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Raj Shekhar
Department of Genetic and Plant Breeding, N.D. University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

Narendra Pratap
Department of Genetic and Plant Breeding, N.D. University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

Rudra Pratap Singh
Department of Entomology, N.D. University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

Archana Singh
Department of Horticulture, Uday Pratap Autonomus College, Varanasi, Uttar Pradesh, India

MP Chauhan
Department of Genetic and Plant Breeding, N.D. University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

RK Vishnoi
Department of Biotechnology, CCSPG College, Saifai, Etawah, Uttar Pradesh, India

Correspondence
Raj Shekhar
Department of Genetic and Plant Breeding, N.D. University of Agriculture and Technology, Kumarganj, Ayodhya, India

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Combining ability analysis in Linseed (*Linum usitassimum* L.)

Raj Shekhar, Narendra Pratap, Rudra Pratap Singh, Archana Singh, MP Chauhan and RK Vishnoi

Abstract
Combining ability analysis of 10x10 diallel (excluding reciprocal) set of 45 crosses in linseed were done for yield and its contributing characters during *Rabi* 2010-11 at Research Farm of Department of Genetic and Plant Breeding, Narendra Deva University of Agriculture & Technology, Narendra Nagar, Kumarganj, Ayodhya (UP) India. ANOVA for combining ability revealed the preponderance of additive gene effects for all the traits. On the basis of good gca effects for seed yield and other characters, Nagarkot was found good general combiner for plant height, number of secondary branches/plant, number of capsules/plant, number of seed/capsule, seed yield/plant, and harvest index. PKDL-62 was found good general combiner for plant height, number of secondary branches/plant, 1000-seed weight, seed yield/plant, biological yield/plant, harvest index, and oil content. PKDL-52 was found good general combiner for plant height, number of secondary branches/plant, 1000-seed weight, seed yield/plant, biological yield/plant, harvest index. On the basis of sca effects and *perse* performance following promising crosses Nagarkot x Shurbhi, Shurbhi x NDL-2004-05, PKDL x Chambal, T-397 x Shekhar and T-397 x Chambal were found suitable for seed yield improvement.

Keywords: combining ability, yield and linseed

Introduction
Linseed (2n=30) is one of the most important self-pollinated crop of the India. It is communally known as '*Alsi'* or '*Tisi'* and belongs to genus Linum of family *Linaceae*. The genus Linum is one of the 9 genera, comprising over 200 species which exhibit diversity in karyotypic, morphological and biochemical characters and is distributed throughout the world. It is under cultivated since prehistoric times in the world by human being for food, fiber, industrial, medicinal and value addition. India, Canada, USA, UK, Germany, Ukraine and Russia are important linseed producing counties in the world. Combining ability analysis provides guidelines for the assessment of relative breeding potential of material, which can be utilized in pursuing systematic breeding. The present experiment was carried out for future breeding an objective to study the combining ability and gene effects involving promising cultivar of divers origin for seed yield and related traits that may lead to the development of superior varieties of Linseed.

Materials and Methods
The experimental material consisted of ten varieties viz., Nagarkot, Padmini, T-397, Shekhar, Surabhi, PKDL-62, PKDL-52, NDL-2004-05, Chambal and Shikha of linseed, based on variation available in genetic material for various characters and forty five crosses and their parents were grown in a randomize block design with three replications at Research Farm of Department of Genetic and Plant Breeding, Narendra Deva University of Agriculture & Technology, Narendra Nagar Kumarganj, Ayodhya (UP) India. The entries were sown in a two row of 5 meter length with inter row spacing of 45 cm apart with plant to plant distance of 15cm. The Recommended agronomic practices were adopted in orders to raise a good experiment. Observations were recorded on 10 randomly selected plants in each replication for days to flowering, days to maturity, plant height, number of secondary branches/plant,

number of capsules/plant, number of seeds/capsule, 1000-seed weight, seed yield/plant, biological yield/plant, harvest index and oil content. Combining ability analysis was carried out according to method 2, model 2 of Griffing (1956 b) [2].

