additive and non-additive genetic variance and hence improvement in all these traits could be made through reciprocal recurrent selection or/and biparental mating as biparental mating accumulates additive and additive x additive genetic variance. Advancing segregating generations in single seed descent method as suggested by Brim (1966) with minimal selection pressure prior to F5 or F6 would also be effective for improvement of these characters.

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COMBINING ABILITY ANALYSIS OVER ENVIRONMENTS IN LINSEED

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ABSTRACT

Preponderance of additive gene effect was observed for days to flower, days to maturity, plant height, test weight, seed yield and oil yield. Additive genetic variation done was significant for primary branches, number of seeds per capsule, biological yield and seed oil content, whereas significant dominance genetic variation was seen for harvest index. However, none of the genetic variation was significant for number of capsules per plant. Both gca and sca were influenced by environments suggesting that to have unbiased estimate of gca and sca, the material may be tested over wide range of environments. The parental lines Chambal and Triveni were identified as a good general combiners for seed yield and oil content, earliness and other yield components. The cross combination LCK 88511 x Triveni exhibited high desired sca effects for seed yield, earliness, oil content and other yield contributing attributes. The additive and non-additive variance may be exploited following inter mating among the progenies within and between promising crosses in early segregating generations.

KEY WORDS : Linseed, combining ability, environmental effect, specific combining ability

Success of any crop improvement programme is mainly dependent upon the selection of parents together with the information regarding nature and magnitude of gene effect controlling quantitative traits of economic importance. The knowledge of combining ability provides a useful tool for selection of desirable parents and hybrids for further exploitation. Such information is more reliable when drawn over various environments. Linseed (*Linum usitatissimum* L.) is one of the important oil crop in India as well as in other countries of the world. However, such information is very meagre in this crop. Hence, in the present study, combining ability analysis under three different environments was undertaken.

MATERIALS AND METHODS

Ten diverse genotypes (Table 2) of linseed were selected for crossing in all possible combinations (excluding reciprocal). These 45 F1S

Table 1. Analysis of variance (mean squares) and t^2 values for different characters

Source of variation	d.f.	Mean /Squares											
		Days to flower	Days to maturity	Plant height	Primary branches/ plant	No.of caps./ plant	No.of seeds/ capsule	500-seeds weight	Seed yield/ plant	Biological yield/ plant	Harvest index	Seed oil content	Oil yield/ plant
GCA	9	553.83**	307.34**	175.70**	5.68**	1875.78	3.28**	2.67**	8.13*	35.82**	0.0039	13.32**	1.91**
SCA	44	37.28**	16.86**	20.56*	0.41	1259.11	0.81	0.21**	4.41*	18.74	0.0040*	1.68	0.77**
Environment (E)	2	1186.76**	3900.74**	3505.31**	70.23**	47309.04**	16.21**	2.86**	33.11**	1248.05**	0.12**	140.26**	3.26**
GCA x Environment	18	5.84**	24.88**	20.42**	0.21**	1536.83**	0.62**	0.07**	3.16**	12.90**	0.0046**	2.57**	0.62**
SCA x Environment	88	4.48**	5.94**	13.37**	0.34**	848.47**	0.59**	0.04**	2.03**	13.80**	0.0027**	1.49**	0.040**
Errot	324	0.96	1.21	1.15	0.12	44.20	0.09	0.01	0.18	1.06	0.0003	0.02	0.03
GCA : SCA		14.85	18.23	8.55	-	-	-	12.71	1.84	-	-	-	2.48

*, ** Significant at 5% and 1% levels, respectively.

and 10 parents were evaluated in randomised block design replicated three times in three environments, i.e. unirrigated (1 October 1994) as well as irrigated (21 October 1994) condition at the Experimental Field, R.C.A., Udaipur and irrigated (10 October 1994) condition at Plant Breeding Farm, Gujarat Agricultural University, Anand Each treatment was represented by a single row plot of 2.5m length, spaced at 25 x 10 cm. The data were recorded on randomly selected ten competitive plants for all the characters (Table 1) except for phenological traits viz, days to flower and days to maturity, and these trait were recorded on population basis. The progeny means were used for statistical analysis. The combining ability analysis was done according to Singh (1973) using method 2, model I of Griffing (1956).

