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Research Article
Line × Tester Analysis for Seed Yield and Yield Components in *Brassica napus* L. Genotypes

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Keywords

Genetic variation, combining ability, seed yield and components

Abstract

The study was conducted to evaluate genetic variation, general and specific combining ability in *Brassica napus* L. genotypes for seed yield and yield components during 2010 – 2011 and 2011 - 2012. Analysis of variance for combining ability for different traits showed that mean sum of squares due to lines (female) were statistically significant ($P<0.05$) for all traits except 1000-seed weight and protein content whereas for testers (male) the mean sum of squares were non significant ($P>0.05$) for the trait of seed yield per plant and other traits exhibited highly significant results ($P<0.05$). Highly significant ($P<0.05$) results were found in line × tester interaction for all traits. The estimates of SCA variance was noticed higher than GCA variance in all traits. The contributions of lines as compared to testers were greater for all parameters except primary branches per plant, 1000-seed weight and protein content.

Introduction

Although Pakistan has made a splendid progress in agriculture but serious shortage of edible oil is persisting. The total available quantity of oil used for edible purposes was 2.9 million tons during 2009-10. Out of which domestic productivity of cooking oil was only 0.662 million tons that contributed about 23% of total available quantity in Pakistan, whereas the rest of 77% was imported from other countries. In nine months from July-March, 2010-2011, a huge quantity of 1.7 million tons cooking oil is equal to 1.65 billion US$ was ensured through imports. The country imports palm oil from South Korea, Norway, Singapore and Malaysia while soybean oil had been bought from Singapore, Argentina, Malaysia and Switzerland. In Pakistan, *Brassica napus* was cultivated on an area of 272 thousand hectares with gross annual productivity of edible oil was 100 thousand tons (Govt. of Pakistan, 2010-11). *Brassica napus* plant has high percentage of oil and protein, is ranked third and second, respectively among the oil seeds. *Brassica napus* seed contains 40-45% oil from its weight. Therefore, it is rich in oil content than other oil crops such as: Cotton (25 %), Soya been (20 %), maize (15 %) and it is close to sunflower (40%). The high percentage of oil in *Brassica napus* makes it the leading oil crop in the world. For that reason, it is cultivated in large areas in many countries. *Brassica napus* seed also contains at least 46.5% protein and 0.35% phosphorus in the meal, is a valuable oil crop in oil industry and animal feed. General and specific combining abilities of different genotypes will be determined using line × tester analysis. In breeding program of *Brassica napus* for the improvement and development of open pollinated varieties and F1 crosses, both GCA and SCA effects are vital initiator of inbred lines potential in varietal combinations. The analysis conducted in line × tester design is an effective way to evaluate a huge number of inbred lines and providing correct information on the relative importance of general combining ability and

specific combining ability effects for determining the genetic basis of plan traits of economical importance (Singh and Chaudhury, 1977). Many workers have reported general and specific combining ability effects for different characters in *Brassica napus* (Sharief *et al*. 2002; Gupta *et al.* 2006; Nassimi *et al.* 2006a; Nassimi *et al.* 2006b; Raziuddin *et al.* 2006; Akbar *et al.* 2008; Huang *et al.* 2009; Rameeh 2011; Singh *et al*. 2011; Rameeh 2012; Turi *et al.* 2011). The present study had been designed with the aim to find out suitable combining parents for different characters in eight genotypes and to select superior crosses with respect to their good specific combining effects for seed yield and yield components of *Brassica napus* L.

Materials and Methods

The present research was conducted in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the year 2010-2011 and 2011-2012. Eight genotypes were sown namely Star, Golarchi, Hybripol, UAF 2, BA 0714 (lines) and Range, DGL, Ayub 2000 (testers) during rabi season of 2010 and were crossed in Line × Tester fashion. Seed obtained by these crosses and the parents were sown next year in randomized complete block design in three replications. Plant to plant distances was 30cm and row to row 60cm in a plot size of 3m x 9m. All the agronomic practices recommended for *Brassica napus* were followed throughout growing season. At the maturity, data of fifteen F1 crosses and their parents were recorded for various plant parameters, i.e. days taken to flowering, days taken to maturity, plant height, primary branches per plant, secondary branches per plant, number of siliqua per plant, number of seeds per siliqua, 1000-seed weight, seed yield per plant, protein content and oil content. The data were subjected to analysis of variance according to (steel *et al*., 1997). Since the expected mean sum of squares are not available for the modified line x tester analysis, the mean of each replication for the eleven characters recorded for the hybrids alone were subjected to analysis and the fresh mean sum of squares, along with the variance of general combining ability (GCA) of the parents and specific combining ability (SCA) of the hybrids were worked out based on the procedure developed by Kempthorne (1957).

