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COMBINING ABILITY OF SOME CANOLA (*Brassica napus*, L.) INBRED LINES AND THEIR HYBRIDS UNDER DIFFERENT PLANT POPULATION DENSITY.

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ABSTRACT

Two field experiments were carried out at the Experimental Station, Fac. of Agric., Mansoura Univ. during the growing seasons of 1997/98 and 1998/99.The objectives of this investigation was aimed to evaluate combining ability of some canola inbred lines and their hybrids under different plant population density. The genetic materials were the four lines of Drakkar, Fido, Serw 4 and Serw 6 as well as all possible combinations among them according to a complete diallel matting design. A split plot design with three replicates was used.

Test of significance of the mean squares for general combining ability (GCA) and specific combining ability (SCA) cleared that GCA and SCA were highly significant for most of studied traits. In addition, the magnitudes of SCA were larger than the corresponding values of GCA in most studied traits and this finding suggested that these traits were mainly controlled by dominance genes, indicating that the non-additive genetic variance played a major role in the inheritance of these traits. On the other hand, the mean squares of reciprocal effects were significant of most of cases but their values were less than the corresponding values of GCA and SCA. This indicates that maternal effect played a minor role in the expression of these traits.

For GCA effects, the parents S 30 and S 32 could be utilized in a breeding program for improving most of studied traits to pass favorable genes for improving hybrids. For SCA effects, the two combinations of P_1 X P_3 and P_2 X P_4 showed the highest positive and significant values for most of studied traits.

INTRODUCTION

Plant breeders are concerned on determination of general combining ability and specific combining ability. The relative magnitude of these two types are of great importance since they dictate the proper of breeding program that should be followed for improvement the genetic materials used. Studied of a full diallel crosses present estimates for general combining ability and specific combining ability as well as maternal effects. Many investigators studied the genetic parameters for most of yield and its components in rapeseed among them Verma *et al.* (1989) studies yield components in 7 yellow sarson (Brassica camestris ,L .) lines and their F1 hybrid . They found that the lines YSTISI and PYS 6 were the highest in GCA for all characters except for 1000-seed weight, Ramsay *et al.* (1994) evaluated crosses between 11 inbreds of *Brassica napus* L. ssp. Rapifera. They detected that both additive and non-additive gene action influenced dry matter yield and other quantitative traits. Patel *et al.* (1996) studied combining ability of yield components in 4 parental genotypes (*Brassica juncea* cultivars Pusa Bold and TM17, *B. carinata* and *B. napus*) and their 12 F_1 hybrids. Variance due to GCA and SCA were significant for all the characters, except for1000-seed weight for SCA variance. Non additive gene action appeared predominant for all characters except days to maturity, which were governed by additive gene action. *B. carinata* was the best general combiner for plant height, number of branches / plant, number of siliqua / plant and oil percentage. Parkash *et al.* (1997) crossed 6 inbred lines of toria *(Brassica campestris* L.*)* to produce their F_1 hybrids. The mean squares due to GCA and SCA were significant, indicating the presence of both additive and non-additive genetic components for oil content. Thakur and Sagwal (1997) evaluated nine diverse inbreeds of rapeseed *(Brassica napus* L.*)* and their 36 F_1 hybrids from a diallel cross for yield and its components and for oil content. Mean squares due to general and specific combining ability were significant for all the studied traits, suggesting the importance of both additive and non-additive components of variation. GSL 8809, HPN1, GSL1501 and HNS8803 were good combiners for seed yield and some of its components, as well as oil contents.

Varshney and Rao (1997) estimated the combining ability in yellow sarson (*Brassica campestris* L.) for 11 quantitative characters. Non-additive genetic variance was predominant for all characters. The parent 66-197-3 and YSIK742 were the best general combiners.The present investgation is aimed to study of gathering information on the genitic behavior of canola for yield and its components and evaluate some homozygous diploid lines as parents and their hybrids under different densities.

MATERIALS AND METHODS

The genetic material used in this investigation included four canola (*Brassica napus, L*) lines, S 30, S 32, S 33 and S 34, which refers to inbred lines of Drakkar, Fido, Serw4 and Serw6, respectively. Drakkar and Fido are French and English homozygous lines, respectively. While Serw4 is a homozygous line obtained via anther culture and Serw6 is a homozygous double haploid line obtained from natural haploid plant. All these lines were supplied by the Oil Crop Research Section, Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Giza, Egypt.

