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Combining Ability and Heteroses Analysis for Seed Yield and Yield Components in *Brassica napus* L.

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Abstract
Line × tester analysis of three testers and five lines of *Brassica napus* L. were used to estimate combining ability and heterosis of plant height, number of primary branches, number of secondary branches, 1000-seed weight and seed yield per plant. Significant mean squares of treatments for yield components and seed yield indicated significant genetic variations among the genotypes including parents and their crosses. Parents Vs crosses mean square indicated, average heterosis was significant for all the traits except plant height. Line × tester mean square was significant for all the traits. High GCA to SCA ratio; indicated the prime importance of additive genetic effects for all traits except seed yield per plant. Significant positive general combining ability (GCA) and specific combining ability (SCA) effects were observed. Most of the crosses had significant positive over better parent heterosis of seed yield, indicating that these hybrids were suitable candidates for improving these traits using combination method.
Key words: Combining ability, Heteroses, Line × Tester, *Brassica napus* L.

1. Introduction

The economy of Pakistan is agro-based and majority of its people are dependent upon this sector. The significant progress in agriculture sector has been achieved in the production and improvement of some important crops such as wheat, cotton, sugarcane, rice maize. Pakistan is lucky to have an over of dozen oilseed crops, which can be grow one or the other season round the year. Despite their importance in our national economy and trade, the oilseed crops in general, are termed as "Miner/ Marginal crops". This status and approach is indirect result of neglecting the oilseed crops as well as agronomic sector. The present crisis demands much attention for the improvement of oilseed crops.

The total availability of edible oils during 2009-10 is 2.9 million tons out of which Local production stood at 0.669 million tons which accounts only 23% of total availability. The remaining 77% was made available through imports by the cost of 1.65 billion US dollars. (Anonymous, 2010-11). Rapeseed (Brassica napus L.) oil ranks third behind soybean and oil palm showing the importance of this product. Apart from direct human and animal consumption, industrial uses include the manufacture of rapeseed oi1 and convert biomass to bio energy have been developed in the recent years in world (Ofori and Becker 2008). Thus considering that the rapeseed oil, beside its use for food, feed and industrial purposes, is also used for metilester, which is important component for biodiesel production

Hybrid seed production is the main method used to increase yield of oilseed crops. As compared to conventional rape-seed cultivars the yield of hybrids rapeseeds is commonly l5% higher and round the world area under hybrids increasing day by day in China about 60% hybrids are cultivated (Fu 2007). Generally it is believed that heterosis increases with broader genetic basis (Seyis *et al.* 2006).

In rapeseed breeding for hybrid and open pollinated varieties, general and specific combining ability effects (GCA and SCA) are important indicators of the potential of inbred lines in hybrid combinations. The line × tester analysis is one of the efficient methods of evaluating large number of inbreds as well as provides information about the relative importance of GCA effects of lines and testers and also SCA effects of pairs of parental genotypes for interpreting the genetic basis of important plant traits (Mather and Jinks, 1982). Estimation of genetic parameters for yield components can be important for indirect selection for seed yield. Although combining ability studies in oilseed Brassica spp. are very little, most of these studies emphasized the predominance effect of GCA on yield and most of the yield components indicating the importance of additive gene action (McGee and Brown, 1995; Wos *et al.,* 1999; Gupta; 2006).

The present study of Line × tester involving five female lines and three male Testers is an attempt to develop Brassica hybrid with diverse genetic background for their potential in various cross combinations for different plant characters the main objective of the study is to:

i. Evaluate Lines, testers and their crosses.
ii. Estimate General combining ability of the lines and testers.
iii. Specific combining ability of the crosses for seed yield and its components.
iv. Identify the Brassica hybrid (s) for higher seed yield potential and more oil content.

2. Material and Methods

The materials for this study consisted of eight genotypes i.e. Golarchi, Star, Range, DGL, Ayub2000, Hybripol, Lagena and BA0714. These parental materials were obtained from the germplasm of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. During Rabi season of 2010-11, 15 F1 hybrids were obtained by crossing five female lines (Golarchi, Star, Range, DGL and Ayub2000) with three male lines (Hybripol, Lagena and BA0714) in line × tester fashion. After emasculation and pollinations all the racemes were covered with butter paper begs to avoid open pollination. The pollens of three male parents were collected separately during morning hours (7:00 to 9:00 AM) and pollinated each female line separately and butter paper bag was replaced after pollination. Next year 15 hybrids and eight parents were laid out in randomized complete block design (RCBD) in three replications. Each entry was sown in plot having dimension 3m × 9m. The plant to plant distance was 30cm and row to distance was 60 cm. All the agronomic practices recommended for *Brassica napus* were followed throughout growing season for raising successful experimental crop.

