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STUDY OF SOME DIRECT AND IN-DIRECT SELECTION INDICES IN *B. campestris* L.

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The present study was conducted to estimate the selection indices directly and indirectly involved in yield of *B. campestris.* Parent lines, 36 F_1 hybrids and commercial hybrids/varieties were sown in the field in a randomized complete block design with three replications. Analysis of variance revealed remarkable differences among genotypes. Number of siliquae per plant had the highest heritability followed by days to maturity. Higher genetic advance was recorded for the 100 seed weight and plant height. Glucosinolates had the highest heritability and erucic acid had the highest genetic advance as percent of mean. Correlation studies showed that genotypic associations were higher than phenotypic associations. Plant height, green biomass, number of siliquae, days to 50% siliquae formation, number of seed per siliqua had considerable relationship with seed yield. Oil content had positive significant correlation with total protein contents. Protein contents had considerable positive correlation with glucosinolate and erucic acid. Glucosinolate had significant positive correlation with erucic acid. Path coefficient analysis showed that harvest index, days to flowering initiation, days to maturity, secondary branches, number of siliquae per plant and seed per siliqua had direct effect on seed yield. Protein content and oleic had direct positive effect on oil content. Therefore, these direct and indirect indices i.e. plant height, green biomass, harvest index, secondary branches, number of siliquae, days to 50% siliqua formation and number of seeds per siliqua needs emphasis for improvement of seed yield while protein content and oleic acid for oil content.
Keywords: Oilseed, canola, genetic variability, heritability, genetic advance, path analysis

INTRODUCTION

Oilseed Brassicas, rapeseed and mustard, are rich source of vegetable oil, contribute 12-14% of world total production and is the third largest source after palm and soybean (Wittkop *et al.,* 2009). Brassica species not only contain vitamins and dietary fiber but also anticancerous compounds (Fahey and Talay, 1999).

Brassica campestris belongs to Brassicaceae/Cruciferae family. The name cruciferae had been given due to flower shape that has four diagonal opposite petals like cross. It is believed that cultivated *B. campestris* developed from a wild strain *B. campestris*, originated from Western Europe to China (Gupta and Pratap, 2007)

Although *B. campestris* has been cultivated as an oilseed crop in subcontinent and yet not known as wild form in Pakistan and India. Breeding of rapeseed for low erucic acid and glucosinolate was started in Canada and Europe in 1960. Canola is high quality and modern form of oilseed brassicas. It was started in Canada from genetic modification in rapeseed through plant breeding. The first cultivar with "double low'' was developed in 1970. The name canola was trademark (Uppstrom, 1995).

The knowledge of the genetic variability, its extent and kind of relationship of quantitative traits in rapeseed and mustard is necessary for a resourceful breeding program. The use of quantitative genetic variability plays an important role for high yielding varietal development and advancement of the economically importance traits (Mahmood *et al.*, 2003). The relationship of seed yield components and quality traits are of main interest. Genetic variations, association and heritability have been studied for quantitative and qualitative traits in different genotypes of rapeseed. Immediate selection for seed, oil yield and protein content might be rewarding for improving oil and protein yield (Khan *et al.*, 2006; Aytac and Knac, 2009).

Genetic advance and heritability are the direct selection criteria that determine the degree to which trait respond to selection. So, for achieving further improvement, it is necessary to determine the genotypic and environmental effects for the trait being considered. High genetic advance along with high heritability indicate the additve gene action and selection would be effective through different selection methods such as pure line selection,mass selection, hybridization and pedigree selection while low heritability with low genetic advance leads to higher influence of environment and selection would be ineffective. Correlation coefficient and path analysis in plant breeding describes the relationship between different plant parameters and component traits on which selection can be relied for genetic improvement of yield. Basic information as the magnitude, phenotypic and genotypic pattern, heritability and association of yield contributing traits would be helpful in species improvement along with the selection of suitable breeding method (Marjanović-Jeromela *et al.*, 2011).