During the growing season of 1996 / 97 at El–Serw Experimental Station, A. R. C. Seeds of these lines were sown. At the flowering stage, all possible combinations among these four parental lines were made according to a complete diallel cross. Hybridization was done by hand. Bud of female plants were emasculated 2–3 days before flower opening and bagged to avoid out–crossing. Crossing was practiced 2–3 days after emasculation according to artificial pollination method. At maturity, the hybrid seed was obtained.

The seed of the six F_1 hybrids and their reciprocals in addition to selfed seed of the four parents were evaluated in 1997 / 1998 and 1998 / 1999 growing seasons at the Experimental Station, Fac. of Agric. Mansoura University and Talkha, respectively.

In each season of 1997 / 98 and 1998 / 99, the experiments were conducted at three plant population densities i.e. 42000, 63000 and 84000 plants / fed (10, 15 and 20 plants / m^2 as D_1, D_2 and D_3 respectively). In each experiment, the four parents, 6 F_1 and 6 F_1 reciprocals were grown in a split-plot design with three replications. Each plot area consists of 6 ridges 3.5

meters length and 50 cm in row width occupying an area 10.5 m^2. The distance between hills were 10, 13.3 and 20 cm apart and plants were thinned before the first watering to secure one plant per hill. Normal agricultural practices as recommended by Ministry of Agriculture and Land Reclamation were followed. In both seasons canola preceded by corn (*Zea mays L.*). Canola seeds were hand sown with the usual dry method (Afir planting) in Nov^{10th} and Nov^{15th} in 1997/98 and 1998/99 winter seasons, respectively.

The studied characters were: 1-Plant height in cm. 2- Leaf area index. 3- Number of days to 50% flowering. 4- Number of primary branches per plant. 5- Number of siliqua per plant. 6- 1000 seed weight. 7- Seed yield per plant. 8- Seed yield per feddan. 9- Straw yield per feddan. 10- Seed oil percentage

An ordinary analysis of variance was firstly performed for each separate plant population density for each season. The effect of both blocks and genotypes were assumed to be fixed. Combined analysis of the three densities was carried out according to Gomez and Gomez (1984). The expectations of mean squares for the combined analysis over the three densities in each season. General and specific combining ability estimates were obtained by employing Griffing (1956) diallel cross analysis designed as method 3 model I. a partitioning of genotypes sum of square for each density was performed.

RESULTS AND DISCUSSIONS

The analysis of variance and mean squares of the complete diallel crosses were made for three plant population densities in the two seasons of 1997/98 and 1998/99 for all studied traits and the obtained results are presented in Tables 1 and 2, respectively.

Table 1: Diallel crosses analysis and the mean squares of the F_1 and F_{1r} hybrids for all studied traits from the data obtained from 1997/98 season at three plant population densities.

S. o. V.	d.f	Den.	L A I	Days to 50% flowering	No. of. Bran. / plant	No. of siliqua / plant	1000 seed weight (g)	Seed yield / plant (g)	Seed yield (t / fed)	Oil %
GCA	3	DI	0.72*	5.43**	4.62**	3423.8**	0.033**	49.22**	0.034**	2.80**
		DII	0.42**	5.15**	3.28**	4074.6**	0.064**	30.20**	0.045**	2.18**
		DIII	1.24**	2.69	1.98**	4937.5**	0.006	13.74**	0.103**	3.20**
SCA	2	DI	0.77*	0.77	7.05**	7902.2**	0.059**	46.07**	0.092**	30.24**
		DII	1.91**	0.73	4.72**	5407.8**	0.043**	31.55**	0.131**	28.31**
		DIII	2.51**	1.40	0.76	4012.0**	0.055**	25.08**	0.170**	29.85**
RE	6	DI	0.37	3.86**	1.04*	3340.0**	0.018*	20.68*	0.004*	0.78**
		DII	0.16**	4.08**	1.28**	1785.8**	0.010	6.34*	0.004**	0.88**
		DIII	0.29*	3.62*	0.21	1672.5**	0.043**	7.86**	0.012**	0.97**
Error	22	DI	0.17	0.51	0.32	294.2	0.007	6.42	0.001	0.02
		DII	0.01	0.90	0.17	400.7	0.004	2.26	0.001	0.02
		DIII	0.11	1.04	0.25	323.4	0.004	1.72	0.002	0.02

*,** Denote significant at 0.05 and 0.01 levels of probability, respectively.