Result and Discussion

The study of combining ability helps in selection of best combiners and provides opportunity for the use of these combiners in hybridization programme. General combining ability (GCA) is primarily a function of additive gene action and additive x additive gene interaction, whereas specific combining ability (SCA) is due to non-additive gene interaction. General combining ability (GCA) and sca effects determine the potential of parent/cross for mobilizing them in an efficient breeding programme. The analysis of variance (Table-1) for combining ability revealed that treatment, parents and crosses in diallel analysis revealed that sufficient variability having in the experimental materials for all the characters except number of seeds/capsule and 1000-seed weight for sca.

General combining ability (GCA)

The General combining ability (GCA) effects of parent are presented in Table-2. While considering gca effect of the parent was found that none of the parent was found as a good general combiner for all the ten characters. However Nagarkot, Padmini, PKDL-62 and PKDL-52 were found good general combiner for Days to 50% flowering. Nagarkot, Surabhi and PKDL-62 were found good general combiner for days to maturity. Nagarkot, PKDL-62 and PKDL-52 were found good general combiner for plant height. Nagarkot, PKDL-62 and PKDL-52 were found good general combiner for number of secondary branches/plant. Shekhar, were found good general combiner for number of seeds/capsule. Padmini, Shekhar, PKDL-62 and Chambal were found good general combiner for 1000-seed weight. Nagarkot, Shekhar and PKDL-52 were found good general combiner for seed yield/plant. Nagarkot, Shekhar, PKDL-62 and PKDL-52 were found good general combiner for biological yield/plant. Shekhar, and NDL-2004-05 were found good general combiner for harvest index. Padmini, T-397, Shekhar, PKDL-62 and Chambal were found good general combiner for oil content. On the basis of overall performance, Nagarkot, Shekhar, PKDL-62, PKDL-52, NDL-2004-05 and Chambal were identified as desirable general combiners for most of the characters. These parents showed both additive and non-additive type of gene action involving different combinations of high and low general combiners. Similar result was also reported by Chandrashekhar *et al.* 1998 and Singh *et al.* 2008 [6].

Specific combining ability (SCA)

Analysis of specific combining ability is important parameter for judging the specific combination for exploiting it through heterosis breeding program. It is assisted with interaction effects, which may be due to dominance and epistasis components of genetic variation that are non-fixable in nature. The maximum merit of significant and positive sca effects in desirable direction are presented in Table-3. The Nagarkot x Surbhi (4.36) was best performing cross combination which exhibited positive and significant sca effects for seed yield/plant followed by Surbhi x NDL-04-05 (2.55), PKDL-62 x Chambal (2.42), T-397 x Shekhar (2.20) and T-397 x Chambal (2.17). Out of forty five cross fifteen promising cross having significant sca effect for days to 50% flowering, sixteen cross for days to maturity, eleven cross for plant height, eighteen cross for number of secondary branches/plant, one cross for number of capsule/plant, six cross for number of seeds/capsule, twenty one cross for 1000-seed weight, twenty one cross for seed yield/plant, seventeen cross for biological yield/plant, twenty five cross for harvest index and twenty five cross for oil content.

Since sca effect of the cross is an estimated for making selection of best cross combinations, high specific combining ability denotes undoubtedly a high heterotic response, this however, dose not mean high performance of the hybrid as well as. The above finding less more closely in agreement with the result of earlier reports (Mishra and Rai, 1996, Ratanparkhi *et al.*, Patel *et al*. 2000, Mukul *et al.* 2000, Chimurka *et al.* 2001, Swarnkar, 2003 and Singh *et al*. 2008.) [3, 5, 4, 1, 6]