MATERIALS AND METHODS

Hybridization for the present studies was done at intraspecific level. For this purpose ten varieties/lines of *B. campestris* were sown in the field and crossed in line × tester fashion following Kempthorne (1957). The genotypes including UAF-11, UAF-12, Span, Quinyou-15, TR-8, 1072 and Toria were used as lines whereas Candle, Torch and Tobin were used as testers. All the breeding material so produced at intra-specific level, parent genotypes, F_1 hybrids, and commercial hybrids/varieties being were sown in field in a randomized complete block design with three replications. Sowing was done with the help of wooden dibbler using 4-5 seeds per hill, maintaining plant to plant distance of 15cm and row to row distance of 45cm. Only one plant was kept per hole after repeated thinning. Recommended dose of fertilizer, plant protection measures and number of irrigations were applied. Ten plants were tagged in each entry in each experimental unit and the data were recorded on morphological, phenological, seed yield and quality related traits from the tagged plants.

Genetic correlations were estimated for all combinations considering morphological, phenological and quality traits following Kwon and Torrie (1964) and path coefficient analysis was performed following Dewey and Lu (1959) using the R program. Broad sense heritability was computed according to Weber and Mort-hy (1952) and genetic advance was calculated at 20% selection intensity (i=1.4) according to formula (Poehlman and Sleper, 1955).

RESULTS

Direct selection indices for quantitative and qualitative traits intraspecific combinations: Analysis of variance for quantitative and qualitative traits showed highly significant differences among the genotypes (Table 1). Heritability and genetic advance are remarkable direct selection indices. The results for quantitative traits (Table 2) shows that days to flowering initiation had high heritability (97.80) along with high genetic advance (32.97) in percentage of meanwhile days to 50% flowering indicated high heritability (71.29) and remarkable genetic advance (56.10) in percentage of mean which indicated additive gene effects. Days to 50% siliqua formation, days to maturity and plant height showed considerable heritability and genetic advance. Number of primary branches, secondary branches, biomass, yield and harvest index revealed high heritability with low genetic advance in percentage of mean that showed non-additive gene action and selection which will not be rewarding in early generations. Number of siliqua per plant and number of seed per siliqua had high heritability and remarkable genetic advance in percentage of mean that revealed additive genetic effects. For qualitative (Table 3) oil contents had high heritability (94.70) and moderate genetic advance (17.7) that

Table 1. Mean square values associated with different plant traits of *B. campestris.*

Source of variation		Replications	Genotypes	Error
Degree of freedom		2	30	60
Phenological traits	Days to flowering initiation	11.36	36.12**	2.92
	Days to 50% flowering	5.83	29.85**	5.21
	Days to 50% siliqua formation	2.78	30.16**	1.51
	Days to maturity	14.91	26.90*	2.04
	Plant height	45.20	2262.17**	16.77
Morphological traits	Primary branches	0.90	15.33*	1.81
	Secondary Branches	0.72	87.24**	1.52
	Green Biomass	20.20	1787.73**	7.78
	Harvest index	4.57	1115.77**	6.01
Yield related traits	Number of siliquae per plant	0.46	44.96**	1.59
	Number of seed per siliqua	4.10	12343.40**	43.70
	100 seed weight	15.12	20.23*	10.43
	Seed yield per plant	1.32	423.20**	0.45
Quality related traits	Oil contents (%)	0.04	37.98**	0.69
	Protein contents (%)	0.50	15.96**	1.90
	Glucosinolates (%)	5.11	1915.00**	5.93
	Oleic acid (%)	47.26	511.02**	20.80
	Erucic acid (%)	5.58	521.88**	3.82

showed additive gene action while protein contents had remarkable heritability (71.13) along with moderate genetic advance (14.14). Glucosinolate also showed high heritability (99.07) and high genetic advance (93.37). For oleic acid and erucic acid high heritability along with remarkable genetic advance were found.

Table 2. Heritability (%) and Genetic advance (%) values mean for quantitative traits.

