replication and were statistically analyzed for variability and heritability of different traits. Recommended cultural practices like weeding, hoeing were performed during the growing season when required. The data were averaged on 30 *carinata* lines belonging to each treatment were subjected to the statistical analysis.

Statistical analysis

Analysis of variance

The data was subjected for analysis of variance using M-STAT C software.

Genotypic and phenotypic coefficients of variation

Genotypic and phenotypic coefficients of variation were computed according to Burton and Devane (1953).

$$\text{Genotypic coefficient of variation (GCV)} = \left(\frac{\sqrt{Vg}}{\bar{X}}\right) \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \left(\frac{\sqrt{Vp}}{\bar{X}}\right) \times 100$$

Where, Vg is genotypic variance, Vp is phenotypic variance and $\overline{X}$ is General mean of character

Heritability estimates

The heritability estimates give information on transmission of parameter (s) from parents to offspring. Such estimates bring about the evaluation of genetic and environmental effects, aiding in selection. Evaluation of heritability can also be used to predict genetic advance under selection, so that the plant breeder can be hopeful of progress from various types and intensities of selection. The mean squares from ANOVA were evaluated following Panse and Sukhatme (1962) for variance components to compute broad sense heritability using the relation:

$$h^2 = \frac{Vg}{Vp}$$

Where, h^2 is heritability, Vg is genotypic variance and Vp is phenotypic variance

All statistical and quantitative genetic analyses were performed on plot means. Hence, the individual plant to plant variations were not recorded. Henceforth, one should consider the genetic variances as genotypic variances and the heritability estimates as broad-sense heritability estimates. Finally, error variances are undervalued and all heritability estimates inflated.

Genetic Advance

Expected genetic advance under selection (GA) was computed according to the formula given by Johnson *et al.* (1955).

$$GA = (k) \times \sqrt{Vp} \times (h^2)$$

Where, k is selection intensity; $\sqrt{Vp}$ is phenotypic standard deviation and h^2 is heritability of the trait expressed in fraction.

Genetic Advance as Percentage of Mean

Genetic advance as per cent of mean (GAM) expressed in percentage was computed by the formula given by Mehdi and Khan (1994).

$$GAM = \left(GA / \overline{X} \right) \times 100$$

Where, $\overline{X}$ is general mean of the character.

Association Analysis

Correlation Coefficients

The correlation coefficients were calculated to determine the degree of relationship of parameters with yield. Phenotypic correlations coefficients were estimated according to the formula given by Al-Jibouri *et al.* (1958).

$$\text{Phenotypic correlation} = r_{xy}(P) = COVxy(p) / \sqrt{Vx(p) \times Vy(p)}$$

Where, Covxy (p) is phenotypic covariance between (x) and (y), Vx (p) is phenotypic variance of characters (x) and Vy (p) is phenotypic variance of characters (y)

RESULTS AND DISCUSSION

Genetic Variability

Plant Height

The plant height exhibit the growth performance of a crop. Environmental factors also play a fundamental role in determining the height of the plant. The analysis of variance for plant height showed highly significant differences among *carinata* lines (Table 1). Mean values for plant height ranged from 175 (Carinata-29) to 251 cm (Carinata-47) with an averaged plant height of 211 cm (Table 2). Environmental variance (V_e) and genetic variance (V_g) for plant height was 96.15 and 325.68. Thus genetic variance was greater than environmental variance, resulting in higher extent of heritability (0.77) with genetic advance (15.43) as % of mean at 5% selection intensity. Genotypic and phenotypic coefficients of variation for plant height was 8.54 and 9.72 days, respectively (Table 3). Our results are supported by the finding of Yadava *et al*. (2011) who studied variability, heritability and genetic advance. They observed highly significant differences for plant height, days to maturity and most of the yield related traits. Our results are further supported by the finding of Poonam and Singh (2004) who observed that the varietal differences were highly significant for plant height and other morphological traits. Our results are further supported by the finding of Belete *et al*. (2012) who observed influence of environment on the expression of genes controlling plant height. Yadava, (1973) found high heritability for plant height among 29 varieties. Katiyar *et al*. (1974) reported high heritability and genetic advance for plant height.

