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Combining Ability Analysis in Linseed (*Linum usitatissimum* L.) for Improvement of Seed Yield and its Attributes Across Environments

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Abstract

A total 36 genotypes (eight parents and their 28 hybrids developed through 8x8 set of diallel mating design (excluding reciprocal) were evaluated in randomized block design with three replications in six environments for twelve various morphological characters during rabi season of 2019-20, to estimateGCA and SCA effects. Both GCA and SCA was highly significant for all the traits. GCAx E and SCA x E were found significant for all the traits. Parent PA2 and RL15583 has been found good general combiner with high significant magnitude of GCA effects for seed yield per plant and its attributes. Hybrids RL15583 x KBA 3 (1.38), RL15582 x KBA 4 (1.07) and RL15582 x PA 2 (1.00) showed higher positive significant SCA effects for seed yield per plant and also for yield attributes indicating potential for exploiting hybrid vigour in breeding programme.

Key words : *Combining ability, gene action, seed yield, GCA x E, SCA x E, linseed,*

Introduction

Linseed (*Linum usitatissimum* L.) is an annual, autogamous diploid crop having chromosome number 2x=2n=30. It belongs to genus linum and family Linaceae, generally grown during winter season in India. It is cultivated for seed (linseed) and its fibre (Flax) since centuries.Linseed oil is best herbal source of omega-3 and omega-6 fatty acid, act as brain tonic kwon to cure the diseases like cardiovascular disease, diabetes, rheumatoid arthritis, cancer and behavioral problem. Linseed oil is the richest source of lignin, a group of plant substance known as phytoestrogen-natural anticancer agent (1).

It is most cultivated on rainfed as well as irrigated conditions in early to late planting window based on availability of irrigation resources by poor farmers on marginal land over 172.71 thousand hectares area with production of 99.07 thousand tones.The average seed yield of linseed in India is 574 Kg/ha which is comparably very low in comparison with world average seed yield that is 975 Kg/ ha. (2). The low seed yield is chiefly due to limited resources available to poor farmers along with non availability of high-yielding cultivars. So, the development of high-yielding varieties is needed to compete with other linseed growing countries. Such varieties can easily be developed through suitable hybridization and selection programmes to isolate superior segregants. The success of any hybridization programme chieflydepends on combining ability of parents used in crossing programme (3). Selections of superior segregants followed by the selection of the best ones are the basic tasks of any breeding process (4). However, the success of any hybridization programme chiefly depends on combining ability of parents used in crossing programme. Combining ability provides an important tool for selection of desirable parents and to get required information regarding the nature of gene action controlling desirable trait. Generally, plant breeders use Griffing's diallel mating design to identify desirableparents along with their specific cross combinations and to get the knowledge of genetic effects, estimates of general combining ability (GCA), specific combining ability. Isolation of parental lines of good combining ability makes the pathway easy, towards the success. The concept of combining ability plays a significant role in crop improvement, as it helps the breeder to study and compare the performance of the new lines in hybrids combination. It provides the base to select good combiners and also to understand the nature of gene action. Moreover, the exploitation of heterosis is primarily dependent on the development of high per se performing lines with good general combining ability. Keeping the above fact in mind, the present study was, therefore, undertaken with a view to estimate general and specific combiningability variances and effects to identify superior hybrids with good yield potential.

Materials and Methods

The experimental material consisted of eight diverse genotype viz., PA2, KBA3, KBA4, Padmani, RL13161, RL15582, RL15582 and Meera of linseed were crossed in all possible combinations using diallel mating design (excluding reciprocals) to obtain 28 hybrids of linseed, during rabi season of 2019-20 under six environments (early, normal and late sowing coupled with rainfed and irrigated conditions) the Agriculture Research Station,

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Table-1 : Analysis of variance for combining ability over the environments for different characters.