Results and Discussion

From Table I showed that Significant (P≥0.01-0.05) difference was recorded among entries for all traits studied. From table II, the analysis of variance of combining ability for different traits in a line × tester design (5×3) showed that the mean sum of squares due to lines (female) were statistically significant (P ≥0.01-0.05) for all traits except 1000-seed weight and protein content whereas for testers (male) the mean sum of squares were non significant (P>0.05) for the trait of seed yield per plant and other traits exhibited highly significant results. Highly significant results were found in line × tester interaction for all traits. The estimates of SCA variance was noticed higher than GCA variance in all traits. The contributions of lines compared to testers were greater for all parameters except primary branches per plant, 1000-seed weight and protein content. However the involvement of lines × testers were noted higher in case of days taken to flowering, days taken to maturity, primary branches per plant, number of seeds per siliqua,1000-seed weight, seed yield per plant, protein content and oil content.

Table I. Mean squares from analysis of variance of various traits in *Brassica napus* L.

Parameters	Replications	Genotypes	Error
Degree of Freedom	2	22	44
Days taken to flowering	6.49	28.19**	2.02
Days taken to maturity	3.17	86.96**	12.07
Plant height (cm)	12.45	284.01**	22.62
Primary branches per plant	0.061	5.39**	0.10
Secondary branches per plant	0.18	8.78**	0.68
Number of siliqua per plant	3793	71720**	1176
Number of seeds per siliqua	0.48	16.22**	0.20
1000-seed weight (g)	0.05	0.35**	0.03
Seed yield per plant (g)	77.93	399.19**	22.16
Oil content	0.71	13.25**	1.56
Protein content	1.36	12.17**	1.07

* Significant (α=0.05) ** Highly significant (α=0.01)

Table II. Analysis of variance for combining ability analysis of various traits in *Brassica napus* L.

Traits	d.f	DTF	DTM	PH	PBPP	SBPP	NSPP
Replication	2	6.49	3.17	12.44	0.06	0.18	3793
Lines (L)	4	13.74**	75.14**	690.05**	1.26**	7.31**	198231**
Testers (T)	2	18.28**	136.06**	101.40*	5.98**	6.86**	16959**
L × T	8	27.84**	102.42**	122.20**	6.67**	1.74*	28907**
Error	44	2.02	12.068	22.616	0.10	0.68	1176
S^2 GCA		0.18	0.10	5.38	0.05	0.07	1578.3
S^2 SCA		8.60	30.12	33.19	2.18	0.35	9243.4
S^2gca/S^2sca		0.020	0.003	0.162	0.022	0.20	0.170
Contribution (%) of							
Lines		17.49	21.59	70.04	7.18	51.37	74.9
Testers		11.63	19.54	5.14	16.98	24.08	3.2
Lines × Testers		70.87	58.86	24.80	75.82	24.53	21.9

Table II. Continue

Traits	d.f	NSPS	SW	SYPP	PC	OC
Replication	2	0.48	0.35	77.92	0.71	1.36
Lines (L)	4	25.83**	3.57	482.87**	2.47	20.89**
Testers (T)	2	1.29**	14.64**	7.92	17.82**	5.99**
L × T	8	14.39**	10.78**	464.74**	11.45**	10.63**
Error	44	0.20	1.93	22.16	1.56	1.07
S^2 GCA		0.04	0.05	2.03	0.05	0.07
S^2 SCA		4.73	2.94	147.52	3.29	3.18
S^2gca/S^2sca		0.008	0.017	0.013	0.015	0.022
Contribution (%) of						
Lines		46.74	11.01	34.09	7.21	46.26
Testers		1.17	22.56	0.28	25.98	6.64
Lines × Testers		52.08	66.42	65.62	66.80	47.08

* Significant (α=0.05) ** Highly significant (α=0.01

Table III. Estimates of GCA effects of female and male parents for various traits in *Brassica napus* L.