Characters	Heritability (%)	Genetic advance (%)
DFI	97.81	32.97
D 50% F	71.29	56.11
D 50% SF	94.95	89.58
DM	98.71	87.08
PH	98.40	136.72
PB	79.12	8.74
SB	61.22	5.92
GB	86.37	7.05
HI	80.19	5.21
SL/p	98.95	43.93
S/S	90.04	60.46
TSW	23.83	214.53

DFI stands for flowering initiation, D50% F for days to 50% flowering, D50% SF for days 50% siliqua formation, DM for days to maturity, PH for plant height, PB for primary branches, SB for secondary branches, GB for green biomass, HI for harvest index, S/PL for siliquae per plant, S/S for seed per siliqua, TSW for 100 seed weight.

Table 3. Heritability and genetic advance for quality traits for intraspecific crosses.

Quality traits	Heritability	Genetic advance
Oil contents (%)	94.70	17.74
Protein contents (%)	71.13	14.14
Glucosinolate contents (%)	99.07	93.73
Oleic acid (%)	88.71	50.02
Erucic acid (%)	97.83	119.94

Indirect selection indices for quantitative traits in intra-specific crosses: Correlation studies indicated that genotypic associations were higher than phenotypic associations (Table 4). Plant height had positive remarkable correlations with green biomass, days to 50% flowering and seed yield per plant. Primary branches had positive significant correlation with secondary branches and secondary branches had negative but significant correlation with seed per siliqua and 100 seed weight. A significant correlation of green biomass was observed with number of siliqua per plant and seed yield per plant. Harvest index had positive association with days to 50% flowering, days to 50% siliquae formation, number of seed per siliqua and seed yield per plant. Positive and significant association was found among days to flowering initiation, days to 50% flowering and days to 50% siliqua formation. Days to 50% siliqua formation presented positive and significant correlation with 100 seed weight and highly significant correlation with seed yield per plant. Days to maturity were significantly associated with number of siliqua per plant. Number of siliqua per plant revealed negative

Table 4. Genotypic (upper) and Phenotypic Correlation (lower) between quantitative traits for intraspecific crosses.

	Morphological traits					Phenological traits				Yield related traits			
	PH	**PB**	**SB**	**GB**	**HI**	**DFI**	**D50% F**	**D50% SF**	**DM**	**SL/p**	**S/S**	**TWS**	**Y/P**
PH	1.000	0.172	-0.035	0.655**	-0.096	-0.068	0.263*	0.203	-0.152	0.180	0.047	-0.057	0.269**
PB	0.142	1.000	0.849**	-0.008	0.026	0.034	0.032	0.092	-0.079	0.085	-0.107	-0.139	-0.093
SB	-0.032	0.753**	1.000	-0.074	-0.003	0.009	-0.084	-0.006	-0.167	0.036	-0.479**	-0.487**	-0.141
B.Y	0.644**	-0.024	-0.072	1.000	-0.163	0.063	0.001	-0.040	0.170	0.285**	-0.165	-0.116	0.504**
HI	-0.093	0.032	-0.003	-0.170	1.000	0.118	0.281**	0.434**	0.019	0.191	0.329**	0.070	0.691**
DFI	-0.052	0.024	0.005	0.051	0.118	1.000	0.347**	0.398**	-0.026	0.114	-0.014	0.386	0.169
D50%F	0.210*	-0.009	-0.057	0.001	0.226*	0.387**	1.000	0.959**	0.083	0.288**	0.217	-0.074	0.248*
D50%SF	0.184	0.109	0.006	-0.036	0.381**	0.338**	0.774**	1.000	0.171	0.215	0.217	0.256*	0.325**
DM	-0.148	-0.060	-0.163	0.157	0.018	-0.023	0.0263	0.139	1.000	0.269**	-0.077	0.079	0.162
SL/p	0.175	0.059	0.030	0.283**	0.189	0.099	0.225*	0.195	0.238*	1.000	0.017	-0.363**	0.401**
S/S	0.034	-0.096	-0.439**	-0.147	0.304**	-0.044	0.155	0.217*	-0.052	0.019	1.000	0.492**	0.184
TWS	-0.021	-0.054	-0.249*	-0.059	0.061	0.130	-0.023	0.087	0.073	-0.168	0.241*	1.000	-0.107
Y/P	0.266**	-0.076	-0.137	0.491**	0.687**	0.156	0.202	0.302**	0.145	0.399**	0.172	-0.044	1.000

*=significant ($p<0.05$);**=highly significant ($p<0.01$).

