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Heterosis and inbreeding depression for seed yield, its components and qualitative characters in linseed (*Linum usitatissimum* L.)

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ABSTRACT

The present investigation was carried out with a set of eight varieties of linseed and their twenty eight F_1's obtained through diallele crossing excluding reciprocals. The eight parents their 28 F_{1S} and the 28 respective F_2s were grown in a randomised block design during *Rabi* season of 2012 and studied for fifteen quantitative characters. The analysis of variance showed highly significant differences among the genotypes for all the characters studied except days to maturity in F_1s as well as F_2s. Heterosis for seed yield per plant was found to be highest in JLS-9 X KL-221 over better parent as well as over standard variety. Oil content is an important qualitative character in which the cross LMS-149-4 X RLC-76 recorded maximum heterosis over better parent (17.16 percent), while that over the standard variety (13.57 percent) was recorded by the cross Meera X KL-221. Whereas, inbreeding depression in F_2s for seed yield per plant was found to be highest in the cross JLS-9 X RLC-76. Negative estimates of heterotic effects observed in some traits may be attributed to inter-allelic interactions. No clear-cut relationship between heterosis and inbreeding depression was observed for seed yield, related traits and qualitative characters. Superior segregants from the cross, JLS-9 X KL-221 may be selected for further improvement in the seed yield and its contributing traits.

Key Words: *Fatty acids profile, Heterosis, Inbreeding depression, Linseed, Seed yield, Oil content*

INTRODUCTION

Linseed (*Linum usitatissimum* L.) is second most important *Rabi* oil seed crop and grown in the country next to rapeseed and mustard in area as well as in production. It is grown for both oil and fiber purposes. Every part of the linseed plant is utilized commercially either directly or after processing. On a very small scale, the seed is directly used for edible purposes, and about 20% of the total oil produced is used in farmer's homes. About 80% of the oil goes to the industries for the manufacturing of the paints, varnish, oil cloths, linoleum, pad-ink, printing ink, etc. It contains very high amount of saturated fatty acids namely palmitic acid and stearic acid along with unsaturated fatty acids *viz,* oleic, linoleic and linoleinic acids. Due to presence of these acids, its oil is largely of drying type and non-edible. Percentage of oil in linseed seed is 33-45% and having protein content of 24% (Gill 1987). Linseed oil is rich in omega-3 fatty acid which is thought to be helpful in decreasing cholesterol level when included in the diet chain (Singh and Marker 2006). It is globally an important oilseeds crop and its production is 22.70 lacs tons from an area of 22.39 lacs ha with an average yield of 986 kg/ha. India ranks third in area and fourth in the production in the world and it contribute 7 percent to the total world linseed pool. Total production of linseed in India is 1.47 lacs tons from an area of 3.38 lacs ha with an average productivity of 435 kg/ha (Anonymous 2015). The present yield level is still very low (435 kg/ha) as compared to the world productivity. Hence, in order to bridge this gap exploitation of hybrid vigour in crop plants for quantum jump in yield and other quantitative characters is one of the approaches in

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crop improvement to cope up with the ever increasing demand for food grains and oil production. In linseed, heterosis cannot be exploited for higher production through commercial hybrids. Hence, the heterosis assumes importance in breeding as heterotic crosses have the potentiality to throw out superior segregants in subsequent generations. The estimates of heterosis and inbreeding depression provide information about the nature of gene action involved in the expression of yield and related traits. The information is also essential to formulate efficient breeding programmes for the improvement of the crop. Though there are a number of reports on heterosis, information is limited in case of inbreeding depression especially for the traits like seed yield, yield components and qualitative traits. Therefore, the present investigation was carried out to estimate the magnitude of the heterosis and inbreeding depression in 28 crosses of linseed in F_1 and F_2 generations, respectively.