The mean of three replications calculated for the parents and hybrids for five characters were subjected to statistical analysis of variance according to Steel *et al.* (1997).

The 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).

Percent heterosis of F_1 over mid parent (MP) and better parent (BP) was calculated as proposed by Falconer and Mackay (1996).

$$\text{Percent Heterosis Over Mid Parent (MP)} = \frac{\text{F1} - \text{MP}}{\text{MP}} \times 100$$

$$\text{Percent Heterosis Over better Parent (BP)} = \frac{\text{F1} - \text{BP}}{\text{BP}} \times 100$$

3. Results and Discussion

3.1. Plant Height

In ANOVA (Table 1) all parents (both male and female) and crosses were notified highly significant results in both F table values (0.05-0.01) .On the other hand interaction between parent and crosses showed non significant results, also female vs. male pattern revealed highly significant results for the trait of plant height.

Table "3'' Out of five lines, female genotypes Star and Range showed highly significant GCA in positive direction while Golarchi and Ayub2000 revealed highly significant GCA effects in negative direction. Whereas in three male parents, the genotype Hybripol indicated highly significant GCA effects in positive and Lagena showed GCA in negative direction.

In case of specific combining ability, (Table 4) the hybrids (DGL × Hybripol, Range × Lagena, DGL × BA0714) were showed significant positive specific combining ability effects while the hybrids Range × Hybripol, DGL × Lagena, Ayub2000 × BA0714 indicated significant SCA effects in negative direction. Whereas the hybrid DGL × Lagena (-24.42) exhibited good specific combiner followed by DGL × BA0714 (12.57) for the trait of plant height.

In table "5" Four crosses (DGL × Hybripol, Range × Lagena, Range × BA0714 and DGL × BA0714) showed highly significant mid parent heterosis. Two crosses (Golarchi × Hybripol and DGL × Lagena) exhibited highly significant negative heterosis. All others showed non significant mid parent heterosis for plant height. Overall range of heterosis was -8.050% to 16.452%.

Non of the hybrid showed significant positive heterosis over better parent. But nine crosses showed highly significant negative heterosis. Range of the mid parent heterosis was -12.89% to 7.0592%

3.2. Number of Primary Branches per Plant

In ANOVA (table 1) all parents, crosses, Parent vs. crosses, females, males and female vs. male were highly significant at both F table values (0.05-0.01) for the trait of number of primary branches per plant.

Table "3" noticed the GCA effects for this trait, only one line Golarchi revealed highly significant result in positive direction while lines Star and Range were showed significant results in negative direction for GCA effects. In tester portion, Lagena showed significant result in positive direction and the genotypes Hybripol and BA0714 revealed significant GCA effects in negative direction for the trait primary branches per plant.

It is noticed from the table "4" that four hybrids (Star × Hybripol, DGL × Hybripol, Ayub2000 × Lagena and Galorchi × BA0714) showed highly significant specific combining ability in positive direction two crosses (Range × hybripol and Galorchi × Lagena) exhibited significant in positive direction, Two crosses (Ayub2000 × Hybripol and DGL × Lagena) showed highly significant but in negative direction two crosses exhibited significant specific combining ability in negative direction, all other hybrids were non significant for primary branches per plant

Out of fifteen crosses (Table 5) five crosses exhibited highly significant heterosis ranging from 4.346% (DGL × Lagena) to 24.36% (Ayub2000 × lagena) over mid parent one cross i.e. Golarchi × Lagena significant positive heterosis 2.166% over mid parent. Sven hybrids registered highly significant heterosis ranging from -4.58% (Star × Hybripol) to -24.6% (Range × BA0714) over mid parent. All other crosses exhibited non significant mid parent heterosis. Overall mid parent heterosis was in the range of -24.6% to 24.36%.