Source of variance	DF	Mean sum of square											
		DF	DM	PH	PBPP	SBPP	CPP	SPC	TW	OC	BYPP	SYPP	HI
Environment (E)	5	87.17**	42.05**	84.46**	0.37**	36.14**	30.04	0.17**	0.31**	0.34	8.36	0.23*	3.00
GCA	7	178.16**	233.65**	410.12**	1.87**	24.14**	2011.92**	1.22**	4.01**	26.46**	29.00**	3.79**	96.89**
SCA	28	10.58**	8.52**	22.32**	1.02**	64.63**	1922.63**	1.98**	1.27**	8.49**	118.28**	5.71**	35.23**
GCA x E	35	6.52**	9.09**	2.75	0.11**	3.25	74.41**	0.26**	0.65**	0.72**	3.94	0.22**	4.94
SCA x E	140	3.04**	3.94**	3.25	0.08**	3.31	80.76**	0.21**	0.46**	0.45**	3.44	0.36**	8.77**
Pool Error	420	1.10	1.03	2.93	0.05	4.27	34.45	0.05	0.02	0.28	3.99	0.09	4.15
^{2}g	175	11.96	5.70	11.32	0.05	4.43	-0.61	0.02	0.04	0.01	0.61	0.02	0.43
^{2}s	35	20.66	27.14	47.51	0.21	2.32	230.70	0.14	0.47	3.05	2.92	-0.16	10.82
^{2}g / ^{2}s		0.58	0.21	0.24	0.24	1.91	0.00	0.14	0.09	0.00	0.21	0.05	-0.01
GCA x E var		44.27	34.96	90.50	4.55	281.69	8811.49	9.01	5.80	38.32	533.38	26.21	145.04
SCA x E (var.)		18.96	28.22	-0.62	0.21	-3.56	139.86	0.72	2.19	1.53	-0.15	0.44	2.78
GCA x E/ SCA x E Ratio		2.3	1.2	-146.0	21.7	-79.1	63.0	12.5	2.6	25.0	-3555.9	59.6	52.2

*,** Significant at 5 and 1 percent respectively (Model I)

Table-2 : Estimation of general combining ability (GCA) of parents (pooled) for different characters in linseed.

S. No.	Characters	Parents							
		PA 2	KBA 3	KBA 4	RL13161	Padmani	RL15582	RL15583	Meera
1.	DF	3.09**	-0.21	0.64**	0.11	-2.86*	0.03	0.43**	0.33**
2.	DM	2.14**	-0.67*	-1.32*	-0.18	-2.30*	-0.40*	-0.49*	3.75**
3.	PH	4.13**	0.62**	-2.10*	0.04	-3.32*	-0.29*	-0.12	3.09**
4.	PBPP	0.27**	-0.10*	0.07**	-0.03	-0.34*	0.08	0.11**	0.05
5.	SBPP	-0.81*	0.40	-0.07	-0.84*	0.86**	-0.09*	0.67**	-0.29
6.	CPP	-6.35*	-5.81*	8.18**	-3.54*	-2.96*	-0.53*	6.36**	5.49**
7.	SPC	0.15**	0.00	-0.23*	-0.02	-0.04	0.03	0.23**	-0.12*
8.	TW	0.43**	-0.00	-0.24*	-0.11*	0.02	-0.40*	0.23**	0.08**
9.	OC	-0.70*	0.32**	1.06**	0.19**	0.56**	-0.29*	-0.20*	-0.95*
10.	BYPP	0.25	0.65**	0.70**	0.27	0.13	0.08	-0.77*	-1.31*
11.	SYPP	0.31**	-0.18*	0.04	-0.01	-0.45*	-0.09*	0.32**	0.06
12.	HI	0.70**	-1.23*	-0.47	-0.19	-1.70*	-0.53*	1.86**	1.56**

Kota, Agriculture university, Kota, (Rajasthan). These twenty eight hybrids, eight parents were evaluated in randomized block design with three replications, in a single row plot of 4 m length, maintaining crop geometry of 30 x 15 cm. All recommended agronomic practices were adopted in order to raise healthy crop. The data were recorded from five randomly selected competitive plants o from each row on twelve distinct morphological characters, except days to 50 per cent flowering, days to maturity and oil content where these observations were taken on complete plot basis. The data on plant height, primary branches per plant, secondary branches per plant, capsules per plant, seeds per capsule, oil content, 1000-seed weight, biological yield per plant, seed yield per plant and harvest index were recorded for statistical analysis. The mean value of the recordeddata was subjected to analysis of variance using the statistical analysis procedures of Panse and Sukhatme, 1985. The combining ability analysis for diallel mating design was performed according to Method-II (parents and one set of F_1's without reciprocals) proposed by (5).

