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Combining Ability Analysis in Linseed (*Linum usitatissimum* L.)

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Abstract
The breeding values of six linseed genotypes viz; LS-1, Chandni, LS-53, LS-62, LS-13 and P-250 were determined in a half diallel experiment using combining ability analysis for seed yield arid five components of seed yield. Significant General Combining Ability (GCA) effects and Specific Combining Ability (SCA) effects were noted for all traits. LS-53, Chandni and IS-1 displayed positive GCA effects for seed yield per plant. LS-53 and Chandni also showed desirable GCA effect for number of branches per plant and number of capsules per plant. Amongst the 15 crosses, 7 (LS-1 x LS-53, Chandni x P250, Chandni x LS-53, Chandni x LS-62, LS-53 x LS-13, LS-53 x P-250 and LS-53 x LS-62) involving at least one parent with good GCA effect for seed yield per plant and at least one component of yield, are expected to throw higher frequency of desirable segregants to develop high yielding linseed lines.

Introduction
Linseed (*Litwin usitatissimum* L.) is a multi-purpose oilseed crop as its seed, oil, cake and stem fibre is extensively used for various purposes. Since long, linseed seeds are used in indigenous medicines for cure of both human and animal diseases. Oil is now being extensively utilized in paints, varnish, leather, lubrication and printing industries.
Linseed breeders are ever engaged to improve genetic potential to achieve higher linseed yield. Several linseed breeders have successfully employed combining ability analysis of Griffing (Khorgade *et al*., 1993; Mishra and Rai, 1996; Nie *et al*., 1991; Singh *et al*., 1990, 1984; Yang and Bo, 1988) to determine the breeding worth ai parents and devising appropriate selection strategy in desirable crosses. However, no such study has ever been conducted in case of linseed in Punjab (Pakistan). Therefore, present study was designed to gather information on combining ability of a set of promising linseed material for further ingenious breeding endeavor to tailor high yielding linseed genotypes.

Materials and Methods
The experimental material comprised of a diallel set of F1 crosses (without reciprocals) derived from six genotype of freed viz; LS-1, Chandni, LS-53, LS-62, LS-13 and P-250. Six parents and their 15 F1 hybrids were grown in randomized complete block design with three replication curng 1996-97, at AARI, Faisalabad. Each plot consisted of five meter long two rows with 30 cm distance between row to row while plants within a row spaced 10 cm apart. The experiment was fertilized at 60:60 N:P kg ha^{-1} and irrigated three times after germination. Weeds were controlled manually. Data of individual 10 well guarded plants were recorded per plot for grain yield per plant (g), number of branches per plant, number of capsules per on, number of seeds per capsule, 1000-seeds weight (g) and plant height (cm). Mean data of 10 plants were used for analysis of variance proposed by Steel and Torrie (1980) and the estimates of combining ability were made by applying Griffing (1956) method-II (Model-2).

Results and Discussion
Mean squares ascribable to genotypes, GCA and SCA for six traits are presented in Table 1. Highly significant mean squares due to genotypes (parents and hybrids) indicated that considerable genetic diversity was present in the experimental material for six traits, GCA mean squares were significant for seed yield per plant and 1000-seeds weight and highly significant for all other traits. SCA mean squares were significant for seed yield per plant and highly significant for others.

The ratio of GCA: SCA effects obtained were >1 for seed yield per plant and plant height while <1 for other traits. Therefore, additive genetic variance was more important for seed yield per plant and plant height, whereas non-additive for others. Khorgade *et al*. (1993), Mishra and Rai (1996), Nie *et al*. (1991), Singh *et al*. (1984, 1990), Thakur and Bhateria (1991) and Yang and Bo (1988), have used relative megnitude of GCA/SCA mean squares as index of relative role of additive and non-additive variation which guides in the choice of breeding plan. Amongst the traits studied, early generation selection will be rewarding for plant height and seed yield while in later generations in case of others.
GCA effects (Table 2) were positive in case of LS-53, Chandni and LS-1 for seed yield per plant; Chandni. LS-53 and P-250 for number of branches per plant; Chandni and LS-53 for number of capsules per plant; Chandni and LS-13 for number of seeds per capsule; LS-53 and LS-13 for 1000-seeds weight and P-250 for plant height. It was observed by Kumar *et al*. (1994), Nie *et al*. (1991) and Yang and Bo (1988), that, crosses involving cultivars with high individual GCA effects produced a higher percentage of superior yielding progeny in the subsequent generations. Chandni and LS-53 with positive GCA effect for seed yield could be useful for further breeding.
LS-53 exhibited the highest array means (Table 3) for seed yield per plant and number of capsules per plant besides high value for other traits. Chandni showed the highest array mean value for number of branches per plant and number of seeds per capsule, whereas LS-13 for 1000-seeds weight. A genotype showing the heighest array mean also demonstrated the highest GCA effect as also observed by Kumar *et al*. (1994). Thus in such situation array mean values are also good indicator of breeding value of the parents.
SCA effects were positive in 12 crosses (Table 4) for seeds

Table 1: Genotypes, Gca and Sca Mean Squares of Six Agronomic Traits in Linseed

	Mean Squares			
Trait	Genotype	GCA	SCA	GCA
Seed yield per plant	1.4265**	1.5047*	1.400*	1.07
Number of branches per plant.	4.3635**	3.9222**	4.5106**	0.87
Number of capsules per plant.	2831.9872**	2572.7989**	2918.3833**	0.88
Number of seed per plant.	1.5557**	0.3827**	1.9466**	0.20
1000-seeds weight	5.1079**	4.4781**	5.3178*	0.84
Plant height.	337.9666**	834.9329**	172.3110**	4.85

* = Significance at 0.05 level of probability.
** = Significance at 0.01 level of probability.