Table 1. ***Replication mean square (RMS), genotype mean square (GMS), error mean square (EMS) and coefficient of variation (CV) among the studied traits.***

Traits	RMS	GMS	EMS	CV (%)
Plant height (cm)	754.02	1073.199**	96.148	4.65
Primary branches plant^{-1}	30.25	30.173**	4.368	6.62
Main raceme length (cm)	6.56	175.222**	14.745	9.05
Pods on main raceme	2.25	71.011**	4.861	9.87
Pod length (cm)	0.26	0.310**	0.017	2.98
Seeds pod^{-1}	1.18	3.329**	0.504	4.75
100 seed wt.(g)	0.04	0.012**	0.002	12.48
Seed yield plant^{-1} (g)	970.83	831.543**	138.94	29.57
Oil content (%)	0.008	8.249**	2.658	3.78

Primary Branches plant^{-1}

The number of primary branches plant^{-1} is the mutual effect of the genotype and the environmental conditions, which play significant role toward the final seed yield of the crops. Highly significant differences for primary branches plant^{-1} were observed among *carinata* lines (Table 1). Mean values of the data presented in Table 2 showed a range of 26.2 (Carinata-23) to 36.9 (Carinata-83) for primary branches plant^{-1} with an average of 31.6 branches (Table2). Environmental variance was 4.37 and genetic variance was 8.60 for primary branches plant^{-1}. Genotypic and phenotypic coefficients of variation for primary branches plant^{-1} was 9.28 and 11.40 branches. The resultant heritability and genetic advance as percent of mean at 5% selection intensity was 0.66 and 15.50 branches plant^{-1}, respectively (Table 3). Our results are in agreement with Khan *et al*. (2008) who studied genetic variability and heritability. They observed highly significantly differences for primary branches plant^{-1} among genotypes. Our results are strengthening by the findings of Afrin *et al*. (2011) who observed that the environmental influence is more on the expression of the genes controlling primary branches plant^{-1}. Our results are in agreement with Ghosh and Gulati (2001) also observed high heritability for primary branches plant^{-1}.

Table 2. ***Mean and range values for various traits studied.***

Traits	Mean	Range	LSD	Best genotype
Plant height (cm)	211.1	175.8-251	16.02	Carinata-29
Primary branches plant^{-1}	31.6	26.2-37	3.42	Carinata-83
Main raceme length (cm)	42.2	27.3-65.7	6.27	Carinata-45
Pods on main raceme	22.3	14.7-35.7	3.60	Carinata-45
Pod length (cm)	4.41	3.8-4.9	0.21	Carinata-7

Seeds pod^{-1}	14.9	11.6-16.2	1.16	Carinata-47
100 seed wt.(g)	0.35	0.25-0.5	0.07	Carinata-38
Seed yield plant^{-1} (g)	39.86	19.4-85.9	19.26	Carinata-83
Oil content (%)	43.1	39-45.5	2.66	Carinata-70

Main Raceme Length (cm)

Analysis of variance for main raceme length showed highly significant differences (P≤0.01) among *carinata* genotypes (Table 1). The data ranged from 27.3 (Carinata-7) to 65.7 cm (Carinata-45). Averaged over 30 lines mean main raceme length was 42.4 cm (Table 2). Genetic and environmental variances were 53.49 and 14.74, respectively (Table 3). The phenotypic coefficient of variation (19.45) and genotypic coefficient of variation (17.22) were close to each other which signify less environmental manipulation on this trait. Heritability and genetic advance as percent of mean at 5% selection intensity for main raceme length was 0.78 and 31.26 cm, respectively (Table 3). Our results are in agreement with Choudhary *et al.* (2002) who reported significant differences among genotypes for main raceme length. Our results are in agreement with Yadava *et al.* (2011) who observed that phenotypic coefficient of variation (10.0%) was higher than their corresponding genotypic coefficient of variance (9.07%), indicating environmental influence on this trait. Our results are in agreement with Ghosh and Gulati (2001) who also observed high heritability for main raceme length.