Table 2: Diallel crosses analysis and the mean squares of F_1 and F_{1r} hybrids for all studied traits from the data obtained from 1998/99 season at three plant population densities.

S. 0. V.	d.f.	Den.	L A I	Days to 50% flowering	No. of. bran. / plant	No. of siliqua / plant	1000 seed weight (g)	Seed yield / plant (g)	Seed yield (t / fed)	Oil %
GCA	3	DI	0.59**	5.52**	4.01**	2903.9**	0.051**	32.31	0.038**	4.11**
		DII	1.08**	6.19*	2.23**	2210.0**	0.060**	36.54**	0.058**	4.17**
		DIII	1.39**	4.33*	1.15*	4965.2**	0.013**	14.94**	0.049**	4.04**
SCA	2	DI	0.85**	0.37	2.60**	6419.5**	0.034**	50.21*	0.197*	35.21**
		DII	1.80**	0.19	4.51**	4837.7**	0.034**	38.18**	0.124**	32.37**
		DIII	3.87**	1.29	2.89**	4900.8**	0.045**	20.97**	0.098**	32.63**
RE	6	DI	0.13	4.70**	0.70**	5009.0**	0.026**	21.08	0.006*	1.29**
		DII	0.23**	7.55**	0.68**	2174.0**	0.012**	9.53	0.018	1.19**
		DIII	0.50**	7.53**	0.49	2926.2**	0.033**	5.64*	0.050**	1.10**
Error	22	DI	0.07	0.57	0.16	65.9	0.000	10.84	0.002	0.02
		DII	0.01	1.56	0.08	96.9	0.001	5.04	0.007	0.03
		DIII	0.09	1.32	0.27	47.8	0.001	1.64	0.001	0.01

*, ** **Denote significant at 0.05 and 0.01 levels of probability, respectively.**

Tests of significance of the mean squares general combining ability (GCA) and specific combining ability (SCA) cleared that GCA and SCA were highly significant for most of the studied traits with respect to the three plant population densities at the separate two seasons. In addition, the magnitudes of SCA were larger than the corresponding values of GCA in the cases of leaf area index (LAI), number of primary branches per plant, number of siliqua per plant, 1000 seed weight, seed yield per plant, seed and oil percentage. This finding suggests that these traits were mainly controlled by non-additive type of gene. While, the other traits appeared to mainly influence by GCA, indicating that the additive genetic variance played a major role in the inheritance of these traits. On the other hand, the mean squares of reciprocal effects were significant for most cases but their values were less than the corresponding values of GCA and SCA. This indicates that maternal effect played a minor role in the expression of these traits. The same trend was observed in the three plant population densities in most of studied traits with respect to the two seasons.

The combined analysis of the complete diallel over all densities was made and the magnitude of mean squares was obtained and the results are presented in Table 3.The results showed that, the general combining ability (GCA) mean squares were significant and highly significant in all studied traits in both seasons. While,the specific combining ability (SCA) mean squares were significant and highly significant in all studied traits in both seasons except for number of days to 50% flowering in both seasons. In addition, the magnitudes of SCA were larger than the corresponding values of GCA in the cases of leaf area index (LAI), number of primary branches per plant, number of siliqua per plant, seed yield per plant, seed yield (t/fed) and oil percentage in both seasons, and 1000 seed weight in the first season. In addition, significant reciprocal effect (R.E.) mean squares were observed in most occasions. Significant interaction effects between GCA X D for the traits plant height and number of siliqua per plant in both seasons and seed yield per plant in the first season.

Table 3: Diallel crosses analysis and the mean squares of the F_1 and F_{1r} hybrids for all studied traits from the combined data over all densities obtained from 1997/98 (Y1) and 1998/99 (Y2) seasons.