Highly significant better parent heterosis was observed in two crosses Ayub2000 × Lagena and Golarchi × BA0714 i.e. 9.166% and 4.17× respectively. One hybrid Golarchi × Lagena showed significant positive heterosis. Eleven crosses showed highly significant negative heterosis over better parent in the range of -3.33% to -29.4% for number of primary branches per plant.

3.3. Number of Secondary Branches per Plant

In ANOVA (table 1) all parents, crosses, male, female, crosses, interaction between parent and crosses and interaction between male and female exhibited highly significant results at both F table values (0.05-0.01 for the trait of number of secondary branches per plant.

Table "3" revealed that the lines Star and DGL were showed significant positive GCA effects while the lines Golarchi and Range expressed significant GCA effects in negative direction. Out of three testers, Hybripol and Lagena noticed significant GCA effects in positive direction while only one male genotype BA0714 exhibited significant negative GCA effect for the trait secondary branches per plant.

Specific combining ability (Table 4) was found highly significant in positive direction for four crosses (Range × Hybripol, Range × Lagena, Ayub × Lagena and DGL × BA0714), four crosses showed highly significant but in negative direction and one cross (Ayub2000 × Hybripol) showed significant but in negative direction all other crosses exhibited non significant specific combining ability for secondary branches per plant.

In table "5" Two crosses (DGL × Hybripol and DGL × BA0714) showed highly significant positive heterosis over mid parent i.e. in the range of 19.62% to 41.69%. Four hybrids registered highly significant negative heterosis in the range of -11.1% (Ayub2000 × BA0714) to -61% (Range × BA0714). Two crosses showed significant negative heterosis. All other crosses exhibited non significant mid parent heterosis.

Positive highly significant heterosis over better parent was observed only in two crosses i.e. 17.14% DGL × Hybripol and 37.40% DGL × BA0714. Eight crosses showed highly significant negative heterosis over better parent in the range of 5.46% () to 65.1% (Range × BA0714). Four crosses showed significant negative heterosis. Overall range of better parent heterosis was -65.1% to 37.40%.

3.4. 1000-seed weight

In ANOVA (table 1) all parents, female, crosses, revealed highly significant and male genotypes notified non significant results in both F table values (0.05-0.01).On the other hand interaction between parent and crosses notified significant results, also female vs. male pattern showed highly significant results for the trait of 1000-seed weight.

For the character 1000-seed weight, (Table 3) there was no female parent exhibited significant GCA effect, Whereas in male parent/tester only one genotype BA0714 indicated significant GCA effect in negative direction.

From table "5" it was noticed that only one cross (Ayub2000 × Hybripol) showed significant specific combining ability in positive direction all other crosses exhibited non significant specific combining ability for 1000-seed weight.

From fifteen crosses (Table 5) four crosses showed highly significant mid parent heterosis in the range of 19.1104% (Golarchi × Hybripol) to 41.9847% (Ayub2000 × Hybripol). Golarchi × Lagena and Star × BA0714 exhibited significant heterosis i.e. 24.9122% and 19.4244% respectively. All other crosses showed non significant mid parent heterosis for 1000-seed weight

Highly significant better parent heterosis was observed in three crosses i.e. 17.384% (Golarchi × Hybripol), 31.277% (Ayub2000 × Hybripol) and 15.359% Golarchi × Lagena however one cross Range × Hybripol exhibited highly significant negative better parent heterosis. All other crosses showed non significant better parent heterosis for 1000-seed weight.

3.5. Seed yield per Plant

In ANOVA (table 1) all parents (both male and female), crosses, interaction between parent and crosses and interaction between male vs female notified highly significant results in both F tab values (0.05-0.01) for the trait of seed yield per plant.

In this trait, (Table 3) female genotypes Golarchi and Ayub2000 showed significant positive GCA effects while the genotypes Range and DGL expressed significant GCA effects in negative direction. In male genotypes, all parents were exhibited non significant results for seed yield per plant.

Four crosses (Table 4) (Range × Hybripol, Ayub2000 × Hybripol, Galorchi × Lagena and Star × Lagena) exhibited highly significant specific combining ability in positive direction and two crosses (Galorchi × Hybripol, Star × Lagena) showed highly significant but in negative direction. One cross (DGL × Hybripol) showed significant positive combining ability and five crosses showed negative significant specific combining ability and three crosses showed non significant specific combining ability for seed yield per plant.