DFI stands for days to flowering initiation, D50% F for days to 50% flowering, D50% SF for days 50% siliqua formation, DM for days to maturity, PH for plant height, PB for primary branches, SB for secondary branches, GB for green biomass, HI for harvest index, S/PL for siliquae per plant, S/S for seed per siliqua, TSW for 100 seed weight, Y/P for yield per plant.

Table 5. Path analysis for quantitative traits of intraspecific crosses.

	Phenological traits				Morphological traits					Yield related traits		
	DFI	**D50% F**	**D50% SF**	**DM**	**PH**	**PB**	**SB**	**GB**	**HI**	**SL/p**	**S/S**	**TSW**
DFI	**0.049**	0.102	-0.120	-0.001	0.005	-0.006	0.001	0.042	0.095	0.007	0.026	-0.0004
D 50% F	0.017	**0.295**	-0.290	0.004	-0.020	-0.005	-0.010	0.001	0.226	0.004	-0.001	-0.0019
D 50% SF	0.020	0.283	**-0.302**	0.009	-0.015	-0.016	-0.001	-0.027	0.350	0.011	0.018	0.0004
DM	-0.001	0.024	-0.052	**0.052**	0.011	0.014	-0.020	0.114	0.016	0.008	0.017	-0.0013
PH	-0.003	0.078	-0.061	-0.008	**-0.075**	-0.029	-0.004	0.438	-0.077	0.010	-0.006	-0.0004
PB	0.002	0.009	-0.028	-0.004	-0.013	**-0.171**	0.102	-0.005	0.021	0.007	0.004	0.0003
SB	0.000	-0.025	0.002	-0.009	0.003	-0.145	**0.120**	-0.049	-0.002	0.003	-0.009	0.0007
B.Y	0.003	0.000	0.012	0.009	-0.049	0.001	-0.009	**0.669**	-0.132	0.001	-0.039	0.0025
HI	0.006	0.083	-0.131	0.001	0.007	-0.004	0.000	-0.109	**0.806**	0.011	-0.013	0.0006
SL/p	0.006	0.085	-0.065	0.014	-0.013	-0.015	0.004	0.190	0.154	**0.038**	0.001	0.0018
S/S	-0.001	0.064	-0.066	-0.004	-0.004	0.018	-0.057	-0.111	0.265	0.001	0.**081**	-0.0025
TSW	0.019	-0.022	-0.077	0.004	0.004	0.024	-0.058	-0.078	0.056	-0.014	0.040	**-0.0050**

DFI stands for days to flowering initiation, D50% F for days to 50% flowering, D50% SF for days 50% siliqua formation, DM for days to maturity, PH for plant height, PB for primary branches, SB for secondary branches, GB for green biomass, HI for harvest index, S/PL for siliquae per plant, S/S for seed per siliqua and TSW for 100 seed weight.

Table 6. Phenotypic and genotypic correlation coefficients for quality traits of intraspecific crosses.

Qualitative traits	**Oil contents (%)**	**Protein contents (%)**	**Glucosinolate contents (%)**	**Oleic acid (%)**	**Erucic acid (%)**
Oil contents (%)	1.000	0.266*	-0.242	-0.03 0	0.203
Protein contents (%)	0.167	1.000	0.621**	-0.580**	0.618**
Glucosinolate contents (%)	-0.230	0.510**	1.000	-0.579**	0.510**
Oleic acid (%)	-0.046	-0.455**	-0.564**	1.000	-0.807**
Erucic acid (%)	0.189	0.509**	0.507**	-0.777**	1.000

association with 100 seed weight but positive with seed yield per plant. Number of seed per siliqua reflected direct and considerable relationship with 100 seed weight.