Results and Discussion

The analysis of variance for combining ability, using diallel mating design in respect of 28 crosses in six environments for all the twelve characters are presented in Table 1 and combining ability effect of seed yield and its component are presented in Tables-2 and 3. The both variances due to GCA and SCA were highly significant for all the characters. These results suggested the existence of additive and non-additive gene actions for various traits in the materials under study. Similar results were earlier reported by (6,7,8). The estimate component of variance for SCA was higher than GCA for all the characters except number of secondary branches per plant, indicate predominance of non-additive gene action to control these characters. Both general and specific combining ability were important but the former played an important role in the expression of all the characters. The combining ability analysis was performed to obtain information on selection of better parents and crosses for their further use in breeding programme.The estimate of GCA effects among the parental lines for yield and its component traits to identify the best parent for subsequent hybrid development programme Table-2. The estimates of GCA effects revealed that PA2 was good general combiner for seed yield per plant, number of seeds per capsule, test weight and harvest index and RL 15583 for seed yield per plant, days to maturity, number of primary branches per plant, number of secondary branches per plant, number of capsules per plant, number of seeds per capsule, test weight and harvest index.In addition to above parents,

Table-3 : Estimation of specific combining ability (SCA) of hybrids (pooled) for different characters in linseed.

S. No.	Hybrids	Characters											
		DF	DM	PH	PBPP	SBPP	CPP	SPC	TW	OC	BYPP	SYPP	HI
1.	KBA 3 x PA 2	-1.14**	1.16**	1.03	0.08	-0.35	4.78*	0.67**	-0.11*	-1.73**	-0.86	0.18	1.77*
2.	KBA 4 x PA 2	-2.15**	-2.35**	0.41	-0.21*	-2.16**	0.83	0.63**	0.21**	0.79**	1.68*	-0.06	-1.74*
3.	RL13161 x PA 2	-0.90*	-1.94**	0.00	-0.11	-1.73*	-1.56	0.46**	0.06	0.82**	0.88	0.32**	-0.01
4.	Padmani x PA 2	-0.71	-0.99*	-0.90	-0.17*	0.52	1.72	-0.37**	0.60**	-0.95**	2.61**	0.67**	-0.11
5.	RL15582 x PA 2	0.57	0.42	-2.26**	-0.21*	2.67**	14.28**	-0.85**	0.33**	0.88**	2.43**	1.00**	1.12
6.	RL15583 x PA 2	0.06	-0.52	-1.81**	0.19*	-1.08	-3.91	-0.60**	-0.11*	0.73**	4.32**	-0.13	-4.25**
7.	Meera x PA 2	1.82**	-0.70	-1.96**	0.42**	1.39	-1.63	0.04	-0.25**	1.59**	-1.45	0.45**	3.23**
8.	KBA 4 x KBA 3	0.59	-0.88*	0.15	0.15	3.14**	-3.12	0.26**	0.78**	-0.08	2.49**	0.47**	-0.55
9.	RL13161 x KBA 3	-0.77	1.20**	-0.18	0.55**	4.59**	15.98**	0.32**	-0.09	-0.64**	9.86**	0.87**	-3.86**
10.	Padmani x KBA 3	0.03	-1.06**	-1.32*	-0.21*	5.19**	20.32**	-0.15	-0.15**	0.91**	0.61	0.98**	2.71**
11.	RL15582 x KBA 3	-0.19	-0.77*	-1.71**	-0.05	-1.35	-13.00**	-0.01	-0.57**	-0.31	0.55	-0.94**	-3.55**
12.	RL15583 x KBA 3	0.97*	-0.65	-2.05**	-0.06	-0.26	22.59**	-1.36**	0.68**	0.54**	1.52*	1.38**	2.84**
13.	Meera x KBA 3	0.18	-0.17	-1.38*	0.02	-0.67	13.24**	-0.11	0.37**	0.65**	-2.69**	-0.27*	1.21
14.	RL13161 x KBA 4	0.60	0.24	-0.24	0.16*	3.01**	7.01**	-0.17	0.39**	1.25**	0.56	0.85**	2.68**
15.	Padmani x KBA 4	-0.32	0.20	-0.30	0.75**	4.99**	-4.38*	-0.19*	0.13*	1.01**	3.83**	-0.17	-3.20**
16.	RL15582 x KBA 4	-0.70	-0.23	-1.12	-0.21**	0.10	24.03**	0.16	-0.41**	-0.35	4.39**	1.07**	0.10
17.	RL15583 x KBA 4	-0.10	0.72	-0.04	0.47**	4.15**	26.02**	-0.60**	-0.20**	-1.59**	0.14	0.88**	2.63**
18.	Meera x KBA 4	-1.06**	-1.24**	-0.66	0.01	-0.23	-2.75	0.13	0.31**	-0.52**	1.30	-0.08	-1.31
19.	Padmani x RL13161	-0.51	-0.61	-1.64*	0.03	2.62**	16.91**	-0.51**	0.25**	0.28	0.12	0.24*	0.70
20.	RL15582 x RL13161	0.55	0.46	-1.23	-0.33**	-2.43**	18.53**	-0.41**	-0.00	-3.27**	-0.62	0.43**	2.11**
21.	RL15583 x RL13161	-0.30	-0.09	0.54	0.48**	2.04**	13.07**	0.07	0.38**	0.99**	0.50	0.60**	1.40
22.	Meera x RL13161	-1.25**	-1.00**	-1.04	0.08	1.30	2.30	0.20*	0.02	0.29	1.61*	0.58**	1.05
23.	RL15582 x Padmani	-0.38	-0.25	2.68**	0.94**	-1.49	1.84	0.20*	0.21**	-0.18	2.69**	0.49**	-0.46
25.	RL15583 x Padmani	-0.28	0.25	1.13	-0.17*	1.88*	-14.62**	0.68**	0.36**	-0.40*	3.85**	-0.53**	-4.80**
26.	Meera x Padmani	-0.29	-0.88*	-2.20**	-0.01	-1.36	9.61**	0.08	-0.05	1.40**	1.19	0.40**	0.42
27.	RL15583 x RL15582	1.34**	-1.06**	2.37**	0.53**	0.47	7.03**	1.15**	0.49**	0.66**	1.26	0.73**	1.27
28.	Meera x RL15582	-3.11**	0.36	0.94	-0.06	1.58*	0.02	0.03	0.37**	0.64**	5.15**	0.38**	-3.21**