S.o. V.	D.F.	Year	L A I	Days to 50% flowering	No. of pri. bran. / plant	No. Of siliqua / plant	1000 seed weight (g)	Seed yield / plant (g)	Seed0 yield (t / fed)	Oil %
GCA	3	Y1	0.51*	4.22**	3.00**	4003.78**	0.028*	29.05**	0.042*	2.44**
		Y2	0.93**	5.22**	2.27**	2990.51**	0.037**	31.11*	0.059**	4.05**
SCA	2	Y1	1.93**	0.82	3.45**	5442.36**	0.050**	33.70**	0.009	28.91**
		Y2	1.98**	0.40	3.28**	5335.65**	0.036**	39.92*	0.167**	33.32**
R.E.	6	Y1	0.11	3.47**	0.58	2156.77**	0.019*	10.25*	0.006	0.98*
		Y2	0.18*	6.15**	0.43	3107.68**	0.019	8.43	0.008*	1.18**
GCA x D	6	Y1	1.87	9.05	6.88	8432.12**	0.075	64.11**	0.140	5.74
		Y2	2.13	10.82	5.12	7088.59**	0.087	52.68**	0.086	8.27
SCA x D	4	Y1	3.26**	2.08	9.08**	11879.64**	0.107**	69.00**	0.384**	59.49**
		Y2	4.54**	1.45	6.72**	10822.35**	0.077**	69.44**	0.252**	66.89**
R.E. x D	12	Y1	0.71**	8.09**	1.95**	4641.53**	0.052**	24.63**	0.014**	1.65**
		Y2	0.68**	13.63**	1.44**	7001.52**	0.052**	27.82**	0.066**	2.40**
Error	66	Y1	0.10	0.82	0.25	339.43	0.010	3.47	0.003	0.02
		Y2	0.06	1.15	0.17	70.20	0.003	5.84	0.003	0.02

*, ** Denote significant at 0.05 and 0.01 levels of probability, respectively.

On the other hand, significant interaction effects between SCA X D were observed for all studied traits except for number of days to 50% flowering. In addition the magnitude of interaction variance was higher for the SCA X D than the GCA X D as presented in Table 3. This indicates that the non-additive genetic variance interacts with densities with a higher degree than the additive genetic variance. Suggesting that the additive genetic additive effects are more stable over densities than the non-additive genetic variance. In addition, the interaction for the (R.E.) X D were significant in all studied traits in both seasons.Similar conclusions were reported by Patel *et al* (1996) and Parakash *et al* (1997)

The estimates of general combining ability effects (g_i) of the parental lines were obtained in 1997/98 and 1998/99 seasons for all studied traits and the results are shown in Tables 4 and 5, respectively. In addition, The estimates of general combining ability effects (gi) of the parental lines for the combined data over all densities were obtained for all studied traits and the results are shown in Table 6. Positive or negative estimates would indicate that a given inbred is much better or much poorer than the average of the group involved with it in the diallel crossing. Comparison of the GCA effects of individual parental lines exhibited that the parent S 33 has the highest positive and significant GCA effects for number of days to 50% flowering in both seasons. In addition, the parent S 30 has the highest positive and significant GCA effects for leaf area index (LAI), number of primary branches per plant, number of siliqua per plant,

Table 4: The general combining ability effect (g_i) of the four parental lines for all studied traits in 1997/98 season at three plant population densities.