Pods on Main Raceme

Number of pods on main raceme is a major yield influential component of *Brassica* species and contributes significantly toward seed yield. Statistical analysis for pods on main raceme showed highly significant differences among *carinata* genotypes (Table 1). Data ranged from 14.7 (Carinata-1) to 35.7 pods on main raceme (Carinata-45). Mean pods on main raceme were 22.3 (Table 2). Genetic variance was 22.07 and environmental variance was 4.86 (Table 3). Genotypic and phenotypic coefficient of variance for pods on main raceme was 21.03 and 23.23. The resultant heritability and genetic advance as percent of mean at 5% selection intensity for pods on main raceme was 0.82 and 39.24 respectively (Table 3). Our results are in agreement with Ahmad *et al*. (2008) who reported that mean squares for pods plant^{-1} were significant at 1% level of probability. Our results are supported by the finding of Yadava *et al*. (2011) who observed less environmental influence on the expression of genes controlling pods on main raceme. Ghosh and Gulati (2001) also observed high heritability for pods on main raceme.

Table 3. ***Error variance (Ve), genotypic variance (V_g), phenotypic variance (V_p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2), genetic advance as percentage of mean (G.A%) for morpho-physiological traits and bio-chemical traits.***

Traits	V_e	V_g	V_p	GCV	PCV	h^2	G.A(%)
Plant height (cm)	96.15	325.68	421.83	8.54	9.72	0.77	15.43
Primary branches plant^{-1}	4.37	8.60	12.97	9.28	11.40	0.66	15.50
Main raceme length (cm)	14.74	53.49	68.23	17.22	19.45	0.78	31.26
Pods on main raceme	4.86	22.07	26.93	21.03	23.23	0.82	39.24
Pod length (cm)	0.02	0.10	0.12	7.16	7.84	0.83	13.42
Seeds pod^{-1}	0.50	0.94	1.44	6.40	8.03	0.65	10.76
100 seed weight (g)	0.002	0.003	0.005	15.30	19.81	0.60	24.48
Seed yield plant^{-1} (g)	138.94	230.87	369.81	38.10	48.24	0.62	61.61
Oil content (%)	2.66	1.86	4.52	3.16	4.92	0.41	4.16

Pod Length (cm)

Pod length play essential role in seed setting and seed yield. The analysis of variance for pod length showed highly significant differences among 30 genotypes of *B. carinata* lines (Table 1). Pod length ranged from 3.77 (Carinata-28) to 4.87 cm (Carinata-7) with a mean pod length of 4.41 cm (Table 2). Environmental variation for pod length was 0.02, while genetic variation was 0.10. Genetic variance was greater than environmental variance representing that the character was controlled genetically. Genotypic and phenotypic coefficients of variation for pod length were 7.16 and 7.84 cm, respectively. Heritability and genetic advance as percent of mean at 5% selection intensity for pod length was 0.83 and 13.42 cm (Table 3). Our results are in agreement with Ahmad *et al*. (2008) who observed highly significant differences for pod length. Our results are supported by the findings of Afrin *et al*. (2011) who observed less environmental effects on pod length as phenotypic

coefficient of variation (8.4%) and genotypic coefficient of variation (6.4%) were close to each other.