Traits	DTF	DTM	PH	PBPP	SBPP	NSPP
GCA for Lines						
Star	1.91*	1.95	-6.66**	0.50**	0.86*	73.77**
Golarchi	0.35	0.28	7.66**	-0.27*	0.04	99.55**
Hybripol	-0.20	3.40*	9.33**	-0.45**	-1.45**	-255.33**
UAF 2	-1.31*	-3.82*	0.44	0.13	0.61*	86.77**
BA 0714	-0.75	-1.82	-10.77**	0.10	-0.07	-4.77
GCA for Testers						
Range	1.15*	2.33*	2.6*	-0.05	-0.21	-34.33**
DGL	-1.04*	1.06	-2.6*	0.65**	-0.54*	32.86**
Ayub 2000	-0.11	-3.40**	0.0	-0.60**	0.75*	1.46

Table III. Continued

Traits	NSPS	SW	SYPP	PC	OC
GCA for Lines					
Star	-1.94**	0.72	-1.67	0.40	0.20
Golarchi	0.36*	0.52	-8.10**	-0.04	-2.04**
Hybripol	-1.12**	-0.33	-5.45*	-0.04	-0.09
UAF 2	2.50**	-0.08	7.94**	-0.82*	2.23**
BA 0714	0.20	-0.82	7.29**	0.51	-0.29
GCA for Testers					
Range	-0.12	0.34	-0.28	-0.26	-0.48
DGL	-0.21	0.77*	-0.54	-0.93*	-0.22
Ayub 2000	0.33*	-1.11*	0.82	1.19*	0.71*

* Significant (α=0.05) ** Highly significant (α=0.01)

Table IV. Estimates of SCA effects of Hybrids for all the parameters in *Brassica napus* L.

Hybrids	DTF	DTM	PH	PBPP	SBPP	NSPP
Star × Range	-3.37**	-4.88*	-2.60	-0.26	0.37	53.55*
Golarchi × Range	1.51	1.77	5.06	-0.98**	0.22	-93.88**
Hybripol × Range	-3.60**	-5.00*	-4.93	1.39**	0.56	-106.00**
UAF 2 × Range	1.51	7.55*	5.28	-0.09	-1.00*	41.55*
BA 0714 × Range	3.95**	0.55	-2.81	-0.06	-0.15	104.77**
Star × DGL	1.48	1.37	3.26	1.066**	-0.40	-43.64*
Golarchi × DGL	-1.95*	-4.62*	-1.40	0.34	-0.48	119.24**
Hybripol × DGL	3.26*	3.26	4.60	-0.14	-0.28	86.13**
UAF 2 × DGL	-0.62	2.15	-11.17**	-2.13**	0.15	-39.64*
BA 0714 × DGL	-2.17*	-2.17	4.71	0.86**	1.00*	-122.08**
Star × Ayub 2000	1.88*	3.51	-0.66	-0.80**	0.03	-9.91
Golarchi × Ayub 2000	0.44	2.84	-3.66	0.63*	0.25	-25.35
Hybripol × Ayub 2000	0.33	1.73	0.33	-1.25**	-0.28	19.86
UAF 2 × Ayub 2000	-0.88	-9.71**	5.88*	2.22**	0.85	-1.91
BA 0714 × Ayub 2000	-1.77*	1.62	-1.88	-0.80**	-0.85	17.31

Table IV. Continued

Hybrids	NSPS	SW	SYPP	PC	OC
Star × Range	0.24	-0.49	-18.02**	0.26	2.39**
Golarchi × Range	-0.88*	-0.69	2.84	1.37	-2.90**
Hybripol × Range	1.30**	-1.67*	16.12**	-1.28	-0.26
UAF 2 × Range	1.66**	-0.05	3.35	1.82*	0.24
BA 0714 × Range	-2.33**	2.91*	-4.29	-2.17*	0.52
Star × DGL	1.50**	1.07	15.29**	1.26	-1.61*
Golarchi × DGL	0.23	-1.26	-7.13*	-1.62*	1.80*
Hybripol × DGL	0.62*	0.16	-2.86	-0.28	0.27
UAF 2 × DGL	-0.91*	1.28	-8.86*	0.48	1.04
BA 0714 × DGL	-1.44**	-1.25	3.56	0.15	-1.51*
Star × Ayub 2000	-1.74**	-0.57	2.72	-1.52*	-0.77
Golarchi × Ayub 2000	0.65*	1.95*	4.29	0.24	1.10
Hybripol × Ayub 2000	-1.92**	1.51	-13.20**	1.57*	-0.01
UAF 2 × Ayub 2000	-0.75**	-1.23	5.50*	-2.31*	-1.29*
BA 0714 × Ayub 2000	3.77**	-1.66*	0.72	2.01*	0.98