In table "5" Positive highly significant mid parent heterosis was observed in two crosses i.e. 110.77% (Golarchi × Lagena) and 79.437% (Star × BA0714) and Golarchi × BA0714 was found significant positive heterosis. Negative highly significant heterosis was observed in seven crosses ranging from -15.56% (Ayub2000 × BA0714) to -46.90% (Golarchi × Hybripol). DGL × Hybripol exhibited significant negative mid parent heterosis. All other hybrids were non significant for seed yield per plant.

Better parent heterosis was positively highly significant for two crosses (Golarchi × Lagena and Star × BA0714) i.e. 96.371% and 60.966% respectively. Nine crosses exhibited highly significant negative heterosis in the range of -19.14% (Ayub2000 × Hybripol) to -60.41% (Range × BA0714). All other hybrids showed non significant better parent heterosis for seed yield per plant.

Table 1. Analysis of variance for five traits of *Brassica napus* L.

SOV	d.f	PH	PBPP	SBPP	SW	SY
Replication	2	17.93	0.0371	0.063	0.3578	17.62
Treatments	22	1655.20**	6.97**	25.1**	12.18**	2288**
Parents	7	2428.95**	10.3**	11.49**	12.33**	3580**
Crosses	14	1385.04**	5.75**	32.7**	9.27**	1701**
Parents vs Crosses	1	21.2	0.61**	13.7**	50.7**	1461**
Females	4	1960.23**	15.9**	5.39**	18.9**	4043**
Males	2	2135.11**	0.86**	28.4**	4.04	3003**
F Vs M	1	7279.4**	15.7**	380**	49.5**	1639**
Error	44	54.47	0.0241	0.3477	1.9327	47.64

Table 2. Analysis of variance for combining ability

Traits	d.f.	Plant Height	Primary Branches	Secondary Branches	1000-seed weight	Seed Yield per Plant
Replication	2	0.96	0.03	0.16	0.0317	3402
Lines (L)	4	2932.8**	10.6**	53.62**	14.64**	709944**
Testers (T)	2	1328**	2.97**	16.08**	3.57	737035**
L x T	8	625.4**	4.02**	26.50**	10.78**	262098**
Error	28	64.88	0.03	0.3907	2.83	1216

Table 3. General Combining Ability effects for Parents in respect to five Characters in *Brassica napus*

Character	Plant Height	Primary Branches	Secondary Branches	1000-seed weight	Seed Yield per Plant
Golarchi	-7.82*	1.64**	-0.63**	0.722	7.79**
Star	13.2**	-0.518**	1.20**	0.522	-3.514
Range	19.7**	-1.302**	-3.49**	-0.37	-12**
DGL	0.957	0.049	3.11**	-0. 088	-4.63*
Ayub2000	-26.3**	0.127	-0.186	-0.83	12.9**
Hybripol	10.8**	-0.326**	0.59**	-0.3	-0.49
Lagena	-6.244*	0.505**	0.92**	0.772	2.96
BA0714	-4.576	-0.179**	-1.19**	-1.3*	-2.55

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

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Table 4. Specific Combining Ability effects for Hybrids

	Crosses	**Plant Height**	**Primary Branches**	**Secondary Branches**	**1000-seed weight**	**Seed Yield per Plant**
1	Golarchi × Hybripol	-9.38	-0.193	0.278	-0.49	-37**
2	Star × Hybripol	7.29	0.523**	-0.555	-0.69	-8.7*
3	Range × Hybripol	-11*	0.260*	2.67**	-1.67	16.3**
4	DGL × Hybripol	11**	1.204**	-1.45**	-0.05	8.997*
5	Ayub2000×Hybrpol	1.513	-1.77**	-0.961*	2.99*	21.2**
6	Golarchi × Lagena	4.024	0.3653*	-2.45**	1.074	48**
7	Star × Lagena	-2.96	-0.327*	0.4514	-1.26	-22**
8	Range × Lagena	12.6*	-0.272*	2.18**	0.167	-6.366
9	DGL × Lagena	-24**	-1.08**	-2.09**	1.284	-6.846
10	Ayub2000 × Lagena	10.90	1.994**	1.84**	-1.25	-12.6*
11	Golarchi × BA0714	5.356	0.559**	2.137	-0.58	-10.4*
12	Star × BA0714	-4.31	-0.175	0.1036	1.960	31.3**
13	Range × BA0714	-1.20	0.026	-4.86**	1.516	-9.87*
14	DGL × BA0714	12.7*	-0.176	3.56**	-1.23	-2.150
15	Ayub2000×BA0714	-12**	-0.220*	-0.9063	-1.66	-8.58*