MATERIALS AND METHODS

The experiment was conducted in the experimental field area of linseed research scheme in Birsa Agricultural University, Kanke, Ranchi. The eight parental lines (Meera, Padmini, LMS-149-4, JLS-9, LMS-153-3, RLC-76, KL-221 and LC-185) were sown in BAU research plot during *Rabi* 20011-12 for making crosses and generate 28 hybrids by crossing the above varieties in all possible combinations excluding reciprocals. A portion of the F_1 seeds were sent for advancement of the generation to off season nursery at Lahaul Spitee (Himachal Pradesh) during summer 2012. However, the field experiments were conducted during *Rabi* 2012-13. These eight parents, 28 F_1s and 28 F_2s along with the check (T-397) constituted the total experimental material for the present investigation sown in randomized block design with 3 replications. All recommended agronomic practices were adopted in the trial of seeds of parents and F_1s were sown by hand dibbling method in 2 rows and F_2s were in 5 lines of 3 m length with inter- and intra- row spacing of 30 cm and 10 cm, respectively. Ten randomly selected competitive plants were observed for nine quantitative traits namely, days to flowering, days to maturity, plant height (cm), technical height (cm), number of capsule per plant, capsule diameter (cm), no. of seeds per capsule, 1000-seed weight (g) and yield per plant (g) along with six qualitative characters *viz.,* oil content (%), palmitic acid (%), steric acid (%), oleic acid (%), linoleic acid (%) and linolenic acid (%). Oil content was determined with the help of Dopi Minispic Pulsed NMR (Nuclear Magnetic Resoonabance). The study of the fatty acid composition was done with the help of Gas Chromatography and Mass Spectrophotometry. The mean values were used for estimating the heterosis over better parent (BP) as per Fonseca and Patterson (1968) was calculated, while standard heterosis (SH) using T-397 variety as standard check was calculated as per Meredith and Bridge (1972). Inbreeding depression (ID) from F_1 to F_2 was calculated by the formula, $ID(\%) = [(F_1 - F_2) / F_1] \times 100$ where F_2 denotes the mean of F_2 population for a trait.

RESULTS AND DISCUSSION

The analysis of variance was done for fifteen quantitative characters in F_1s as well as F_2s to test the significance of differences among all the genotypes, parents and crosses (Table 1). The result revealed highly significant differences among the genotypes for almost all the characters except days to maturity in F_1s as well as F_2s. This indicates the presence of variability among treatments. The presence of large amount of variability might be due to diverse source of materials. Exploitation of heterosis is considered to be one of the outstanding achievements in plant breeding. In self-pollinated plant like linseed utilization of heterosis depends upon direction and magnitude of heterosis and feasibility and types of gene action involved. Estimation of heterosis over better parent (heterobeltiosis) may be useful in identifying true heterotic cross combinations but these crosses can be of immense practical value if they show superiority over the check variety. This is why apart from heterotic response over better parent heterosis; over the Standard variety has also been estimated in the present study using T-397 as the standard variety (Table 2). One of the most important breeding objectives in Linseed was to breed early maturity varieties. Table 2 revealed that 15 crosses over better parent and 19 crosses over standard check variety T-397 exhibited significant to highly significant negative (desirable) heterosis in case of days to 50% flowering. It is also evident from the table that the cross JLS-9 X LC-185 exhibited maximum negative heterbeltiosis over better parent (-20.77) while the cross RLC-76 X LC-185 was depicted maximum standard heterosis over the check variety (-17.11). On other hand 7 crosses over better parents and 6 crosses over standard check showed significant negative heterosis. Saraswat *et al* (1993) and Tak and Gupta (2001) were also reported a significant negative heterosis and heterobeltiosis in days to 50 percent flowering and days to maturity.

In case of plant height, the overall heterosis over better parent and the standard variety was in negative direction. The cross Meera X Padmini exhibited maximum negative heterosis over better parent (-19.90), and Padmini X LMS-153-3 over the standard variety (-21.12).). Nine crosses over better parent and 14 crosses over standard check, T-397 exhibited significant to highly significant negative (desirable) heterosis. Similar results were also reported by earlier worker Sharma *et al* (2005) and Shikha *et al* (2011). Like plant height, the overall heterosis for the character technical height observed to be desirable in negative. Ten crosses over better parent recorded highly significant negative heterosis while fourteen crosses over the standard variety exhibited significant heterosis as shown in Table-2. The cross Meera X LMS-153-3 showed the maximum heterosis over the better parent (-33.74 percent) while the cross Padmini X LMS-153-3 showed maximum heterosis over the standard variety (-26.69). Similar type of finding were reported by Ratnaparkhi *et al* (2004) and Kiran and Kanojia (2014). The magnitude of heterosis for number of capsules per plant showed highly significant positive heterosis. The maximum heterobeltiosis (76.92 percent) and heterosis over the standard variety (58.62 percent) was recorded by the same cross *viz;* LMS-149-4 X LMS-153-3. Many earlier workers also reported appreciable heterobeltiosis for number of capsules per plant in linseed. Rao and Singh (1983), Ratnaparkhi *et al* (2004), Ameta *et al* (2005) and Singh *et al (*2006) reported almost similar result as is found in the present investigation.