RESULTS AND DISCUSSION

The analysis of variance for combining ability of the data pooled over environments (Table 1) revealed that mean squares due to general combining ability (*gca*) and specific combining ability (*sca*) were highly significant with preponderance of additive genetic variance for days to flower, days to maturity, plant height, 500-seeds weight, seed yield per plant and oil yield per plant. For primary branches per plant, number of seeds per capsule, biological yield and seed oil content, only additive genetic component of variation was significant whereas non-additive genetic component of variation was only important for harvest index. None of the genetic components of genetic variation was significant for number capsules per plant. The findings for days to flowe days to maturity, plant height, test weigl biological yield and harvest index and seed yie per plant are in agreement with Dhakar (1994) ar Singh *et al.* (1981). Badwal and Gupta (1970) als observed importance of only additive variance fo primary branches per plant. The results for seed per capsule, oil content and oil yield are i accordance with Dhakar (1994) and Dhakhore *e al.* (1987).

The environmental had a significant role in the expression of all the characters. The mean squares due to *gca* x environment and *sca* x environment interaction were highly significant for all the characters with greater magnitude of *gca* x environment interaction for days to maturity, plant height, capsules per plant, 500-seeds weight, seed yield per plant, harvest index, seed oil content and oil yield per plant suggesting that the additive variance was more variable over environments compared to non-additive variance, whereas both variances were equally variable over environments for days to flower, primary branches per plant. seeds per capsule and biological yield per plant. Shehata and Comstock (1971) as well as Dhakar (1994) also reported both additive and non-additive genetic variance variable over environments for all the above characters.

Persual of mean performance of the parents and their gca effects (Table 2) revealed that *per se* performance of the parents might give a good able 2. **Estimates of general combining ability effects and mean perormance (in parenthesis) of parents for twelve characters in linsed**