Parent	Den.	L A I	Days to 50% flowering	No. of bran. / plant	No. of siliqua / plant	1000 seed weight (g)	Seed yield / plant (g)	Seed yield (t / fed)	Oil %
S 30	DI	0.58**	0.43	1.24**	39.10*	0.131*	5.12*	0.133**	- 0.74**
	DII	0.48**	0.34	1.29**	41.88*	0.163*	4.07**	0.157**	- 0.79**
	DIII	0.76*	0.63	0.96*	46.10**	0.051	2.73*	0.233**	- 1.14**
S 32	DI	0.05	- 0.38	0.01	- 14.93	- 0.051	- 0.89	- 0.071*	- 0.66**
	DII	- 0.10*	- 0.08	- 0.20	- 19.58	- 0.011	- 0.77	- 0.037	- 0.40**
	DIII	0.08	- 0.10	0.08	- 34.63*	- 0.008	- 0.85	- 0.024	- 0.24*
S 33	DI	- 0.29**	1.34*	- 1.39**	- 28.28*	- 0.068	- 2.80	- 0.007	0.44**
	DII	- 0.11*	1.23	- 0.82*	- 29.45*	- 0.147*	- 1.85	- 0.046	0.33*
	DIII	- 0.37	0.60	- 0.64	- 18.24	- 0.044	- 1.37	- 0.121**	0.46**
S 34	DI	- 0.34**	- 1.39*	0.14	4.10	- 0.013	- 1.43	- 0.055*	0.96**
	DII	- 0.26**	- 1.49*	- 0.28	7.15	- 0.004	- 1.45	- 0.074*	0.86**
	DIII	- 0.47*	- 1.12	- 0.39	6.76	0.001	- 0.51	- 0.088*	0.91**
S.E. (g_i)	DI	0.03	0.31	0.06	7.43	0.035	1.10	0.016	0.06
	DII	0.03	0.41	0.18	8.67	0.029	0.65	0.015	0.06
	DIII	0.14	0.44	0.22	7.79	0.026	0.57	0.018	0.06
S.E. (g_i- g_j)	DI	0.09	0.26	0.16	147.1	0.004	3.21	0.001	0.01
	DII	0.01	0.45	0.09	200.35	0.002	1.13	0.001	0.01
	DIII	0.06	0.52	0.13	161.7	0.002	0.86	0.001	0.01

Table 5: The general combining ability effect (g_i) of the four parental lines for all studied traits in 1998/99 season at three plant population densities.

Parent	Den.	L A I	Days to 50% flowering	No. of pri. bran. / plant	No. of siliqua / plant	1000 seed weight (g)	Seed yield / plant (g)	Seed yield (t / fed)	Oil %
S 30	DI	0.55*	- 0.33	1.45**	29.80**	0.165**	3.94	0.145**	- 0.88**
	DII	0.70**	0.00	1.10**	28.09**	0.163**	4.37*	0.174**	- 0.80**
	DIII	0.84**	- 0.20	0.74*	46.49**	0.066**	2.88*	0.154**	- 0.73**
S 32	DI	- 0.03	- 0.80	- 0.36	- 12.75*	- 0.064**	0.04	- 0.053	- 0.77**
	DII	0.05	- 1.03	- 0.31	- 11.09	- 0.008	- 0.48	- 0.101**	- 0.93**
	DIII	- 0.15	- 0.50	- 0.37	- 37.00**	- 0.012	- 0.98	- 0.110**	- 0.98**
S 33	DI	- 0.25	1.74*	- 0.79*	- 30.69**	- 0.082**	- 2.63	- 0 061*	0.40**
	DII	- 0.51**	1.75*	-0.58*	- 25.84**	- 0.135**	- 2.47	- 0.042	0.59**
	DIII	- 0.14	1.51**	- 0.42	- 13.38*	- 0.072**	- 1.19	- 0.035	0.65**
S 34	DI	- 0.27	- 0.60	- 0.32	13.64*	- 0.018	- 1.35	- 0.032	1.25**
	DII	- 0.24**	- 0.72	- 0.21	8.84	- 0.020	- 1.43	- 0.031	1.13**
	DIII	- 0.55*	- 0.82*	0.04	3.89	0.018	- 0.71	- 0.008	1.06**
S.E (g_i)	DI	0.12	0.33	0.17	3.52	0.007	1.43	0.018	0.06
	DII	0.04	0.54	0.12	4.26	0.010	0.97	0.037	0.08
	DIII	0.13	0.25	0.22	2.99	0.010	0.56	0.014	0.05
S.E (g_i- g_j)	DI	0.04	0.29	0.08	32.95	0.001	5.42	0.001	0.01
	DII	0.01	0.78	0.04	48.45	0.001	2.52	0.004	0.02
	DIII	0.05	0.66	0.14	23.90	0.001	0.82	0.001	0.01

*,** Denote significant at 0.05 and 0.01 levels of probability, respectively.

Table 6: The general combining ability effect (g_i) of the four parental lines from data combined over all densities for all studied traits in 1997/98 and 1998/99 seasons.