Highly significant positive heterosis for capsule diameter over better parent was recorded by nine crosses and over the standard variety recorded by twenty two crosses. The cross Padmini X JLS-9 recorded maximum heterobeltiosis (15.14 percent) as well as maximum heterosis (26.77) over standard T-397. Similar results were also reported by Mishra and Rai (1993) and Reddy *et al* (2013). The magnitudes of heterosis better and the standard variety in case of number of seeds per capsule have been presented in Table 2. Four crosses exhibited significant positive heterosis over the standard variety, five crosses over better parent exhibited highly significant positive heterosis. The cross Padmini X JLS-9 exhibited the maximum heterobeltiosis (38.10 percent), whereas, same cross recorded maximum heterosis over the standard variety (23.33 percent). Similar results were also reported by Mishra and Rai (1993), Kumar *et al* (2002), Sood *et al* (2011), Reddy *et al* (2013). Almost, all the crosses exhibited positive heterosis over better or the standard variety for 1000-seed weight. Highly significant positive heterosis over better parent was recorded by seventeen crosses and over the standard variety recorded by all the twenty six crosses. The cross JLS-9 X LC-185 recorded maximum and positive heterosis over the standard variety (71.86 percent), whereas, maximum heterobeltiosis was recorded in RLC-76 X KL-221 (29.87). Positive and almost similar extent of heterosis for 1000-seed weight was also reported by Kausal *et al (*1981), Mishra and Rai (1993) and Pali and Mehta (2014). In the present study, positive heterosis over better parent for seed yield per plant was observed in majority of crosses. Similar was the case for heterosis over the standard variety, where also majority of crosses exhibited positive heterosis. A total of twenty four crosses recorded significant positive heterosis each over better parent as well as over standard variety. It may be revealed in the table-2 that the cross JLS-9 X KL-221 exhibited maximum heterosis over better parent (137.08 percent) as well as over standard variety (142.46 percent) and hence could be regarded as the best cross so far as heterosis is concerned. Heterosis in seed yield has been reported by almost linseed workers with varying extent. Almost similar result as in the present finding was observed by Singh *et al* (1987), Ratnaparkhi *et al* (2004), Ameta *et al* (2005), Pant *et al* (2008), Kumar *et al* (2013), Mishra *et al* (2013) with regard to extent of heterosis in seed yield.

In case of oil content a total of twelve crosses expressed highly significant positive heterosis over better parent and thirteen crosses over the standard variety showed highly significant positive heterosis. The cross LMS-149-4 X RLC-76 recorded maximum heterosis over better parent (17.16 percent), while that over the standard variety (13.57 percent) was recorded by the cross Meera X KL-221. The present result is in agreement with Singh *et al* (2009) and Kumar *et al* (2013).

In case of palmitic acid content, the cross Meera X RLC-76 recorded maximum heterosis over better parent (-21.87 percent), while, none of the crosses recorded significant and negative heterosis over the standard variety. Negative heterosis for this trait was also reported by Kumar *et al* (2013).

Table 1 Analysis of variance of parents and crosses for seven quantitative characters in linseed.

Source of variance	Degree of freedom	Days to 50% flowering	Days to maturity	Plant height (cm)	Technical height (cm)	Number of capsule/ plant	Capsule diameter (cm)	Number of seeds / capsule
Replications	2	0.84	5.95	12.76	2.90	16.79	0.00	0.15
Genotypes	35	46.77***	9.84*	74.81**	43.23***	280.85***	0.01***	2.32***
Parents	7	61.09***	19.76**	107.72***	73.07***	165.88***	0.01***	8.67***
F_1s	27	43.53***	6.14	67.29***	37.05***	193.27***	0.01***	0.60***
F_2s	27	37.15***	8.65	26.32	15.52	115.21***	0.01***	1.86**
Parent Vs. crosses	1	34.08**	40.35**	47.25	1.07	3450.17***	0.05***	4.23***
Error	97	3.10	5.53	17.32	3.87	6.43	0.01	0.17

*, **, ***: Significant at 5%, 1% and 0.1% levels, respectively

Table 1a Analysis of variance of parents and crosses for eight quantitative characters in linseed.