Table 1: Analysis of variance for 11 quantitative characters in linseed

Source of variance	df	Day of 50% flowering	Day to maturity	Plant height (cm)	Number of secondary branches /plant	Number of capsules/ plant	Number of seeds/ capsule	1000 seed weight (g)	Seed yield/ plant (g)	Biological yield/ plant (g)	Harvest index (%)	Oil content (%)
GCA	9	64.18**	207.41**	414.19**	300.08**	7653.81**	3.55**	7.36**	3.81**	94.08**	9.73**	2.48**
SCA	45	5.13**	7.39**	7.86**	30.46**	888.05**	0.31	0.76	3.55**	15.89**	8.37**	1.31
Error	108	0.49	0.80	1.09	1.03	36.86	0.35	0.01	0.40	0.98	0.37	0.01

*, ** significant at 5% and 1% level, respectively

Table 2: Estimates of general combining ability (GCA) effect for 11 quantitative characters in linseed

Parent	Day of 50% flowering	Day to maturity	Plant height (cm)	Number of secondary branches /plant	Number of capsules/ plant	Number of seeds/ capsule	1000 seed weight (g)	Seed yield/plant (g)	Biological yield/plant (g)	Harvest index (%)	Oil content (%)
Nagarkot	5.11**	7.69**	14.10**	8.08**	55.35	0.66	-0.17**	1.23**	3.72**	0.30	-0.21**
Padmini	-1.81**	-4.87**	-6.03**	-3.11**	-13.59	-0.55	0.29**	-0.41	-1.60	0.33	0.04**
T-397	-1.03	-2.89**	1.15	-4.02**	-14.30	-0.04	-0.94**	-0.58	-2.47*	0.42	0.97**
Shekhar	-0.14	0.49	-3.19**	-3.52**	12.87	0.73*	0.86**	1.22**	2.72**	1.03**	0.24**
Surbhi	-0.19	0.83	-4.57**	-1.39	-27.68	-0.26	-0.59**	-1.48**	-3.86	-1.08**	-0.04**
PKDL-62	1.90**	3.19**	2.30*	8.03**	-0.41	-0.97**	1.59**	0.72	2.11*	0.24	0.26**
PKDL-52	1.53**	4.24**	4.02**	4.83**	29.31	-0.30	-0.02**	0.89*	2.67**	0.22	-0.54**
NDL-04-05	-1.86**	-4.73**	-3.42**	-3.19**	-14.10	0.40	-0.29**	0.19	-0.18	0.74*	-0.28**
Chambal	-2.61**	-3.73	-2.66*	-4.48**	-12.57	0.37	0.17**	0.06	0.61	-0.20	0.15**
Shikha	-1.17	-0.039	-1.70	-1.23	-20.88	-0.05	-0.89**	-1.82**	-3.72**	-2.00**	-0.60**
SE (gi)	0.04	0.06	0.08	0.08	2.76	0.03	0.0007	0.03	0.07	0.03	0.0009
SE (gi-gj)	0.08	0.13	0.18	0.17	6.14	0.06	0.002	0.07	0.16	0.06	0.002

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

Table 3: Estimates of specific combining ability (GCA) effect for 11 quantitative characters in linseed