Parent	Year	L A I	Days to 50% flowering	No. of pri. bran. / plant	No. of siliqua / plant	1000 seed weight (g)	Seed yield / plant (g)	Seed yield (t / fed)	Oil %
S 30	Y1	0.61**	0.47	1.16**	42.36*	0.12*	3.97*	0.17**	- 0.89**
	Y2	0.70**	- 0.18	1.10**	34.79**	0.13**	3.73*	0.16**	- 0.80**
S 32	Y1	- 0.01	- 0.19	- 0.04	- 23.05	- 0.02	- 0.84	- 0.04	- 0.43**
	Y2	- 0.04	- 0.78	- 0.35	- 20.28*	- 0.03	- 0.47	- 0.09*	- 0.89**
S 33	Y1	- 0.26*	- 1.06**	- 0.95**	- 25.32*	- 0.09	- 2.01	- 0.06	0.41**
	Y2	- 0.30	- 1.67*	- 0.60*	- 23.30**	- 0.10**	- 2.10	- 0.05	0.55**
S 34	Y1	- 0.36*	- 1.33	- 0.18	6.00	- 0.01	- 1.13	- 0.07*	0.91**
	Y2	- 0.35*	- 0.71	- 0.16	8.79	- 0.01	- 1.16	- 0.02	1.15**
S.E. (g_i)	Y1	0.07	0.39	0.15	7.96	0.03	0.77	0.02	0.06**
	Y2	0.10	0.37	0.17	3.59	0.01	0.99	0.02	0.06**
S.E. (g_i-g_j)	Y1	0.05	0.41	0.125	169.72	0.01	1.74	0.01	0.01
	Y2	0.03	0.58	0.085	35.10	0.01	2.92	0.01	0.01

*, ** Denote significant at 0.05 and 0.01 levels of probability, respectively.

1000 seed weight, seed yield per plant and seed yield (t/fed) in both seasons. On the other hand, the parent S 34 has the highest positive and significant GCA effects for oil percentage. Similar conclusion were reported by Verma *et al* (1998) and Thakur and Sagual (1997)

It can be suggested that these lines could be utilized in a breeding program for improving these traits to pass favorable genes for improving hybrids.

The specific combining ability effects (S_{ij}) for all possible combinations with respect to the studied traits from each season for three plant population densities were obtained and the results are presented in Tables 7 and 8, respectively. In addition, The specific combining ability effects (S_{ij}) for all possible combinations with respect to the studied traits from combined data over all densities were obtained and the results are presented in Table 9.The results revealed that no hybrid exhibited positive and significant values in the first and second seasons for number of days to 50% flowering. This finding verified that mentioned earlier dealing with these two traits, which were mainly controlled by additive genes. However, two combinations of P_1 X P_3 and P_2 X P_4 showed the highest positive and significant values for leaf area index (LAI), number of primary branches per plant, number of siliqua per plant, seed yield per plant, seed and straw yields (t / fed) in both seasons. While, two combinations of P_1 X P_4 and P_2 X P_3 showed the highest positive and significant values for 1000 seed weight and positive and insignificant values for number of days to 50% flowering in both seasons. In addition, the best combinations for oil percentage were between P_1 X P_2 and P_3 X P_4 in both seasons Similar results were reported by Ramsay *et al* (1994) and Varshny and Rao (1997).

Table 7: Specific combining ability effects (S_{ij}) for each cross combination for all studied traits form the data obtained from the first season (1997/98) at three plant population densities.