Source of variance	Degree of freedom	1000-seed weight (g)	Seed yield per plant	Oil content (%)	Palmitic acid (%)	Steric acid (%)	Oliec acid (%)	Linoleic acid (%)	Linolenic acid (%)
Replications	2	0.02	0.03	0.06	0.01	0.01	0.08	0.00	0.00
Genotypes	35	3.61***	3.14***	34.33***	5.05***	21.98***	34.86***	7.03***	139.85***
Parents	7	4.38***	0.29***	13.76***	2.53***	7.97***	27.71***	11.66***	16.90***
F_1s	27	2.54***	3.05***	40.84***	5.82***	18.20***	23.96***	5.86***	164.87***
F_2s	27	3.37***	1.25***	19.86***	2.33***	37.39***	9.60***	2.64***	179.37***
Parent Vs. crosses	1	27.10***	25.46***	2.37**	2.01***	222.06***	379.19***	6.21***	325.15***
Error	97	0.04	0.05	0.22	0.01	0.01	0.48	0.00	0.01

*, **, ***: Significant at 5%, 1% and 0.1% levels, respectively

Table 2 Estimate of heterobeltiosis (over better parent) and Standard heterosis (over T-397) for five characters in linseed.

Characters	Days to 50% flowering		Days to maturity		Plant height (cm)		Technical height (cm)		Number of capsule/ Plant	
Cross	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis
Ieera X admini	9.61	11.89*	7.27	10.03	-19.90 **	-14.16 **	-27.87 **	-15.33**	-7.25	-11.72*
Ieera X LMS-49-4	-9.61	-7.44	10.54*	11.31*	-14.81 **	-8.71	-23.36 **	-10.04*	15.22 **	9.66*
Ieera X JLS-9	-7.43	8.78	7.80	10.58*	-11.07 *	-4.70	-18.60 **	-4.45	3.70	35.17**
Ieera X LMS-53-3	-11.78 *	-9.67	-12.27*	-12.03*	-15.39 **	-9.33	-33.74 **	-22.22**	24.64 **	18.62**
Ieera X RLC-76	10.83 *	15.44**	-8.27	9.48	-12.69 *	-6.44	-28.77 **	-16.39**	8.05	11.03*
Ieera X KL-221	15.26 **	17.67**	8.05	12.86*	-18.27 **	-12.41 *	-18.76 **	-4.64	17.39 **	11.72**
Ieera X LC-185	-12.26 **	-11.00*	-8.07	-12.86*	-4.26	2.60	-15.62 **	-0.95	29.71 **	23.45**
admini X LMS-49-4	7.47	-11.00*	7.00	1.93	-13.33 *	-21.12 **	-2.21	-23.74**	27.69 **	14.48**