Seeds pod^{-1}

Number of seed pod^{-1} contributes considerably toward the final seed yield. Highly significant differences (P≤0.01) for seeds pod^{-1} were observed among 30 *carinata* lines (Table 1). Data presented in Table 2 related to number of seed pod^{-1} was in range of 11.6 (Carinata-60) to 16.2 (Carinata-47) seeds. Mean number of seeds pod^{-1} was 14.9 (Table 2). Environmental and genetic variances were 0.50 and 0.94 with the resultant heritability and genetic advance as percent of mean at 5% selection intensity for seeds pod^{-1} was 0.65 and 10.76, respectively. Genotypic and phenotypic coefficients of variation for seeds pod^{-1} was 6.40 and 8.03, respectively (Table 3). Our results are supported by Yadava *et al*. (2011) who studied genetic variability and parameters association studies in Indian mustard. They observed genetic variation for seed pod^{-1} among mustard cultivars. Our results are further strengthened by finding of Afrin *et al*. (2011) who reported that phenotypic variance (31.04%) and phenotypic coefficient of variation (23.8%) were higher than their consequent genotypic variance (13.6%) and genotypic coefficient variance (15.85%). Afrin *et al*. (2011) also observed high heritability with significant genetic advance as percent of mean for seed pod^{-1}.

100 Seed Weight (g)

Weight of seed expresses degree of seed improvement and is an imperative yield determinant. Seed weight plays an influential role in determining the yield potential of a genotype. The analysis of variance for 100 seed weight showed highly significant differences among *carinata* lines (Table 1). Data for 100 seed weight ranged from 0.25 g (Carinata-28) to 0.50 g (Carinata-38). Mean value for 100 seed weight was 0.35 g (Table 2). Environmental variance and genetic variance were 0.002 and 0.003 with the resultant heritability and genetic advance as percent of mean at 5% selection intensity for seeds pod^{-1} was 0.60 and 24.48, respectively. Genotypic and phenotypic coefficients of variation for seeds pod^{-1} was 15.30 and 19.8, respectively (Table 3). Our results are in agreement with Dar *et al*. (2010) who observed highly significant differences among genotypes for 100 seed weight. Mahla *et al*. (2003) observed high heritability with high genetic advance for 1000 seed weight.

Seed Yield plant^{-1} (g)

Seed yield plant^{-1} is collective consequence of various components like number of pods plant^{-1}, seeds pod^{-1} and 100 seed weight. Highly significant differences for seed yield plant^{-1} were observed among *carinata* lines (Table 1). Data presented in Table 2 ranged from 19.36 (Carinata-80) to 85.87 g (Carinata-83). Average seed yield plant^{-1} of 30 *B. carinata* lines was 39.86 g (Table 2). Environmental variance was138.94 and genetic variance was 230.9. Genotypic and phenotypic coefficients of variation for seed yield plant^{-1} were 38.10 and 48.24 g, respectively. Heritability for seed yield plant^{-1} was 0.62 and genetic advance as percent of mean at 5% selection intensity was 61.61 (Table 3). Ali *et al*. (1985) observed significant variation among mustard strains for seed yield^{-1}. Afrin *et al*. (2011) reported high heritability with high genetic advance and recommended that phenotypic selection for seed yield plant^{-1} would be valuable.

Oil Content (%)

An oil seed crop rich in oil content of high value is the considerable goal of many research projects. The quality of seed is determined from its oil content. Statistical analysis for oil content showed highly significant differences among *carinata* lines (Table 1). Oil content ranged from 39.0 (Carinata-80) to 45.5 % (Carinata-70). Mean oil contents were 43.1% (Table 2). Environmental variance was 2.66 and genetic variance was 1.86. Genotypic and phenotypic coefficients of variation for seed yield plant^{-1} were 3.16 and 4.92 g, respectively. Heritability for oil content was 0.41 and genetic advance as percent of mean at 5% selection intensity was 4.16 (Table 3). Highly significant genetic variation among oil quality traits were also recorded by Khan *et al*. (2008). Our results are also in agreement with the finding of Belete *et al*. (2012) who observed low genetic advance with low percent of mean for oil content.

Correlation Coefficients

Coefficients of correlation among various yield contributing traits are presented in Table 4.