Parent	Days to flower	Days to maturity	Plant height	Primary branches/ plant	No.of caps./ plant	No.of seeds/ capsule	500-seeds weight	Seed yield/ plant	Biological yield/ plant	Harvest index	Seed oil content	Oil yield/ plant
C 1048	8.38**	4.79**	-0.98**	0.98**	8.27**	0.31**	-0.36**	0.14	0.55**	0.00	0.06*	0.07
	(85.44)	(121.67)	(46.64)	(6.39)	(110.89)	(7.84)	(3.32)	(4.81)	(18.47)	(0.26)	(41.98)	(2.01)
CK 88062	-1.23**	0.57*	1.91**	-0.27**	-3.31*	0.19**	0.09**	0.05	-0.04	0.00	-0.18**	0.00
	(66.67)	(117.67)	(49.81)	(4.06)	(92.89)	(7.74)	(4.16)	(4.80)	(16.09)	(0.30)	(41.77)	(1.98)
CK 88511	5.07**	4.09**	3.86**	0.00	-0.25	0.27**	0.17**	0.47**	0.80**	0.01**	-0.34**	0.18**
	(85.56)	(121.33)	(56.28)	(5.02)	(109.11)	(7.73)	(3.89)	(5.12)	(18.38)	(0.29)	(42.22)	(2.18)
W 28-9	-3.17**	-3.31**	-2.42**	-0.02	-11.83**	-0.36**	-0.16**	-0.89**	-1.67**	-0.02**	-0.67**	-0.41**
	(57.56)	(108.0)	(43.64)	(5.00)	(100.78)	(6.64)	(3.75)	(4.22)	(14.26)	(0.30)	(40.36)	(1.72)
CK 8605	-1.58**	-1.39**	-2.31**	0.23**	-3.98**	-0.31**	-0.20**	-0.37**	-1.11**	-0.02**	-0.53**	-0.35**
	(61.89)	(108.67)	(41.16)	(5.61)	(105.78)	(6.44)	(3.64)	(4.06)	(15.87)	(0.27)	(41.64)	(1.66)
KL 79	-2.73**	-2.01**	0.23	-0.19*	1.73	0.10	0.01	0.18	0.19	0.00	0.26**	0.09
	(59.22)	(110.67)	(52.16)	(4.87)	(148.33)	(7.71)	(4.16)	(7.55)	(21.74)	(0.35)	(43.18)	(3.26)
LC 29	-2.98**	-2.66**	-0.85**	0.14	-5.30**	0.17**	0.05**	-0.02	0.25	0.00	-0.40**	-0.03
	(58.78)	(106.00)	(45.44)	(5.16)	(130.22)	(7.80)	(4.10)	(6.58)	(17.88)	(0.37)	(41.96)	(2.77)
LC 35	0.29	0.52*	-2.25**	-0.34**	7.35**	0.27**	-0.35**	0.00	-0.58*	0.01**	-0.27**	-0.02
	(68.22)	(118.33)	(43.53)	(4.17)	(138.11)	(8.24)	(3.17)	(5.94)	(17.20)	(0.35)	(41.41)	(2.45)
Chambal	1.21**	2.20**	2.72**	-0.31**	11.47**	-0.51**	0.49**	0.63**	1.87**	0.00	1.15**	0.34**
	(68.67)	(115.33)	(51.99)	(4.57)	(137.00)	(7.58)	(4.58)	(7.57)	(20.09)	(0.38)	(45.29)	(3.42)
Triveni	-3.27**	-2.79**	0.09	-0.24**	-4.15**	0.13*	0.26**	0.18	-0.26	0.01**	0.91**	0.14**
	(58.67)	(108.33)	(48.73)	(3.83)	(117.33)	(8.08)	(4.40)	(6.77)	(17.77)	(0.39)	(45.39)	(3.08)
SE ± gi	0.16	0.17	0.17	0.05	1.05	0.05	0.02	0.07	0.16	0.003	0.022	0.03
r	0.9371*	0.9297*	0.9309*	0.9130*	0.5327	0.7221*	0.9371*	0.6251	0.7483*	0.4599	0.9573*	0.7354*

*, ** Significant at 5 and 1 % levle, respectively

indication of their *gca* effects for all the attributes except for number of capsules per plant, seed yield per plant and harvest index, which was also confirmed by positive and significant correlation coefficient between *per se* preformance and *gca* effects of parents for various characters under study. Further, *gca* effects revealed that none of the parents was good general combiner for all the traits. It also showed that parent Chambal was good or average combiner for number of capsules, test weight, seed yield, biological yield, seed oil content and oil yield, whereas the parental line Triveni was good or average combiner for earliness, seeds per capsules, test weight, harvest index, oil content and oil yield. However, none of the parent was observed to be good general combiner for earliness, dwarfness, seed yield and seed yield components traits.

Nearly one-third hybrids depicted significant and positive *sca* effect for seed yield. The cross combination LCK 88511 x Triveni (G x A) had highest *sca* effect followed by LC 1048 x Chambal (A x G) and LCK 88062 x LCK 8605 (A x P), these crosses also exhibited significant high heterobeltiosis. These three hybrids appear to be promising as they were good specific combiners at least for two yield contributing components. The crosses LC 1048 x LW 28-9, LC 1048 x RLC 35, LCK 88062 x Chambal and LCK 88511 x RLC 29 are important as they showed significant desired *sca* effects for seed yield, oil yield, earliness, short plant stature and at least for one yield contributing components.

The *sca* effects of the crosses revealed that all possible combinations between A x P, A x A, G x A and G x P could give promising segregants. The crosses involving G x A/G x P combining parents *eg.*, LC 1048 x Chambal, LCK 88062 x Chambal, LCK 88511 x LW 28-9, LCK 88511 x RLC 29, LCK 88511 x Triveni, LW 28-9, x AKL 79 and AKL 79 x RLC 35. Which involved at least one good general combiner may be exploited for isolating desirable transgressive segregants in F_2, if the additive genetic system present in the good combiner and the complementry epistatic effects in the F_1 acted in the same direction to maximise the desirable plant attributes.