KBA3 also good general combiner for days to maturity, oil content and biological yield per plant, KBA4 for days to maturity, plant height, number of primary branches per plant, number of capsules per plant , oil content and biological yield per plant. RL13161 for oil content, Padmani for days to flowering, days to maturity, plant height, primary branches per plant and oil content, RL15582 for days to maturity and plant height and Meera for number of capsules per plant, test weight and harvest index. This result indicate the preponderance of additive and additive x additive gene effects (5,9). The high GCA effects in desirable direction for yield and its contributing traits indicated that such lines would combine well with other lines to produce superior progeny. (9) reported that the SCA effect is due to non-additive genetic proportion. The SCA effect is considered a reliable index for the identification of superior crosses. Estimates of SCA effect of the hybrids for different characters are presented in Table 3. Among the hybrids, RL15583 x KBA3, showed highest significant SCA effects in positive direction for seed yield per plant followed by RL15582 x KBA 4 and RL15582 x PA2.These hybrids also exhibited significant positive SCA effects for plant height, number of capsules per plant and biological yield per plant, indicating potential for exploiting hybrid vigour in breeding programme. The cross combinations, KBA4 x PA2 for days to 50% flowering, days to maturity, number of seeds per capsule, test weight and oil content; RL15583 x KBA3, RL15582 x KBA4 and RL15582 x PA2 for plant height, number of capsules per plant and biological yield per plant; RL15582 x Padmani, Padmani x KBA4 and RL13161 x KBA3 for Number of primary branches per plant;Padmani x KBA3, Padmani x KBA4 and RL13161 x KBA3 for Number of secondary branches per plant; RL15583 x KBA 4, RL15582 x KBA 4 and RL15583 x KBA3 for number of capsules perplant; RL15583 x RL15582, RL15583 x Padmani and KBA 3 x PA 2 for number of seeds per capsule; KBA 4 x KBA 3, RL15583 x KBA 3 and Padmani x PA2 for Test weight; Meera x PA2, Meera x Padmani and RL13161 x KBA4 for Oil content; RL13161 x KBA 3, Meera x RL15582 and RL15582 x KBA 4 for biological yield per plant; Meera x PA 2, RL15583 x KBA3 and Padmani x KBA3 for harvest index were the good specific combinations. Similar finding for identification of superior inbred lines and hybrids based on GCA and SCA effects for seed yield and its components in linseed by (8,10,11).

Conclusions

The hybrid RL15583 x KBA3 was the best specific combination for seed yield per plant followed by TL11 RL15582 x KBA4 and RL15582 x PA2. These hybrids also showed significant positive SCA effects for plant height, number of capsules per plant and biological yield per plant, indicating potential for exploiting hybrid vigour in breeding programme.

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