admini X JLS-9	-8.82	-11.00*	-8.91*	14.75*	-1.03	-9.93	-6.50	-24.49**	14.81 **	49.66**
admini X LMS-53-3	-9.79	-14.11**	-9.50*	-13.65*	-13.96 *	-21.69 **	-2.32	-26.69**	49.22 **	31.72**
admini X RLC-6	-16.79 **	-12.78**	9.35*	11.58*	-6.36	-14.78 **	-7.22	-17.66**	20.81 **	24.14**
admini X KL-21	-12.94 **	-15.44**	-10.94*	7.83	-11.79 *	-19.72 **	-10.63 *	-21.29**	21.74 **	15.86**
admini X LC-85	-19.15 **	-10.56*	-7.80	8.93	-8.16	-16.41 **	-7.29	-20.64**	42.19 **	25.52**
MS-149-4 X LS-9	-9.27	-11.44*	7.54	9.48	1.13	-10.64	-5.48	-23.66**	-14.29 **	11.72**
MS-149-4 X MS-153-3	-10.72	-15.00**	8.35	10.31*	-11.15	-21.50 **	-0.74	-22.60**	76.92 **	58.62**
MS-149-4 X LC-76	-14.23 **	-10.11*	-8.08	8.10	-1.98	-13.39 *	10.15*	-20.26**	10.74 *	13.79**
MS-149-4 X L-221	-11.11 *	-13.67*	-8.57	-11.31*	2.25	-9.66	-16.72 **	-26.65**	23.91 **	17.93**
MS-149-4 X C-185	-14.69 **	8.33	7.27	10.03*	2.19	-9.71	-6.99	-20.37**	70.00 **	52.41**
LS-9 X LMS-53-3	-12.45 **	-14.56**	-8.91*	-9.10	5.04	-14.22 **	-6.85	-24.77**	-12.17 **	14.48**
LS-9 X RLC-76	-17.64 **	-13.67**	7.81	12.03*	7.81	-6.88	-4.84	-15.55**	0.00	30.34**
LS-9 X KL-221	-15.18 **	-17.22**	-8.84*	-10.03*	5.63	-13.74 *	-7.45	-18.49**	5.82	37.93**
LS-9 X LC-185	-20.77 **	-12.33*	-7.27	10.48*	17.18 **	-4.31	8.86	-6.80	-11.11 **	15.86**
MS-153-3 X LC-76	-9.13	9.22	7.08	9.31	10.85	-4.25	-1.75	-12.80**	51.01 **	55.17**
MS-153-3 X L-221	7.00	-9.67	-7.26	11.68*	37.89 **	11.38**	31.07 **	15.44**	33.33 **	26.90**
MS-153-3 X C-185	-19.96 **	-11.44*	-7.80	-15.58**	19.44 **	-3.55	5.94	-9.31*	47.20 **	26.90**
LC-76 X KL-21	-15.94 **	-11.89*	-8.84*	13.03*	-0.88	-14.38**	7.03	-5.01	4.70	7.59
LC-76 X LC-85	-18.74 **	-17.11**	7.61	14.41*	2.25	-11.68*	7.75	-4.37	38.26 **	42.07**
L-221 X LC-85	-19.55 **	-17.00**	-8.05	-16.86**	5.49	-14.80**	6.09	-6.56	10.87 *	5.52

