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Estimating gene action and combining ability analysis for yield and yield attributing traits in linseed (*Linum usitatissimum* L.)

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Abstract

Aim: The aim of the study was to estimate gene action, identify and select superior parents and best hybrid combinations on the basis of estimates of general and specific combining abilities for yield, its related traits in linseed.

Methodology: Twenty eight offspring were synthesized by crossing eight diverse parents in a diallel scheme excluding reciprocals during *rabi* 2017-18. These 28 crosses along with eight parents and one national check T-397 were sown in *rabi* 2018-19 in randomized block design with three replication.

Results: Difference among genotypes were highly significant for most of the characters under study. Estimates of variance due to general combining ability (gca) and specific combining ability (sca) and their ratio revealed that both additive and non-additive gene effects were important for different characters studied. Four parents *viz.,* Neelam, Divya, Surbhi and RLC-171 showed highly significant positive general combining ability effects. Divya showed highly significant positive general combining ability effect and observed to be good general combiner for seed yield per plant. The specific combining ability (sca) effects for seed yield per plant varied between -1.11 (NL-260 X Surbhi) and 2.32 (Divya x RLC-171). Sixteen crosses showed positive sca in which ten crosses showed highly significant and positive sca effect. While the cross combination Divya x RLC-171 exhibited positive and significant sca effect for maximum characters under study.

Interpretation: These crosses may be used in developing high yielding variety by selecting transgressive segregants.

Key words: Gene action, Combining ability, Linseed, Yield

2017-18 → Eight parental lines of linseed crossed in half diallel manner to produce F_1 seeds

2018-19 → 28 F1 along with eight parental lines and one check variety were evaluated at ZRS, Chianki

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Data recorded and analyzed statistically

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Variance due to *gca* and *sca* and their ratio revealed that both additive and non-additive gene effects were important for different characters. Also *gca* and *sca* effects were calculated for parents and their offspring respectively.

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Identified four parents as best general combiners namely, Neelam, Divya, Surbhi and RLC-171 and three best crosses viz. Divya x RLC-171, NL-260 x Divya, Surbhi x RLC-171 as best specific combiners for seed yield and its attributing traits.

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Introduction

Linseed (*Linum usitatissimum* L.) is second important *rabi* oil seed crop of India after rapeseed-mustard. Linseed oil is non-edible but plant biomass have some commercial values. It has been proved for medicinal importance of grain and in india several dishes like *laddu, pitha, tisi (alsi) ki roti* etc. are prepared Therefore, linseed is grown for both seed as well as for fiber extraction for industrial purposes. It occupies an important position for technical grade vegetable oil. Fiber yielding property of linseed stalk is an additional advantage of this crop. Tolerance to biotic and abiotic stresses is an important feature of this crop. This property of linseed helps for wider adaptability and survival of crop in climate resilient conditions. It may be grown in a wider range of tropical, sub-tropical and temperate climatic conditions of India and abroad. The grain have nutrition importance due to some extra ordinary bio-components in the constituents of seeds. Therefore, incorporation of linseed grain in food and in food products within a certain limit has been increasing its health importance for human beings. Due to high content of essential omega-3 fatty acid, alpha-linolenic acid, edible dietary fibre and natural phenolic antioxidants (Singh and Marker, 2006), it is rated as future crop for human health besides its commercial importance as popular in the world. Range of bio-constituents of linseed grain varies on the basis of cultivar and growing conditions with the values ranging from 40-50% of oil, 23-34% of protein, 4% of ash, 5% of mucilage, and 0.9 -3.0% lignan precursors (Muir and Westcott, 2003).

India ranks is third in area and fourth in production after Canada, Russia and China. In the world scenario, linseed crop occupies an area of 2.572 million ha yielding about 2.062 million tons having an average productivity of 802 kg ha^{-1}. The production of this crop, *i.e.,* 0.173 million tons is realized from an area 0.326 million ha with low productivity of 545 kg ha^{-1} in national arena. The major part of linseed growing area lies in MP, Chhattisgarh, UP, Maharastra, Bihar, Odisha, Jharkhand, Karnataka and Assam occupying more than 97 % of total area of India.