Path coefficient analysis (Table 5) showed that harvest index had considerable positive and direct effect on seed yield per plant (0.806) and positive indirect effect on yield via days to 50% flowering (0.083). These findings showed that as the harvest index and days to 50% flowering increase, the yield will also increase. Days to flowering initiation showed positive direct effect (0.049) on seed yield and the highest indirect effect (0.102) via days to 50% flowering. Days to 50% siliqua formation had direct effect (-0.30) and indirect positive effect (0.35) via harvest index on seed yield. By reducing the days to 50% siliqua formation harvest index and seed yield will be increased. Days to maturity exerted positive direct effect (0.05) on seed yield and maximum positive indirect effect (0.11) via green biomass. It indicates that as days to maturity increase, the biological yield will also increase that will ultimately increase in yield. Plant height had negative direct effect (-0.08) while positive direct effect (0.44) via biomass. By reducing the plant height will increase in green biomass yield. Primary branches showed direct effect negatively (-0.17) and maximum indirect effect (0.10) via secondary branches on seed yield. Yield may be increased by reducing the number of primary branches. Positive direct effect (0.12) of secondary branches on seed yield was noted and the highest indirect positive effect (0.003) via number of siliqua per plant. Green biomass had positive direct effect (0.67) on seed yield and the highest indirect positive effect (0.01) via days 50% siliqua formation. Number of siliqua per plant has direct positive effect (0.03) on seed yield and highest indirect positive effect (0.19) via biological yield on seed yield. Seed per siliqua presented direct effect (0.08) positively on seed yield whilst maximum indirect effects (0.26) positively via harvest index. Negative direct effect of 100 seed weight (-0.005) was recorded for seed yield.

***Indirect selection indices for quality traits for intra-specific crosses*:** Oil content has positive and significant correlation with protein while protein content had considerable positive correlation with glucosinolate and negative significant correlation with oleic acid and significant positive correlation with erucic acid (Table 6). Glucosinolate has positive and significant correlation with erucic acid and negative with oleic acid. Oleic acid was negatively correlated with erucic acid. Protein contents had direct positive effect (.094) and highest indirect effect (.004) via erucic acid on oil contents (Table 7). Glucosinolate contents had direct negative effect (-0.04) and indirect effect (0.017) was positive via protein contents. Oleic acid had direct positive effect (.076) and Erucic acid had direct negative effect (-0.072) on oil contents.

Table 7. Direct (Diagonal) and indirect effect path coefficients of quality traits.

Quality traits	Protein contents (%)	Glucosinolate contents (%)	Oleic acid (%)	Erucic acid (%)
Protein contents (%)	**0.094**	-0.007	-0.002	0.004
Glucosinolate contents (%)	0.017	**-0.040**	0.010	-0.048
Oleic acid (%)	-0.003	-0.005	**0.076**	0.000
Erucic acid (%)	-0.006	-0.027	0.000	**-0.072**

*=significant (p<0.05);**=highly significant (p<0.01)

DISCUSSION

***Heritability and genetic advance for intra-specific combinations*:** Prediction for effective selection is more reliable on heritability along with genetic advance than heritability alone (Johnson et al., 1955) while trait having low genetic advance do not respond the selection (Pant and Singh, 2001). Heritability is the ratio between the genotypic and phenotypic variances and is the outcome of genetically inherited properties of the material and the interaction of the environment in which the experiment is being performed (Falconer and Mackay, 1996). Genetic advance and heritability are the direct selection criteria that determine the degree to which trait respond to selection. So, for achieving further improvement it is necessary to determine the genotypic and environmental effects for the trait being considered. Ali et al. (2003), Amiri-Oghan et al. (2009) and Zare and Sharafzadah (2012) reported similar findings that high heritability along with high genetic advance in percentage of mean indicate heritability was due to additive gene actions and selection for the trait may be effective.