Table 2: Estimates of General Combining Ability Effects of Six Parents for Six Agronomic Traits

Genotypes	Seed yield/ plant	Number of branches/ plant	Number of capsules/ plant	Number of seeds/ capsules	1000-seed weight	plant height
LS-1	+0.042	-0.207	-2.010	-0.039	-0.150	-0.836
Chandni	+0.166	+0.564	-11.430	+0.136	-0.215	1.197
LS-53	+0.363	+0.122	-14.130	-0.008	+0.003	-2.678
15-62	-0.306	-0.153	-7.079	-0.134	-0.285	-0.486
LS-13	-0.023	-0.590	11.058	+0.165	+0.859	-7.003
P-250	-0.241	+0.264	-5.412	-0.120	-0.212	+10.806
S.E.(gi)	±0.40	±0.50	±0.790	±0.130	±0.070	±0.430

Table 3: Arra Means of Six Linseed Varieties for Seed Yield and Yield Components

	Genotypes					
Trait	LS-1	Chandni	LS-53	LS-62	LS-13	P-250
Seed yield/plant (g)	3.60	3.77	4.07	3.19	3.52	3.32
Number of Branches/plant	5.59	6.29	6.00	5.78	5.38	6.21
Number of capsules/plant	90.92	103.65	113.38	86.07	83.91	87.57
Number of seeds/capsules	6.84	6.93	6.89	6.63	6.85	6.89
1000-seeds weight (g)	5.86	6.20	6.04	5.66	6.67	5.71
Plant height (cm)	65.67	68.08	65.92	67.38	62.63	78.53

Table 4: Estimates of Specific Combining Ability Effects of 15 Crosses for Six Agronomic traits

Crosses	Seed yield/ plant	Number of branches/ plant	Number of capsules/ plant	Number of seeds/ capsules	1000-seed weight	plant height
LS-1 x Chandni	+0.09	-0.64	+0.13	+0.17	+0.17	+0.25
LS-1 x LS-53	+1.31	+1.071	+25.81	+0.79	-0.66	+1.12
LS-1 x LS-62	+0.75	+1.05	-7.71	-0.01	-0.84	-2.20
LS-1 x LS-13	-0.12	-0.28	-0.93	-0.17	-0.23	+1.58
LS-1 x P-250	+0.40	-0.20	-28.22	-0.49	-0.45	-14.90
Chandni x LS-53	+0.20	-0.43	-72.37	-0.86	-0.35	-4.91
Chandni x LS-62	+0.25	-0.35	2.65	-0.93	+0.61	+0.96
Chandni x LS-13	+0.20	-0.56	-7.30	-0.26	-0.01	-4.91
Chandni x P-250	+0.69	+0.29	-31.78	+1.21	+2.06	+0.96
LS-53 x LS-62	+0.32	+1.42	-4.15	+0.31	+0.05	-8.30
LS-53 x LS-13	+0.36	-0.48	+9.53	-1.05	-0.10	+11.70
LS-53 x P-250	+0.49	+0.80	+5.02	+1.40	-1.02	+7.88
LS-62 x LS-13	+0.60	+0.76	+34.80	-0.34	-1.50	+7.50
LS-62 x P-250	-0.30	-0.12	+9.49	-0.09	-1.08	+2.89
LS-13 x P-250	-0.31	+2.05	+21.14	-0.15	-2.25	-1.13
S.E. (Sii)	±0.33	±0.35	±4.92	±0.13	±0.56	±3.16

yield per plant (range = 0.09 to 1.31); in 9 crosses for branches per plant (range = 0.29 to 2.05); in 10 crosses for number of capsules per plant (range = 0.13 to 72.37); in five crosses for number of seeds per capsule (range 0.17 to 1.08) and in 9 crosses for 1000-seeds were (range = 0.09 to 1.40) and in 7 crosses for plant has (range = 0.25 to 11.70).

In contrast to GCA effects, the SCA effects represent dominance and epistatic components of variation which are nonfixable in nature (Griffing, 1956; Kumar *et al*., 1994; Nie *et al*., 1991; Mishra and Rai, 1996). These investigators also provided evidence that if crosses showing high SCA effects involve both or one of the high combining parents, they could be successfully exploited for varietal improvement and expected to throw superior transgressive segregants. Amongst the 15 crosses studied, seven involving at least one parent with good GCA effect i.e. LS-1 LS-53, Chandni x P-250, LS-53 x P-250, LS-53 x LS-13, LS-53 x LS-62, Chandni x LS-62 and Chandni x LS-53 depicted positive SCA effect for seed yield and for at least one seed yield component. These crosses are expected to generate relatively higher degree of desirable segregants compared to other eight.

Combining ability analysis in the present study provided useful information on the prepotency of linseed genotypes and identified Chandni and LS-53 as useful progenators for the development of better yielding varieties.

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