The present productivity level in India is still very low (545 kg ha^{-1}) as compared to the production potential of crop is up to 2000 kg ha^{-1}. Therefore, a chance of big opportunity existed in this crop for mining of gene pool to develop a high potential genotype. Hence, in order to realize this gap appropriate suitable breeding techniques adopted and open a new vista for the breeder. Considering the facts available for this crop, this investigation was started. Development of linseed varieties with high yield potential combines with good quality attributes and oil content could help sustaining the future demand of the country. Information on genetic behavior and type of gene action desired traits is a basic principle to design an appropriate breeding procedure for genetic improvement. It will also help in the selection of parents for hybridization programs. Combining ability is an important tool for selecting suitable parents for hybridization and understanding the inheritance of quantitative traits as well as identifying the promising cross combinations for further use of genotypes in breeding. Therefore, the present experiment was conducted to study the combining ability of linseed genotypes for yield and its attributing characters.

Materials and Methods

The experiment was conducted at Zonal Research Station (Birsa Agricultural University), Chianki, Palamau-822102 (Jharkhand), India. A crossing programme was started during 2017-18 with eight parents' *viz.*, NL-260, Neelam, Divya, Surbhi, Shekhar, BAU-13-01, RLC-171 and LC-185 having desirable characters. Crosses were made using Diallel biometric design Griffing's Method- II (Model-I) and obtained 28 F_1 offspring. These 28 F_1s along with eight parents, and one check (T-397) constituted the total experimental material for evaluating genotypes to find out the combining ability and gene action in linseed. Field trial was laid out in a randomized block design with three replications during *rab*i 2018-19 in upland ecology with limited irrigation facility. The soil of the experimental plots was loamy with pH range 6.5 to 7.0, rich in organic matter content and good water holding capacity. Recommended package of practices were followed to raise the normal crops. The seeds of parents and F_1s were sown by hand dibbling method in 2 rows of 3 m length with inter and intra row spacing of 30 cm and 10 cm, respectively. Crops were harvested at physiological maturity stage and drying, threshing winnowing etc., operation was carried separately and desired data were recorded accordingly. Ten randomly selected competitive plants were selected for recording observation. Nine quantitative traits namely, days to flowering, days to maturity, plant height, technical height, number of branches per plant, number of capsule per plant, capsule diameter, number of seeds per capsule, 1000-seed weight and seed yield per plant were taken under consideration for the evaluation of genotypes to better compare with check as well as parental lines. Mean data of all characters were analyzed for studying the combining ability and gene action as suggested by Griffings (1956).

Results and Discussion

The analyzed data showed significant effect for all the characters under study. The analysis of variance for combining ability and estimation of variance components of the present study is presented in Table 1. The mean squares of general combining ability (GCA) were highly significant for all the characters. The estimates of mean square due to specific combining ability (SCA) were highly significant, except for days to maturity where it was non-significant. This indicated that both additive as well as non-additive genetic components were involved in determining the inheritance of character. Variances due to general combining ability and specific combining ability were highly significant for all the traits under study indicating importance of both additive and non-additive gene action for the inheritance of all the studied characters. Earlier Patil and Chopde (1981), Banerjee and Cole (2009), Kalia *et al.* (2011) and Rastogi and Shukla (2018) reported variance due to gca and sca were

Table 1 : Analysis of variance for combining ability for different characters in linseed

Source of variance	Degree of freedom	Days to 50% flowering	Days to maturity	Plant height (cm)	Technical height (cm)	No. of branches/ plant	Number of capsules/ plant	Capsule diameter (cm)	Number of seeds/ capsule	1000-seed weight (g)	Seed yield/ plant
GCA	7	42.95**	7.15**	32.76**	37.65**	0.72	67.87**	0.01**	0.76**	3.21**	0.79**
SCA	28	7.93**	2.41	21.85**	7.98**	1.12**	98.98**	0.01**	0.79**	0.71**	1.11**
Error	70	1.04	1.79	5.77	1.31	0.38	2.15	0.10	0.07	0.01	0.02

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

Table 2 : Estimates of variance components in combining ability for different quantitative characters in linseed

Variance	Days to 50% flowering	Days to maturity	Plant height (cm)	Technical height (cm)	No. of branches/ plant	Number of capsule/ plant	Capsule diameter (cm)	Number of seeds/ capsule	1000-seed weight (g)	Yield/ plant
ó^2 gca	4.22	0.51	12.75	7.21	14.00	6.75	0.01	0.08	0.34	0.69
ó^2 sca	7.74	0.55	3.08	3.68	9.65	98.76	0.02	0.74	0.71	1.10
GCA/SCA ratio	0.55	0.93	4.13	1.96	1.45	0.07	0.50	0.11	0.48	0.63

significant for the characters under investigation indicating role of both additive and non-additive gene action for the inheritance of characters studied.