*,**,***: Significant at 5%, 1% and 0.1% levels, respectively

Table 2a Estimate of heterobeltiosis (over better parent) and Standard heterosis (over T-397) for five characters in linseed.

Characters Cross	Capsule diameter (cm)		Number of seeds/capsule		1000-seed weight (g)		Seed yield/plant (g)		Oil content (%)	
	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis
Meera X Padmini	3.21	13.64	3.70	-6.67	12.55 **	45.23**	23.11 **	50.07**	3.43 **	9.24**
Meera X LMS-149-4	0.90	13.13**	-3.33	-3.33	9.87 **	47.96**	108.30 **	134.45**	-5.58 **	-6.26**
Meera X JLS-9	2.33	11.11**	3.70	-6.67	4.06	46.01**	-4.05	-1.87	-11.81 **	-12.44**
Meera X LMS-153-3	-0.44	14.65**	-3.23	0.00	-4.81 *	37.02**	23.43 **	28.70**	-12.42 **	-10.09**
Meera X RLC-76	0.94	8.59*	14.81 **	13.33**	7.45 **	28.81**	29.70 **	28.84**	-12.99 **	-13.62**
Meera X KL-221	8.13 **	14.14**	-6.90	-10.00**	13.65 **	36.24**	33.93 **	29.64**	12.63 **	13.57**
Meera X LC-185	0.96	6.57	-9.09 **	0.00	-2.98	16.30**	24.55 **	20.56**	11.21 **	10.67**
Padmini X LMS-149-4	10.81 **	24.24**	-3.33	-3.33	7.75 **	45.11**	21.25 **	47.80**	3.36 **	9.16**
Padmini X JLS-9	15.14 **	26.77**	38.10 **	23.33**	11.26 **	56.11**	95.73 **	138.58**	-13.11 **	-8.23**
Padmini X LMS-153-3	5.26	21.21**	-6.45	-3.33	4.23 *	50.03**	-8.87	11.08	-11.62 **	-6.66**
Padmini X RLC-76	12.39 **	23.74**	7.41	-3.33	9.17 **	40.87**	-2.63	18.69**	-16.63 **	-11.95**
Padmini X KL-221	11.93 **	23.23**	3.45	0.00	7.01 **	38.08**	-6.46	14.02	-19.58 **	-15.07**
Padmini X LC-185	10.09 **	21.21**	18.18 **	10.00**	7.66 **	38.92**	28.37 **	56.48**	-16.86 **	-12.19**
LMS-149-4 X JLS-9	9.91 **	23.23**	0.00	0.00	4.58 *	46.73**	17.91 **	32.71**	13.88 **	11.37**
LMS-149-4 X LMS-153-3	6.58 *	22.73**	16.13 **	13.33**	-3.45	38.97**	23.37 **	38.85**	-1.34	1.28
LMS-149-4 X RLC-76	4.95	17.68**	-10.00 **	-10.00**	2.45	37.97**	50.53 **	69.43**	17.16 **	11.14**
LMS-149-4 X KL-221	7.66 **	20.71**	-6.67	-6.67	15.88 **	56.06**	98.58 **	123.50**	7.89 **	8.79**
LMS-149-4 X LC-185	-2.25	9.60**	-18.18 **	-10.00**	-15.46 **	13.85**	50.77 **	69.69**	4.59 **	4.09**
JLS-9 X LMS-153-3	-1.32	13.64**	-3.23	0.00	16.91 **	68.29**	14.85 *	19.76**	7.68 **	10.54**
JLS-9 X RLC-76	4.65	13.64**	7.41	-3.33	0.20	40.59**	65.80 **	69.56**	-2.20 *	-4.36**
JLS-9 X KL-221	5.58	14.65**	-3.45	-6.67	15.00 **	61.36**	137.08 **	142.46**	0.23	1.06
JLS-9 X LC-185	0.93	9.60**	-15.15 **	-6.67	22.48 **	71.86**	30.03 **	32.98**	5.50 **	4.99**
LMS-153-3 X RLC-76	-10.09 **	3.54	-12.90 **	-10.00**	-0.27	43.55**	48.27 **	54.61**	3.76 **	6.52**
LMS-153-3 X KL-221	-6.58 *	7.58*	-6.45	-3.33	1.98	46.79**	21.51 **	26.70**	-0.44	2.20*
LMS-153-3 X LC-185	-6.14 *	8.08**	-15.15 **	-6.67	-16.33 **	-20.44**	17.54 *	22.56**	-7.28 **	-4.81**
RLC-76 X KL-221	-1.41	6.06	3.45	0.00	29.87 **	44.44**	21.91 **	21.09**	-12.21 **	-11.47**
RLC-76 X LC-185	-6.10 *	1.01	-18.18 **	-10.00**	11.03 **	9.60**	36.02 **	35.11**	-7.33 **	-7.78**
KL-221 X LC-185	-2.46	0.00	21.21 **	0.33	4.67	16.42**	20.48 **	13.89	3.60 **	4.47**

*,**,***: Significant at 5%, 1% and 0.1% levels, respectively

Table 2b Estimate of heterobeltiosis (over better parent) and Standard heterosis (over T-397) for five characters in linseed.