Our results were partially agreed with that of Paikhomba *et al.* (2014) for days to 50% siliqua formation, days to maturity and plant height. Heterosis breeding and population improvement through recurrent selection will be effective because the traits such as number of primary branches, secondary branches, biomass yield and harvest index showed non-additive gene action and selection will not be rewarding in early generations. Findings were not in contrary with results presented by Ali *et al.* (2003), Aytac *et al.* (2008) and Mahmud (2008). High heritability and remarkable genetic advance that means additive genetic effects are involved for number of siliquae per plant and number of seed per siliqua as reported by Ali *et al.* (2003), Aytac *et al.* (2008), Mahmud (2008). The low heritability and high genetic advance for 100 seed weight were due to additive gene action and selection may be effective in such case. In case of yield both heritability and genetic advance were high and selection will be effective way for the improvement in yield. Observations were agreed with the findings of Singh and Singh (1997) and Sheikh *et al.* (1999). High heritability along with genetic advance in percentage of mean, prediction can be made for the advancement in *Brassica rapa* L. through direct selection via traits like days to 50% siliquae formation, days to maturity, number of siliquae/plant, number of seed per siliqua and plant height.

***Heritability and genetic advance for quality traits*:** Oil contents had high heritability and correlation coefficient is a statistical expression that determines the degree of relationship between two or more variables. In plant breeding, Correlation coefficient describes the relationship among various plant parameters for which selection can be relied on for the genetic improvement of yield. Results were supported by previous findings like (Tyagi et al.1996; Thakral et al., 1998; Oezer et al., 1999; Ghosh and Gulati, 2000; Khan et al., 2006, Aytac and Kinaci, 2009; Zare, 2011) who indicated that positive remarkable correlations of plant height with green biomass, days to 50% flowering and seed yield per plant but some researchers reported the negative correlation for these traits in rapeseed (Sadaqat et al., 2003; Zare and Shrafzadeh, 2012).

Positive significant correlation of primary with secondary branches was reported by Cheema and Sadaqat (2004). Similar findings on correlation studies for other traits such as secondary branches, seed per siliqua, 100 seed weight, green biomass, number of siliqua per plant, seed yield per plant, harvest index, days to 50% flowering, days to 50% siliqua formation, number of seed per siliqua and seed yield per plant were reported by Tyagi et al. (1996), Thakral et al. (1998), Sadaqat et al. (2003) and Zare and Shrafzadeh (2012).

***Path analysis for quantitative traits of intraspecific crosses*:** Path analysis is a standardized partial regression that split the correlation coefficients into measure of direct and indirect effects. Correlation may not provide the comparative value of direct and indirect effect of each yield components on seed yield. Path analysis has been used to know inter-correlation between seed yield and yield contributing traits.

Studies showed that plant height reduction will increase in green biomass yield. Belete (2011) noted direct negative effect on seed yield. However, direct positive effects were also found by Ali *et al.* (2003). Basalma *et al. (*2008) also indicated that yield can be increased by reducing the number of primary branches.

Previous findings of Shabana *et al.* (1990), Ali *et al.* (2002), Tusar-Patra *et al.* (2006), Tuncture and Ciftci (2007), Hashmei *et al.* (2010) and Zare (2011) supported our results for effects of different traits on yield. Ali *et al.* (2002), Tuncture and Ciftci (2007) and Zare (2011) reported positive direct effect for number of seed per plant while Belete (2011) reported negative direct effect of 100 seed weight on seed yield.

***Correlation and path analysis for quality traits for intra-specific crosses*:** Positive relationship between oil and protein content was not supported by Alemeyehu and Becker (2001), who reported negative correlation. Azam *et al.* (2013) observed that Protein content had positive and significant correlation with erucic acid and none significant with glucosinolate content. Abideen *et al.* (2013) also reported positive non-significant association between glucosinolate and erucic acid content. Similar findings were supported by Krzymanski and Downey (1969) that oleic acid had negative association with erucic acid. Tahira *et al.* (2015) also noted that negative direct effect of oil contents on erucic acid and indirect effects via total glucosinolate (-0.167) and oleic acid (-0.088) were also negative. Glucosinolate had positive direct effect (0.384) on erucic acid.

***Conclusion*:** This study showed that selection indices such as plant height, green biomass, harvest index, secondary branches, number of siliquae, days to 50% siliquae formation, number of seeds per siliqua might be considered for the improvement of seed yield while total protein contents and oleic acid for oil contents.

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