The estimates of variance components (σ^2 gca and σ^2 sca) were estimated in order to determine the relative magnitude of additive and non-additive gene effects for different characters. A perusal of Table 2 indicated that in all the characters studied, it was observed that the ratio of variance of gca and sca was much more than unity for the characters plant height, technical height, number of branches per plant which indicated the predominant role of additive gene action in the inheritance of these traits (Badwal *et al.*, 1970; Singh *et al.*, 2016; Wadikar *et al.*, 2019). In all the other characters non-additive genetic variance (σ^2 sca) was higher than the corresponding additive genetic variance (σ^2 gca) and the ratio of gca variance to that of sca variance (σ^2 gca σ^{-2} sca) was less than unity. This suggests that non-additive genetic components are more important than additive genetic components in determining the inheritance of these characters. The result obtained in the present study express the nature and magnitude of gene effects for different characters in improving oilseeds as a whole and linseed in particular. High gca than sca and preponderance of additive gene action in above characters are in agreement with the previous reports (Badwal *et al.*,1970; Wadikar *et al.*, 2019). While characters exhibiting non-additive genetic components in determining inheritance are in accordance with the study of Yang *et al.* (1988) and Pali *et al.* (2014).

The parents included in the study were categorized for each of the nine characters in three group *viz*., good, average and poor combiners based on the general combining ability effects. None of the parents were found to be good general combiners for all the characters. Table 3 also indicate that all the parents were poor combiner for days to maturity, plant height, capsule diameter, number of seeds per capsule and seed yield per plant. NL-260 was good general combiners for days to 50 percent flowering, days to maturity plant height and technical height. Neelam was good general combiners for capsule diameter and 1000 seed weight. Divya was good general combiner for seed yield per plant. Surbhi was good general combiner for number of capsule per plant, number of seeds per capsule and 1000 seed weight. Shekhar was good general combiner for number of seeds per capsule and average general combiner for number of capsule per plant and seed yield per plant. BAU-13-01 was average general combiner for days to 50 percent flowering but poor general combiner for rest of the characters. RLC-171 was average general combiner for days to maturity and technical height. LC-185 was average general combiner for days to 50 percent flowering and number of seeds per capsule (Singh *et al.*, 2016).

The *per se* performance of parents was largely related with the general combing ability effects of the parents (Nirala *et al.,* 2018). Higher the value of mean performance, greater was the general combing ability effect of the parent in majority of the characters under study. It was observed that in the characters like days to 50 percent flowering, days to maturity, number of capsule per plant, number of seeds per capsule, 1000-seed weight and seed yield per plant, at least one parent was same when selected on the basis of *per se* performance. It may be concluded that *per se* performance of parent was an adequate measure of general combing ability for most of the characters and parents may be selected on the basis of *per se* performance. (Mohammadi *et al.* (2010).

The specific combining ability effects of crosses for different characters are presented in Table 4. The perusal of data, indicated that NL-260 X RLC-171 and Shekhar x BAU-13-01 for days to 50 percent flowering, Shekhar x RLC-171 and Neelam x BAU-13-01 for days to maturity, Shekhar x RLC-171 and Shekhar

Table 3 : General combining ability (GCA) effects of eight linseed genotypes for grain yield and its contributing characters

Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Technical height (cm)	No. of branches/ plant	Number of capsule/ plant	Capsule diameter (cm)	Number of seeds/ capsule	1000-seed weight (g)	Seed yield/ plant
NL-260	3.80**	0.72	4.15**	3.28**	-0.9	-3.52**	-0.03**	0.15	-0.18**	-0.16**
Neelam	-1.34**	-1.12**	-2.19**	-2.40**	0.24*	-1.72**	0.05**	-0.55**	0.29**	0.21**
Divya	-1.19**	-0.14	-1.15	-2.19**	0.29*	-0.26	0.04**	0.12	0.86**	0.61**
Surbhi	-1.67**	-0.66	-0.04	-0.98**	0.56**	4.59*	0.02**	-0.32**	0.17**	0.39**
Shekhar	-2.25**	-0.99*	-0.08	-0.86*	-0.31*	2.12*	0.05**	0.26**	0.42**	-0.36**
BAU-13-01	1.24**	0.29	0.14	0.59	0.11	1.39*	-0.02**	0.05	-0.54**	-0.15**
RLC-171	-0.93**	1.18**	-0.75	1.43**	0.41**	-2.31**	-0.03**	0.12	-0.05	0.52**
LC-185	1.87**	0.69	0.10	1.18**	-0.26*	-0.39	-0.06**	0.24**	-0.98**	-0.24**
SEd± at 5%	0.74	0.96	1.73	0.82	0.13	1.04	0.02	0.19	0.10	0.11
CD Gi—Gj at 5%	1.09	1.45	2.52	1.22	0.19	1.57	0.01	0.25	0.11	0.14
CD Gi—Gj at 1%	1.62	2.14	3.70	1.80	0.28	2.32	0.02	0.39	0.20	0.20

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

Table 4 : Estimate of specific combining ability effects of F_1 crosses for different yield contributing characters in linseed

Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Technical height (cm)	No. of branches/ plant	Number of capsule/ Plant	Capsule diameter (cm)	Number of seeds / Capsule	1000-seed weight (g)	Seed yield/ plant (g)
NL-260 x Neelam	2.78**	0.99	-3.70	-1.09	0.25	-9.12**	-0.03	0.41	0.46**	0.37**
NL-260 x Divya	-1.45	0.31	-1.29	0.51	0.67*	-0.31	-0.01	0.06	0.70**	2.29**
NL-260 x Surbhi	0.75	1.18	0.22	1.26	-0.55*	7.29**	-0.01	0.13	-0.11	-1.11**
NL-260 x Shekhar	-2.04*	0.85	-2.76	-5.18**	0.16	1.76	0.02	0.23	-0.17	0.25*
NL-260 x BAU-13-01	2.99**	-1.05	-1.04	-4.50**	-0.21	-1.17	0.00	0.80**	0.23*	0.04
NL-260 x RLC-171	6.68**	-0.25	-4.11	-1.14	-0.05	2.83*	0.04**	-0.60**	0.20	-0.13
NL-260 x LC-185	-1.11	0.21	4.87*	0.41	-0.35	6.59**	0.03	0.30	-0.03	0.05
Neelam x Divya	0.98	0.44	-3.08	1.36	-0.65*	0.21	0.02	0.74**	0.09	-0.37**
Neelam x Surbhi	1.47	1.95	3.13	-0.16	0.72**	12.46**	0.04**	1.13**	0.05	2.18**
Neelam x Shekhar	-0.26	0.95	-4.50*	-1.05	-0.26	6.26**	0.01	0.56*	0.15	-0.42**
Neelam x BAU-13-01	-2.62**	2.05	-0.16	0.77	-0.24	3.33*	0.05**	0.80**	0.50**	-0.48**
Neelam x RLC-171	-2.55*	-2.15	-2.55	-1.36	-0.34	2.99*	0.04**	1.06**	-0.13	-0.75**
Neelam x LC-185	-1.58	-0.35	-1.20	-0.89	0.63*	5.76**	0.07**	-0.04	0.87**	0.71**
Divya x Surbhi	0.98	0.61	1.51	-0.17	-0.54	-7.41***	0.03*	0.83**	-0.41**	-0.89**
Divya x Shekhar	-1.12	1.95	-5.53*	0.12	-0.04	17.73**	0.03*	-1.07**	-0.41**	-0.16
Divya x BAU-13-01	-0.82	-1.95	-0.42	-0.45	0.26	-3.21*	0.02	-0.50*	0.43**	0.41**
Divya x RLC-171	-1.43	-0.15	2.85	-3.57**	0.59*	2.46	0.04**	0.84**	1.04**	2.58**
Divya x LC-185	1.91*	-0.02	2.01	-1.09	0.31	17.23**	0.00	-0.67**	-0.53**	0.64**
Surbhi x Shekhar	-0.29	-2.87*	-1.87	-1.92	-0.11	-8.36**	-0.02	0.69**	0.68**	-0.38**
Surbhi x BAU-13-01	-2.99**	0.92	2.74	-0.01	0.21	0.07	0.02	0.57*	-0.12	0.67**
Surbhi x RLC-171	-3.58**	0.05	-0.92	-1.90	0.72**	7.39**	0.02	0.16	0.66**	2.33**
Surbhi x LC-185	-2.62**	-0.15	4.43	2.51*	-0.01	-5.17**	0.02	0.06	2.24**	-0.05
Shekhar x BAU-13-01	4.31**	1.58	4.48*	0.87	0.55*	14.53**	-0.05**	-0.67**	0.54**	0.86**
Shekhar x RLC-171	2.72**	2.38	15.49**	10.10**	0.01	4.53**	-0.03	-0.07	0.26*	0.01
Shekhar x LC-185	-1.36	1.51	4.96*	1.52	0.12	2.63	0.02	-0.50*	-0.36**	0.28*
BAU-13-01 X RLC-171	-2.35*	-0.85	-1.46	1.41	-0.23	-4.07**	-0.01	0.50*	1.02**	-0.38**
BAU-13-01 X LC-185	-3.72**	1.28	-0.51	1.88	0.18	10.69**	-0.01	-0.60**	-0.11	0.36**
RLC-171 X LC-185	-2.32*	-0.25	-1.71	0.26	-0.15	-3.31*	-0.02	-1.00**	-0.17	-0.33**
SE ± at 5%	1.91	2.54	4.48	2.12	0.39	2.73	0.04	0.43	0.23	0.24
CD Sij—Sik at 5%	2.81	3.74	6.61	3.12	0.56	4.03	0.04	0.65	0.33	0.35
CD Sij—Sik at 1%	3.79	5.05	8.93	4.22	0.61	5.44	0.05	0.88	0.44	0.48
CD Sij—Skl at 5%	2.65	3.53	6.24	2.95	0.51	3.80	0.04	0.61	0.31	0.34
CD Sij—Skl at 1%	3.56	4.77	8.43	3.99	0.74	5.14	0.05	0.84	0.43	0.45