Parent	Day of 50% flowering	Day to maturity	Plant height (cm)	Number of secondary branches /plant	Number of capsules/plant	Number of seeds/ capsule	1000 seed weight (g)	Seed yield/plant (g)	Biological yield/plant (g)	Harvest index (%)	Oil content (%)
Nagarkot x Padmini	4.12**	8.69**	1.75	4.52**	13.74	0.21	-0.30**	-1.11**	-0.64	-2.52**	-0.18**
Nagarkot x T-397	0.01	0.72	7.28**	-2.77**	27.64	-0.04	0.05**	0.80**	1.73	0.62	-0.03**
Nagarkot x Shekhar	-4.82**	-5.01**	-4.48**	-0.07	12.35	0.00	0.40**	-0.63	-3.69**	1.19**	-10.03**
Nagarkot x Surbhi	-3.49**	0.65	2.47**	4.40**	7.96	0.46	-0.24**	4.36**	7.25**	5.02**	0.34**
Nagarkot x PKDL-62	2.07**	-3.37**	5.93**	-0.62	8.96	0.09	1.31**	-0.87**	-1.35	-1.08**	-0.39**
Nagarkot x PKDL-52	-1.55**	-1.76**	1.45	-2.28**	-0.04	0.15	1.30**	-1.70**	0.59	-4.39**	1.66**
Nagarkot x NDL-04-05	1.84**	1.55**	-1.85	-3.40**	5.52	-0.01	-0.45**	0.90**	-1.34**	3.30**	-1.22**
Nagarkot x Chambal	-4.07**	-0.96	2.91**	1.03	19.72	-0.65**	-1.05**	0.41	-2.35**	2.77**	0.94**
Nagarkot x Shikha	-2.52**	-4.78**	-1.00	0.38	22.30	-0.10	1.66**	1.96**	4.47**	1.81**	-1.51**
Padmini x T-397	-1.08**	-2.40**	-0.15	4.57**	4.58	0.17	0.78**	0.63	3.16**	-0.74	0.60**
Padmini x Shekhar	0.09	-3.12**	1.34	7.00**	-6.66	0.01	-0.16**	1.41**	2.07**	1.79**	0.76**
Padmini x Surbhi	-0.58	0.55	2.07**	-1.34	19.89	0.50	0.23**	1.47**	5.83**	-0.20	1.29**
Padmini x PKDL-62	-1.67**	-0.15	-1.81	-1.49	24.62	0.18	-0.59**	0.68	-0.94	1.47**	-1.60**
Padmini x PKDL-52	-0.30	-0.87	-1.98**	-2.62**	-41.30	-0.49	0.44**	-1.72**	-4.04**	-1.31**	-1.49**
Padmini x NDL-04-05	-0.91**	0.10	-0.78	-5.27**	-5.62	-0.40	0.80**	0.00	2.38**	-2.12**	-0.34**
Padmini x Chambal	0.84**	-1.06	0.07	-4.98**	9.98	0.84**	-0.17**	1.16**	-0.43	3.34**	0.71**
Padmini x Shikha	0.40	-2.23**	-0.04	-7.43**	-1.64	-0.14	-0.24**	-0.41	-1.25	-0.11	-0.81**
T-397 x Shekhar	-0.68	-1.09	0.35	4.64**	25.99	0.63**	-0.11**	2.20**	4.36**	2.01**	0.73**
T-397 x Surbhi	1.65**	0.58	-1.90	-0.10	16.54	-0.12	-0.17**	-0.72**	1.30	-3.03**	-2.92**
T-397 x PKDL-62	0.55	-1.78**	-2.69**	-6.38**	-44.73	-0.41	-0.75**	-3.95**	-8.66**	-4.09**	-0.20**
T-397 x PKDL-52	0.93**	-1.84**	-1.91	-6.44**	-24.25	-0.55	-0.89**	1.27**	1.00	2.55**	1.27**
T-397 x NDL-04-05	-0.02	-1.87**	3.07**	2.44**	13.09	-0.91**	-0.33**	-0.52	-2.38**	0.91**	1.03**
T-397 x Chambal	-0.27	0.97	-0.62	1.93**	15.36	-0.08	0.86**	2.17**	4.37**	2.05**	-1.05**
T-397 x Shikha	-1.38**	0.87	-0.57	1.54	-30.13	0.54	-0.40**	-1.81**	-2.08**	-3.79**	1.00**
Shekhar x Surbhi	-1.52**	1.19	1.90	10.34**	39.58	-0.28	0.82**	-0.58	-2.49**	0.90**	0.22**
Shekhar x PKDL-62	-0.96**	1.83**	-1.39	-3.35**	35.50	-0.10	-0.55**	0.13	-2.26**	1.91**	0.87**
Shekhar x PKDL-52	-0.24	2.77**	-2.11**	-12.21**	-1.62	0.96**	0.27**	0.88**	-1.19	2.97**	0.82**
Shekhar x NDL-04-05	4.15**	-1.26	2.76**	-8.92**	31.73	-0.54	0.38**	1.62**	4.09**	0.61	0.12**
Shekhar x Chambal	-0.44	-1.42	-0.87	-4.24**	-99.60**	0.16	0.01**	-3.38**	-2.12**	-7.12**	-2.59**
Shekhar x Shikha	-0.54	0.41	0.58	1.98**	-23.43	0.11	0.68**	-0.25	-1.30	0.96**	-0.70**
Surbhi x PKDL-62	-0.29	-3.51	-1.69	-1.55**	-37.22	0.21	0.12**	-1.68**	-1.68	-2.98**	0.84**
Surbhi x PKDL-52	1.09**	-0.56	-3.95**	-0.88	-22.87	-0.13	-0.49**	-1.88**	-7.01**	1.08**	-1.43**
Surbhi x NDL-04-05	-2.52**	-1.59**	-0.52	-1.99**	0.48	0.97**	1.79**	2.55**	7.41**	0.92**	-0.10**
Surbhi x Chambal	-2.77	-1.76**	-0.65	-3.04**	10.88	0.61	-0.05**	1.05**	2.46**	0.99**	0.59**
Surbhi x Shikha	1.79**	0.08	0.73	0.05	-26.95	-0.31	-0.54**	-1.78**	-3.52**	-3.06**	-0.94**
PKDL-62 x PKDL-52	-0.35	0.08	1.28	2.57**	-4.08	0.45	-0.64**	1.85**	1.55	3.09**	0.23**
PKDL-62 x NDL-04-05	-0.62	2.05**	1.68	6.59**	-14.92	0.95**	1.33**	1.82**	1.94**	2.84**	1.05**