* Significant (α=0.05) ** Highly significant (α=0.01)

Days taken to flowering

Table III showed that among the lines Star and Golarchi recorded significant results for positive and negative GCA effects respectively. Out of three testers, Range and DGL exhibited significant positive and negative GCA effects. Table IV, out of 15 hybrids, only one cross i.e. BA 0714 × Range showed highly significant results for positive SCA effects but the hybrids viz., Star × Range and Hybripol × Range revealed highly significant results in negative direction of SCA effects for days taken to flowering. The cross combination BA 0714 × Range was the best specific combiner. Gupta *et al*. (2006); Nassimi *et al*. (2006a) and Rameeh (2012) exhibited highly significant results for both GCA and SCA effects for days taken to flowering in *B. napus L.*

Days taken to maturity

From Table III, Out of 5 lines, the female parents Hybripol and UAF 2 showed significant results for positive and negative GCA effects respectively. The cultivar Hybripol (3.40) was good general combiner in the female genotypes. Among the 3 testers, Ayub 2000 (-3.40) exhibited highly significant results in relation to negative GCA effects whereas the genotype Range (2.33) showed positive GCA effects. Table IV. among the fifteen cross combinations, UAF 2 × Ayub 2000 expressed highly significant results for negative SCA effects for this trait. The hybrid UAF 2 × Ayub 2000 (-9.71) was identified as the best specific combiner for this character. Whereas other crosses expressed non significant results for this plant parameter. Sharief *et al*. (2002); Nassimi *et al*. (2006b) and Huang *et al*. (2009) reported significant results for this character.

Plant height (cm)

From Table III, The lines Hybripol, Golarchi, BA 0714 and Star observed to be good general combiner seen highly significant results for GCA effects in positive and negative direction. In three testers Range and DGL exhibited significant results in relation positive and negative GCA effects correspondingly. Table IV, In case of specific combining ability out of fifteen hybrids, the only F1 cross UAF 2 × DGL expressed highly significant results in direction of negative specific combining ability effects and identified as best specific combiner. Sharief et al. (2002); Rameeh *et al*. (2011); Turi *et al*. (2011) and Rameeh (2012) were calculated both general combining ability and specific combining ability significant effects in *Brassica*.

Primary branches per plant

From Table III, among lines Star and Hybripol showed highly significant results for positive and negative GCA effects. Out of three testers, DGL (0.65) and Ayub 2000 (-0.60) exhibited significant positive and negative general combining ability effects and the male parent DGL was identified as good general combiner for the trait primary branches per plant. From Table IV, out of 15 hybrids, these crosses UAF 2 × Ayub 2000, Hybripol × Range, Star × DGL showed highly significant results for positive SCA effects. The cross combination UAF 2 × Ayub 2000 was the best specific combiner. Sharief et al. (2002); Gupta *et al*. (2006) and Singh *et al*. (2010) studied the both GCA and SCA effects for the trait primary branches per plant.

Secondary branches per plant

From Table III, the female parents Hybripol observed to be good general combiner as seen highly significant results for GCA effects in negative direction. In three male parents Range and DGL exhibited significant results for GCA effects in negative and positive relation. From table IV, in case of specific combining ability out of fifteen hybrids, only 2 hybrids i.e. BA 0714 × DGL and UAF 2 × Range expressed highly significant results in direction of positive and negative specific combining ability effects while the other cross combinations exhibited non significant reults for the trait of Secondary branches per plant. Sharief et al. (2002); Turi *et al*. (2011) was also explained both GCA and SCA significant effects in *Brassica napus*.

Number of siliqua per plant

From Table III, among the lines, Golarchi, UAF 2, Star and Hybripol showed highly significant results for positive and negative GCA effects. Out of three testers, DGL and Range exhibited highly significant positive and negative general combining ability effects. From Table IV, Out of 15 hybrids, these crosses Golarchi × DGL, BA 0714 × Range, Hybripol × DGL showed highly significant results for positive SCA effects but the hybrids viz., BA 0714 × DGL, Hybripol × Range and Golarchi × Range revealed highly significant results in negative direction of SCA effect for number of siliqua per plant. The cross combination Golarchi × DGL (119.24) was the best specific combiner. Sharief et al. (2002); Huang *et al*. (2009) studied the both GCA and SCA effects for the trait number of siliqua per plant in mustard.