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

x LC-185 for plant height, Shekhar x RLC-171 and Surbhi x LC-185 for technical height, Divya x Shekhar and Divya x LC-185 for number of capsules per plant, Neelam X LC-185 and Neelam X BAU-13-01 for capsule diameter, Neelam x Surbhi and Divya x Surbhi for number of seed per capsule, Surbhi x LC-185 and Divya x RLC-171 for 1000 seed weight, Surbhi x RLC-171 and Neelam x Surbhi for seed yield per plant were two crosses for each characters having most desirable specific combining ability effects.

The crosses selected on the basis of *per se* performance were almost similar as selected on the basis of specific combining ability effects in most characters, although the ranking was not same in most cases. It may be therefore concluded that there was almost close correspondence between *per se* performance of the crosses and specific combining ability effect in most cases. Similar results were also reported by linseed worker (Bhatnagar and Mehrotra, 1980; Naik, 2017).

On the basis of above findings, it is concluded that the crosses Divya x RLC-171, NL-260 x Divya, Surbhi x RLC-171 adjudges as best specific combiners for seed yield per plant. The parents NL-260, Divya, RLC171 and Surbhi were found to be good general combiners whereas specific combining ability was better in crosses NL-260 x Divya, Neelam x Divya, Divya x RLC171, Surbhi x RLC-171 etc. The crosses selected on the basis of *per se* performance were almost same as selected on the basis of specific combining ability effects in most characters, although the ranking was not same in most cases. The information obtained from the present investigation on gene action may be helpful in improving traits in accordance with employing suitable breeding method.

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Add-on Information

Authors' contribution: E. Ahmad: Formulation, conduction of field trial and data recording; **A.M. Ansari:** Formulation, associated with data recording and statistical analysis of data; **D.N. Singh:** Concept of the experiment and supervision.

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