PKDL-62 x Chambal	-2.87**	0.88	3.43**	6.74**	9.60	-0.75**	1.99**	2.42**	3.96**	2.71**	-1.72**
PKDL-62 x Shikha	1.35**	-0.29	0.80	7.29**	35.25	-0.60	-0.09**	1.74**	1.38	3.77**	1.50**
PKDL-52 x NDL-04-05	-4.24**	-1.01	2.04**	10.00**	65.21	0.41	-0.18**	2.01**	4.98**	0.90**	-1.60**
PKDL-52 x Chambal	-0.49	-4.27**	2.50**	9.81**	37.48	-0.82**	0.85**	0.06	-2.30**	1.90**	0.04**
PKDL-52 x Shikha	-1.60**	-1.34	5.45**	9.16**	13.19	-1.14**	-0.92**	-1.67**	-1.15	-3.57**	0.21**
NDL-04-05x Chambal	-0.10	-0.20	-3.48**	2.90**	-12.83	0.48	-0.57**	0.41	2.18**	-0.80**	0.23**
NDL-04-05 x Shikha	0.12	-2.37**	-0.10	2.71**	-9.65	-0.10	-0.72**	-0.76**	1.13	-2.88**	0.54**
Chambal x Shikha	-0.46	0.46	-0.35	0.94	12.94	0.53	0.58**	0.99**	2.81**	0.47	1.73**
SE (Sij)	0.42	0.68	0.93	0.88	31.27	0.30	0.02	0.34	0.83	0.32	0.01
SE (Sij-Sjk)	0.90	1.46	2.00	1.89	67.57	0.65	0.008	0.73	1.79	0.68	0.02

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

Conclusion

Based on the above discussion combining ability analysis revealed that Nagarkot, Shekhar, PKDL-62 and PKDL-52 were emerged as good general combiner for yield and its important contributors. The cross Nagarkot x Surbhi was identified as most promising cross for yield and components based on *sca* effects.

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