Table 3. Crosses showing positive and significnat sca effcts for sed yield and dsired effects for componnt characters

Crosses	*sca* effects	*Per se* perfor-mance	Hetero-beltiosis	*gca* effects of parent	Desired *sca* effects for other characters
LC 1048 x LW 28-9	0.67*	6.96	44.69**	A x P	DM(-4.09**), pH(-2.04*), PBr(0.59*), CAPS(15.48**), HI(0.03*) HI(0.03**) and OY(0.27**)
LC 1048 x RLC 29	0.66*	7.82	18.84*	A x A	PBr(0.73**), TR(0.15*), BOY(1.86), Oil % (0.49**) and OY(0.29**)
LC 1048 x RLC 35	0.71*	7.89	32.83**	A x A	DF (-3.67**), DM(-1.92*), PH(-1.74**), SEDS (0.48**), TW (0.39**), HI (0.02*) and OY (0.29*)
LC 1048 x Chambal	1.84**	9.64	27.34**	A x G	CAPS (39.29**), HI (o.06**) and OY (0.78**)
LCK 88062 x LCK 8605	1.80**	8.15	69.79**	A x P	DF (-2.18**), CAPS (22.32**), SEEDS (0.43**), HI (0.07**) and OY (0.76**)
LCK 88062 x AKL 79	1.16**	8.43	11.66	A x A	SEEDS (0.48**), HI (0.05**) and OY (0.48**)
LCK 88062 x RIC 35	1.17**	8.25	38.89**	A x A	PBr (0.60*), CAPS (30.00**), BOY (3.20**) and OY (0.45**)
LCK 88062 x Chambal	1.17**	8.96	18.36**	A x G	DF (-4.41**), DM (-4.27**), CAPS (33.65**), TW (0.40**), BOY (3.18**), and OY (0.41**)
LCK 88511 x LW 28-9	0.88**	7.50	46.48**	G x P	DM (-3.39**), CAPS (12.23*), SEEDS (0.46*), HI (0.02*), Oil% (0.75**) and OY (0.41**)
LCK 88511 x RLC 29	1.60**	9.09	38.15**	G x A	DF (-4.86**), DM (-4.15**), PH (-2.97**), HI (0.05**) and OY (0.67**)
LCK 88511 x Triveni	3.03**	9.58	58.35**	G x A	CAPS (32.33**), TW (0.53**), BOY (3.99**), HI (0.06**) and OY (1.19**)
LW 28-9 x AKL 79	0.74**	7.07	-6.36	P x G	SEEDS (0.80**), HI(0.03**) and OY (0.32*)
LCK 8605 x Triveni	0.70**	7.20	6.35	P x A	CAPS (19.94**), BOY (2.27**)
AKL 79 x RLC 35	0.64*	7.86	4.11	G x A	DM(-1.68*), CAPS (17.54**), BOY (3.38**), +

Correlation coefficient (r) between : *sca* and *per se* performance; as well as = 0.81** *sca* and heterobeltiosis = 0.57*

** Significant at 0.05 and 0.1 % level respectively.

Notation:

(1) Days to flower (DF) (2) Days to maturity (DM) (3) Plant height (PH) (4) Primary branches (PBr) (5) Capsules/plant (CAPS) (6) Seeds/capsules (SEEDS) (7) 500-seeds wt (TW) (8) Biological yield (BOY) (9) Harvest index (HI) (10) Oil content (BOY) (11) Oil yield (OY) (12) Poor (P) (13) Average (A) (14) Good (G)

From this study parents *viz.*, Chambal and Triveni were found as superior general combiner for seed yield and/or other contributing traits and earliness as well. It is therefore, suggested that intermating of randomly selected progenies in early segregating generations (especially in F_2 and F_3) obtained by crossing these parents will release the hidden genetic variability through breakage of undesirable linkages involved in different characters. It may produce an elite population for selection of high yielding lines in advanced generations.

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