Plant Height

Highly significant positive phenotypic correlation for plant height was found with primary branches plant^{-1}

(0.44), main raceme length (0.40), pods on main raceme (0.34), pod length (0.33), seed pod^{-1} (0.28), 100 seed weight (0.33), seed yield plant^{-1} (0.3). Positive non-significant relationship for plant height was estimated with oil content (0.03). This indicated that if plant height increased then primary branches plant^{-1}, main raceme length, pods on main raceme, pod length, seed pod^{-1}, 100 seed weight, and seed yield plant^{-1} were also increased. Significant positive correlation between plant height and seed yield plant^{-1} was reported by Khan and Khan (2003). Chaudhury *et al*. (1990) found positive correlation of plant height with number of seeds pod^{-1}. Similar results were reported by Srivastava *et al*. (1983).

Primary Branches plant^{-1}

Primary branches plant^{-1} showed highly significant positive phenotypic relationship with plant height (0.44), pod length (0.33) and seed yield plant^{-1} (0.55). Significant positive phenotypic correlation for primary branches plant^{-1} was recorded with seeds pod^{-1} (0.27). Positive but non-significant phenotypic correlation for primary branches plant^{-1} was found with main raceme length (0.1), 100 seed weight (0.17). Negatively non-significant phenotypic correlation for primary branches plant^{-1} was observed with pods on main raceme (-0.08). These results are suggesting that if number of primary branches increases then yield plant^{-1} also increases. Malik *et al*. (2000) reported similar results for number of primary branches and seed yield at phenotypic level.

Table 4. ***Phenotypic correlation (rp) for morpho-physiological traits and bio-chemical traits.***

Traits	PH	PBP	MRL	PMR	PL	SP	SW	SYP	OC
PH	-	0.44**	0.40**	0.34**	0.33**	0.28**	0.33**	0.29**	0.03
PBP		-	-0.09	-0.08	0.33**	0.27*	0.17	0.55**	-0.04
MRL			-	0.79**	0.07	-0.05	0.12	-0.25*	0.02
PMR				-	-0.20	-0.03	0.16	-0.16	0.02
PL					-	0.17	0.27**	0.09	-0.27*
SP						-	0.07	0.23*	0.15
SW							-	-0.01	-0.13
SYP								-	0.13

PH = Plant height (cm) PBP = Primary branches plant^{-1} MRL = Main raceme length (cm)
PMR = Pods on main raceme PL = Pod length (cm) SP = Seeds pod^{-1}
SW = 100 seed weight (g) SYP = Seed yield plant^{-1} (g) OC = Oil content (%)

Main Raceme Length (cm)

Highly significant positive phenotypic correlations for main raceme length was found correlated with plant height (0.40), pods on main raceme (0.79). Positive but non-significant phenotypic correlation for main raceme length was found with primary branches plant^{-1} (0.1), pod length (0.07), 100 seed weight (0.12), and oil content (0.02). Significant but negative correlation was observed with seed yield plant^{-1} (-0.25). Negative but non-significant phenotypic correlation for main raceme length was observed with seed pod^{-1} (-0.05). This indicated that if main raceme length increases then yield plant^{-1} decreases. Choudhary *et al.* (2003) reported opposite result for main raceme length and seed yield plant^{-1} in interspecific hybrids.

Pods on Main Raceme

Pods on main raceme showed highly significant positive phenotypic correlation with plant height (0.34) and main raceme length (0.79). Positively but non-significant phenotypic correlation of pods on main raceme was found with 100 seed weight (0.15) and oil content (0.02). Phenotypic relationship of pods on main raceme with primary branches plant^{-1} (-0.08), pod length (-0.2), seeds pod^{-1} (-0.03), seed yield plant^{-1} (-0.16) was negative and non-significant. Our results are inconsistent with the findings of Rameeh (2011) who observed positive significant association of pods on main raceme with pod length whereas, positive but non significant correlation with seed pod^{-1} and seed yield. Yadava *et al*. (2011) also observed positive non significant phenotypic correlation for pods on main raceme with 1000 seed weight and negative non-significant correlation with seed pod.