Number of seeds per siliqua

From Table III, Out of five female parents, three lines i.e. Star, Hybripol and UAF 2 expressed highly significant results for GCA effects in negative and positive direction respectively. In three male parents, only one tester exhibited Ayub 2000 significant results for GCA effects in positive relation. Table IV. in case of specific combining ability out of fifteen hybrids, the F1 crosses viz., BA 0714 × Ayub 2000, UAF 2 × Range, Hybripol × Range, Star × DGL and BA 0714 × Range, Hybripol × Ayub 2000, Star × Ayub

2000, BA 0714 × DGL, UAF 2 × Ayub 2000 expressed highly significant results in direction of positive and negative specific combining ability effects. The hybrid BA 0714 × Ayub 2000 (3.77) was the best specific combiner. Sharief *et al*. (2002); Nassimi *et al*. (2006a) and Akbar *et al.* (2008) were also explained both GCA and SCA significant effects for number of seed per siliqua in *Brassica napus*.

1000-seed weight (g)

From Table III, among the lines, all female indicated non significant results for good general combiner GCA effects while in male parents only Ayub 2000 revealed significant results in direction of positive GCA effects. From Table IV, In case of specific combining ability out of fifteen hybrids, the crosses i.e. BA 0714 × Range, Golarchi × Ayub 2000 and Hybripol × Range, BA 0714 × Ayub 2000 expressed significant results in direction of positive and negative specific combining ability effects while the other cross combinations exhibited non significant reults for the trait of 1000-seed weight. The hybrid BA 0714 × Range was good specific combiner for this character. Akbar *et al.* (2008) was estimated significant results for both GCA and SCA effects.

Seed yield per plant (g)

From Table III, Out of five female parents, 3 lines i.e. UAF 2, BA 0714 and Golarchi expressed highly significant results for GCA effects in negative and positive direction respectively. In three testers there was no good general combiner present for general combining ability effects for the trait of seed yield per plant. Table IV. In case of specific combining ability out of fifteen hybrids, the F1 crosses viz., Hybripol × Range and Star × DGL expressed highly significant results in direction of positive specific combining ability effects while the hybrids Star × Range and Hybripol × Ayub 2000 showed highly significant results in negative direction. The hybrid Hybripol × Range (16.12) was the best specific combiner. Rameeh *et al*. (2011) and Turi *et al*. (2011) were also explained both GCA and SCA significant effects for seed yield per plant in *B. napus* L.

Protein content

From table III, among the lines, only UAF 2 showed significant results for negative GCA effects. Out of three testers, Ayub 2000 and DGL exhibited significant positive and negative general combining ability effects. Table IV. Out of 15 hybrids, these crosses BA 0714 × Ayub 2000, UAF 2 × Range and Hybripol × Ayub 2000 showed significant results for positive SCA effects but the hybrids viz., UAF 2 × Ayub 2000, BA 0714 × Range and Golarchi × DGL and Star × Ayub 2000 revealed significant results in negative direction of SCA effect for the trait of oil content. The cross combination BA 0714 × Ayub 2000 (2.01) followed by UAF 2 × Range (1.82) was the best specific combiner. Huang *et al*. (2009) studied the both GCA and SCA effects for the trait number of siliqua per plant in mustard.

Oil content

From Table III, the female parents UAF 2 and Golarchi observed to be good general combiner as seen highly significant results for GCA effects in positive and negative direction. In three male parents Ayub 2000 exhibited significant results for GCA effects in positive relation. From Table IV, in case of specific combining ability out of fifteen hybrids, only 2 hybrids i.e. Star × Range and Golarchi × Range expressed highly significant results in direction of positive and negative specific combining ability effects. While the other cross combinations viz., Golarchi × DGL and Star × DGL, BA 0714 × DGL, UAF 2 × Ayub 2000 exhibited significant positive and negative SCA effects. Huang *et al*. (2009) and Turi *et al*. (2011) were also explained both GCA and SCA significant effects in *Brassica napus* L.

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