Crosses	Den.	L A I	Days to 50% flowering	No. of pri. Bran. / plant	No. of siliqua / plant	1000 seed weight (g)	Seed yield / plant (g)	Seed yield (t / fed)	Oil %
P1 X P2	DI	- 0.24	0.16	- 1.42**	- 22.15*	- 0.036	- 2.57	- 0.163**	3.06**
	DII	-0.65**	- 0.09	- 1.23**	- 32.57*	- 0.068	- 2.49**	- 0.188**	2.95**
	DIII	- 0.87**	- 0.33	- 0.50	- 27.09*	- 0.093*	- 2.03*	- 0.192**	3.03**
P1 X P3	DI	0.51*	- 0.50	1.21**	51.17**	- 0.100*	3.85*	0.137**	- 0.79**
	DII	0.72**	- 0.37	0.82**	39.87**	- 0.052	3.04**	0.173**	- 0.73**
	DIII	0.68**	- 0.35	0.32	43.82**	- 0.039	2.80**	0.218*	- 0.77**
P1 X P4	DI	- 0.27	0.34	0.22	- 29.02**	0.135**	- 1.28	0.026	- 2.27**
	DII	- 0.08*	0.47	0.41	- 7.30	0.119**	- 0.56	0.015	- 2.22**
	DIII	0.19	0.68	0.17	- 7.73	0.132**	- 0.78	- 0.026	- 2.27**
P2 X P3	DI	- 0.27	0.34	0.22	- 29.02**	0.135**	- 1.28	0.026	- 2.27**
	DII	- 0.08*	0.47	0.41	- 7.30	0.119**	- 0.56	0.015	- 2.22**
	DIII	0.19	0.68	0.17	- 7.73	0.132**	- 0.78	- 0.026	- 2.27**
P2 X P4	DI	0.51*	- 0.50	1.21**	51.17**	- 0.100*	3.85*	0.137**	- 0.79**
	DII	0.72**	- 0.37	0.82**	39.87**	- 0.052	3.04**	0.173**	- 0.73**
	DIII	0.68**	- 0.35	0.32	43.82**	- 0.039	2.80**	0.218*	- 0.77**
P3 X P4	DI	- 0.24	0.16	- 1.42**	- 22.15*	- 0.036	- 2.57	- 0.163**	3.06**
	DII	-0.65**	- 0.09	- 1.23**	- 32.57*	- 0.068	- 2.49**	- 0.188**	2.95**
	DIII	- 0.87**	- 0.33	- 0.50	- 27.09*	- 0.093*	- 2.03*	- 0.192**	3.03**
S.E.(S_{ij})	DI	0.17	0.29	0.23	7.00	0.033	1.03	0.015	0.06
	DII	0.03	0.38	0.17	8.17	0.027	0.61	0.014	0.05
	DIII	0.14	0.42	0.20	7.34	0.024	0.54	0.017	0.06
S.E.(S_{ij} - S_{ik})	DI	0.09	0.26	0.16	147.1	0.004	3.21	0.001	0.01
	DII	0.01	0.45	0.09	200.35	0.002	1.13	0.001	0.01
	DIII	0.06	0.52	0.13	161.7	0.002	0.86	0.001	0.01

*, ** Denote significant at 0.05 and 0.01 levels of probability, respectively .

Table 8: Specific combining ability effects (S_{ij}) for each cross combination for all studied traits form the data obtained from the second season (1998/99) at three plant population densities.

Crosses	Den.	L A I	Days to 50% flowering	No. of pri. bran. / plant	No. of siliqua / plant	1000 seed weight (g)	Seed yield / plant (g)	Seed yield (t / fed)	Oil %
P1 X P2	DI	- 0.46**	- 0.32	- 0.68**	- 24.91**	- 0.021*	- 2.56	- 0.235**	3.25**
	DII	- 0.68**	- 0.25	- 0.94**	- 24.58**	- 0.061**	- 2.88*	- 0.186**	3.18**
	DIII	- 1.00**	- 0.43	- 0.62*	- 27.17**	- 0.084**	- 2.02*	- 0.092**	3.19**
P1 X P3	DI	0.46**	0.29	0.89**	46.21**	- 0.080**	4.04*	0.206**	- 0.68**
	DII	0.66**	0.08	1.15*	39.79**	- 0.046**	3.27*	0.164**	- 0.86**
	DIII	0.96**	- 0.21	0.97**	39.50**	- 0.035*	2.49**	0.181**	- 0.86**
P1 X P4	DI	0.01	0.03	- 0.22	21.30**	0.101**	- 1.49	0.030	- 2.57**
	DII	0.02	0.17	- 0.21	- 15.22**	0.107**	- 0.39	0.022	- 2.32**
	DIII	0.04	0.64	- 0.36	- 12.33**	0.119**	- 0.46	- 0.088**	- 2.33**
P2 X P3	DI	0.01	0.03	- 0.22	21.30**	0.101**	- 1.49	0.030	- 2.57**
	DII	0.02	0.17	- 0.21	- 15.22**	0.107**	- 0.39	0.022	- 2.32**
	DIII	0.04	0.64	- 0.36	- 12.33**	0.119**	- 0.46	- 0.088**	- 2.33**
P2 X P4	DI	0.46**	0.29	0.89**	46.21**	- 0.080**	4.04*	0.206**	- 0.68**
	DII	0.66**	0.08	1.15*	39.79**	- 0.046**	3.27*	0.164**	- 0.86**
	DIII	0.96**	- 0.21	0.97**	39.50**	- 0.035*	2.49**	0.181**	- 0.86**
P3 X P4	DI	- 0.46**	- 0.32	- 0.68**	- 24.91**	- 0.021*	- 2.56	- 0.235**	3.25**
	DII	- 0.68**	- 0.25	- 0.94**	- 24.58**	- 0.061**	- 2.88*	- 0.186**	3.18**
	DIII	- 1.00**	- 0.43	- 0.62*	- 27.17**	- 0.084**	2.02*	- 0.092**	3.19**
S.E.(S_{ij})	DI	0.11	0.31	0.16	3.32	0.007	1.34	0.017	0.06
	DII	0.04	0.51	0.12	4.02	0.009	0.92	0.035	0.08
	DIII	0.12	0.47	0.21	2.82	0.009	0.52	0.013	0.05
S.E.(S_{ij} - S_{ik})	DI	0.04	0.29	0.08	32.95	0.001	5.42	0.001	0.01
	DII	0.01	0.78	0.04	48.45	0.001	2.52	0.004	0.02
	DIII	0.05	0.66	0.14	23.90	0.001	0.82	0.001	0.01