Table 5. Heterosis for five traits

Sr.	Cross Name	Plant Height		Primary Branches		Secondary Branch		1000-seed weight		Seed yield per Plant	
		MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
1	Golarchi × Hybripol	-8.05**	-8.7**	0.142	-3.33**	0.835	-5.94*	19.1104**	17.384**	-46.90**	-56.58**
2	Star × Hybripol	4.46	-1.14	-4.58**	-9.28**	3.903	-5.46*	10.4338	6.7221	-24.68**	-40.38**
3	Range × Hybripol	-1.72	-7.6**	-24.3**	-29.4**	-5.96*	-15.1**	-8.5637	-16.29**	-33.27**	-39.33**
4	DGL × Hybripol	8.45**	7.05**	24.35**	2.086*	19.62**	17.14**	31.5430**	14.635	-11.22*	-25.27**
5	Ayub200 × Hybripol	-2.80	-10.91	-15.9**	-23.8**	-0.95	-4.90	41.9847**	31.277**	-9.837	-19.14**
6	Golarchi × Lagena	-3.98	-10**	2.166*	2.166*	-27.4**	-32.5**	24.9122*	15.359*	110.77**	96.371**
7	Star × Lagena	-2.32	-12**	-8.16**	-15.5**	-4.85*	-9.25**	2.21031	-1.101	-11.13	-13.75
8	Range × Lagena	7.41**	-4.80	-24.4**	-27.1**	-21.0**	-23.9**	0.09484	-2.283	-36.06**	-53.68**
9	DGL × Lagena	-12.1**	-16**	4.346**	-16.6**	-1.34	-12.38*	35.2733**	11.471	2.8334	-7.296
10	Ayub2000 × Lagena	-0.18	-2.742	24.36**	9.166**	0.529	-9.10*	3.72300	-9.721	-18.08**	-41.20**
11	Golarchi × BA0714	5.02	-9.1**	8.695**	4.166**	2.197	-5.55**	7.86686	6.6566	20.849*	4.4457
12	Star × BA0714	4.90	-12**	-8.86**	-12.7**	-2.01	-11.6	19.4244*	15.038	79.437**	60.966**
13	Range × BA0714	8.96**	-9.8**	-24.6**	-30.2**	-61.0**	-65.1**	3.48326	-5.555	-42.58**	-60.41**
14	DGL × BA0714	16.452**	2.6392	11.92**	-7.57**	41.69**	37.40**	9.54214	-4.263	9.1993	-8.403
15	Ayub2000 × BA0714	-4.884	-10**	1.659	-7.27**	-11.1**	-15.5**	-6.2096	-13.01	-15.56**	-42.27**

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

4. Conclusion

The analysis of variance for combining ability indicated highly significant male × Female interaction. The parents Golarchi, Ayub2000 (Female) were found good general combiner lines for seed yield per plant. The best hybrid on the basis of SCA effects was DGL × Hybripol for plant height, Golarchi × Lagena best for seed yield per plant. High degree of desirable heterosis over mid and better parent was observed in many hybrids for most of the characters studied. The hybrid combination DGL × Hybripol showed highest better parent heterosis for plant height, Ayub2000 × Lagena for primary branches per plant, DGL × BA0714 for secondary branches per plant, Ayub2000 × Hybripol for 1000-seed weight, Golarchi × Lagena for seed yield per plant.

The present investigation resulted in identification of higher combinations with higher value of heterosis over mid and better parent for more than one traits, cross Ayub2000 × Hybripol for 1000-seed weight, seed yield per plant, Ayub2000 × BA0714 best heterotic cross for seed yield per plant.

The study revealed that parents Golarchi, Ayub2000, Lagena, Hybripol were good general combiners for seed yield and other yield attributing traits therefore these parental lines can be utilized for developing further hybrids.

Based on SCA effects the crosses Range × Hybripol, Ayub2000 × HYbripol, Golarchi × Lagena, Star × BA0714 were found to be good for seed yield and Star × Lagena was best hybrid for oil contents. It is suggested to test these hybrids on large scale to know their potential and stability.

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