Pod Length (cm)

Significantly positively phenotypic correlation of pod length with plant height (0.33) and primary branches plant^{-1} (0.33), 100 seed weight (0.27) was found. Positive and non-significant phenotypic correlation for pod

length was found with main raceme length (0 .07), seeds pod^{-1} (0.17) and seed yield plant^{-1} (0.09). Significantly negative correlation was recorded with oil contents (-0.27). Phenotypic correlation for pod length was observed with pods on main raceme (-0.2). Our results are compatible with the findings of Khan *et al.* (2008), who reported high significantly positive correlation of pod length with 1000 seed weight and positive but non-significant association with seed pod^{-1}. Rameeh, (2011) reported opposite result for pod length and seed yield plant^{-1} in rapessed.

Seeds pod^{-1}

Highly significantly positive phenotypic correlation for seeds pod^{-1} was found with plant height (0.28), while positive significant correlation was estimated with primary branches plant^{-1} (0.27) and seed yield plant^{-1} (0.23). Positive but non-significant correlation was observed with pod length (0.17), 100 seed weight (0.07) and oil content (0.15). Negatively non-significant phenotypic correlation for seeds pod^{-1} was observed with main raceme length (-0.05) and pods on main raceme (-0.03). These results are suggesting that if seed pod^{-1} increases then yield plant^{-1} will also increase. Akbar *et al*. (2007) found that seeds pod^{-1} had significant positive correlation with seed yield in *B. Junceae*.

100 Seed Weight (g)

Highly significant and positive phenotypic correlation for 100 seed weight was found with plant height (0.33) and pod length (0.27). Positive but non-significant phenotypic correlation of 100 seed weight was found with primary branches plant^{-1} (0.17), main raceme length (0.12), pods on main raceme (0.16) and seeds pod^{-1} (0.07). Negative but non-significant phenotypic correlation for 100 seed weight was observed with seed yield plant^{-1} (-0.01), oil content (-0.13). Tuncturk and Ciftci (2007) reported positive correlation between seed yield with 1000-seed weight in *B. napus* which does not support the present findings.

Seed Yield plant^{-1} (g)

Yield is a complex product being influenced by quantitative characters. Thus selection for yield may not be effective unless the other yield components influencing it directly or indirectly are given due consideration. Seed yield plant^{-1} showed positive highly significant phenotypic correlation with plant height (0.3) and primary branches plant^{-1} (0.6). Seed yield plant^{-1} shows positive and significant correlation with seeds pod^{-1} (0.23). Positive and non-significant phenotypic correlation for seed yield plant^{-1} was found with pod length (0.09) and oil content (0.13). Negative but significant phenotypic correlation for seed yield plant^{-1} was found with main raceme length (-0.25). Negative and non- significant phenotypic correlation for seed yield plant^{-1} was found with 100 seed weight (-0.01) and pods on main raceme (-0.16). Jeromel *et al.* (2007) and Kumar *et al.* (1999) reported that in Brassica species, seed yield had positive significant correlation with plant height.

Oil Content (%)

Positive and non-significant correlations of oil contents with plant height (0.03), main raceme length (0.02), pods on main raceme (0.02), seed pod^{-1} (0.15) and seed yield plant^{-1} (0.13) was observed. Negative but significant phenotypic association for oil content was observed with pod length (-0.27). Negative and non-significant phenotypic correlation for oil content was found with primary branches plant^{-1} (-0.04) and 100 seed weight (-0.13). Our results are in agreement with Gangapur *et al*. (2009) who reported negative non-significant association for oil content with primary branches plant^{-1}. Tahira *et al.* (2011) reported positive but non-significant association of oil content with plant height and seed pod^{-1}. Singh *et al*. (2011) observed positive non-significant correlation of oil content with plant height, main raceme length, pods on main raceme and seed yield plant^{-1}.

CONCLUSIONS AND RECOMMENDATIONS

High heritability was found for pod length followed by pods on main raceme indicating that phenotypic selection for these traits would be effective so we can easily manipulate these changes. Phenotypic correlation studies indicated that plant height, number of primary branches plant^{-1} and seed pod^{-1} were the most important contributors to seed yield plant^{-1} which could be taken into consideration in future hybridization programs of *B. carinata*.

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