*, ** Denote significant at 0.05 and 0.01 levels of probability, respectively .

Table 9: Specific combining ability effects (S_{ij}) for each cross combination for all studied traits form the combined data over all densities in the two seasons of 1997/98 (Y1) and 1998/99 (Y2).

Crosses	Year	L A I	Days to 50% flowering	No. of pri. bran. / plant	No. of siliqua / plant	1000 seed weight (g)	Seed yield / plant (g)	Seed yield (t / fed)	Oil %
P1 X P2	Y1	- 0.59**	- 0.09	- 1.05**	- 27.27*	- 0.07	- 2.36*	- 0.18**	3.01**
	Y2	- 0.71**	- 0.33	- 0.75**	- 25.55**	- 0.06**	- 2.49*	- 0.17**	3.21**
P1 X P3	Y1	0.64**	- 0.41	0.78*	44.95**	- 0.06	3.23**	0.18**	- 0.76**
	Y2	0.69**	0.05	1.00**	41.83**	- 0.05**	3.27*	0.18**	- 0.80**
P1 X P4	Y1	- 0.05	0.50	0.27	- 14.68	0.13**	- 0.87	0.01	- 2.25**
	Y2	0.02	0.28	- 0.26	- 2.08	0.11**	- 0.78	- 0.01	- 2.41**
P2 X P3	Y1	- 0.05	0.50	0.27	- 14.68	0.13**	- 0.87	0.01	- 2.25**
	Y2	0.02	0.28	- 0.26	- 2.08	0.11**	- 0.78	- 0.01	- 2.41**
P2 X P4	Y1	0.64**	- 0.41	0.78*	44.95**	- 0.06	3.23**	0.18**	- 0.76**
	Y2	0.69**	0.05	1.00**	41.83**	- 0.05**	3.27*	0.18**	- 0.80**
P3 X P4	Y1	- 0.59**	- 0.09	- 1.05**	- 27.27*	- 0.07	- 2.36*	- 0.18**	3.01**
	Y2	- 0.71**	- 0.33	- 0.75**	- 25.55**	- 0.06**	- 2.49*	- 0.17**	3.21**
S.E. (S_{ij})	Y1	0.11	0.36	0.20	7.50	0.03	0.73	0.02	0.06
	Y2	0.09	0.43	0.16	3.39	0.01	0.93	0.02	0.06
S.E. (S_{ij}-S_{ik})	Y1	0.05	0.41	0.125	169.72	0.01	1.74	0.01	0.01
	Y2	0.03	0.58	0.085	35.10	0.01	2.92	0.01	0.01

*, ** Denote significant at 0.05 and 0.01 levels of probability, respectively .

In general, the best combination for these traits involved at least one parent with high general combining ability effect. Indicating that predictions of yield of hybrids based on the general combining ability effects of the parents would generally be valid. Furthermore, in such hybrids, it would be expected that diverse gene contributing to the general combining ability of the parents are available in the hybrids and in segregating generations, it is to likely to give transgressive segregant.

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