Characters Cross	Palmitic acid (%)		Steric acid (%)		Oliec acid (%)		Linoleic acid (%)		Linolenic acid (%)	
	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis	Heterobel -tiosis	Standard heterosis
Meera X Padmini	-19.82 **	14.78**	63.45 **	91.89**	7.36 **	-6.94**	-20.89 **	16.85**	25.04 **	42.00**
Meera X LMS-149-4	-19.38 **	15.40**	27.89 **	98.58**	0.94	-20.74**	-25.80 **	17.03**	34.41 **	44.32**
Meera X JLS-9	-19.95 **	14.59**	35.87 **	94.17**	-20.90 **	-20.90**	-21.01 **	16.68**	32.25 **	42.00**
Meera X LMS-153-3	-19.69 **	14.97**	44.09 **	97.64**	-8.40 **	-20.85**	-21.12 **	16.50**	25.89 **	37.81**
Meera X RLC-76	-21.87 **	11.83**	16.29 **	84.33**	-9.40 **	-23.53**	-20.91 **	16.82**	32.02 **	41.75**
Meera X KL-221	-21.60 **	15.03**	-10.68 **	96.93**	-8.75 **	-21.15**	-24.04 **	12.20**	26.43 **	37.85**
Meera X LC-185	-19.69 **	14.97**	46.63 **	78.03**	5.13 *	-23.63**	-17.90 **	21.26**	22.74 **	40.42**
Padmini X LMS-149-4	-8.96 **	25.92**	64.81 **	155.91**	-23.38 **	-33.58**	-9.91 **	42.08**	-6.81 **	5.82**
Padmini X JLS-9	-8.96 **	25.92**	95.87 **	179.92**	-33.11 **	-33.11**	3.91 **	52.29**	-6.72 **	5.93**
Padmini X LMS-153-3	-2.85 **	34.38**	87.54 **	157.24**	-19.93 **	-30.59**	-8.25 **	34.47**	-5.51 **	7.30**
Padmini X RLC-76	-5.32 **	33.75**	68.90 **	167.72**	-23.98 **	-34.10**	-6.76 **	36.66**	-5.51 **	7.30**
Padmini X KL-221	-8.79 **	33.81**	21.14 **	167.09**	-21.41 **	-31.88**	-10.19 **	31.62**	-5.33 **	7.50**
Padmini X LC-185	-3.53 **	33.44**	112.52 **	158.03**	-18.57 **	-29.41**	-13.75 **	26.41**	-8.62 **	4.54**
LMS-149-4 X JLS-9	-4.96 **	25.86**	70.28 **	164.41**	-27.39 **	-27.39**	-14.89 **	34.23**	8.13 **	8.88**
LMS-149-4 X LMS-153-3	-7.28 **	22.79**	69.83 **	163.70**	-21.08 **	-31.81**	-17.18 **	30.61**	-1.29 **	8.06**
LMS-149-4 X RLC-76	-4.43 **	35.00**	66.72 **	164.25**	17.96 **	30.76**	-9.32 **	43.02**	0.32	7.51**
LMS-149-4 X KL-221	36.15 **	99.75**	37.21 **	202.52**	-33.67 **	-42.69**	-17.74 **	29.74**	-1.74 **	7.13**
LMS-149-4 X LC-185	38.11 **	82.91**	90.72 **	196.14**	-19.18 **	-36.54**	-17.89 **	29.50**	-6.59 **	6.86**
JLS-9 X LMS-153-3	41.44 **	73.32**	76.58 **	152.36**	-39.76 **	-39.76**	17.68 **	27.66**	0.39 *	9.90**
JLS-9 X RLC-76	-3.81 **	35.88**	66.67 **	164.17**	-39.48 **	-39.48**	6.98 **	26.20**	1.58 **	8.87**
JLS-9 X KL-221	31.67 **	93.17**	39.79 **	208.19**	-38.61 **	-38.61**	21.66 **	44.79**	25.51 **	36.84**
JLS-9 X LC-185	70.31 **	90.04**	105.56 **	193.78**	-40.58 **	-40.58**	5.35 **	36.87**	18.73 **	35.83**
LMS-153-3 X RLC-76	-11.52 **	24.98**	-18.23 **	-27.72**	-8.06 **	-20.56**	45.71 **	71.89**	-10.47 **	-1.99**
LMS-153-3 X KL-221	-13.70 **	26.61**	-42.07 **	-29.61**	-12.58 **	-24.46**	33.37 **	58.72**	-10.07 **	-1.56**
LMS-153-3 X LC-185	-0.46	21.98**	-9.59 **	-24.02**	-10.54 **	-22.70**	14.09 **	48.23**	-10.45 **	2.45**
RLC-76 X KL-221	-13.83 **	26.42**	-24.18 **	67.17**	-25.76 **	-35.85**	23.42 **	46.87**	1.86 **	11.06**
RLC-76 X LC-185	-13.08 **	22.79**	-8.99 **	44.25**	-24.44 **	-36.22**	13.24 **	47.12**	-6.56 **	6.90**
KL-221 X LC-185	-17.67 **	20.79**	-31.07 **	-51.97**	-27.60 **	-37.44**	14.09 **	48.23**	-9.90 **	3.08**

*,**,***: Significant at 5%, 1% and 0.1% levels, respectively

Table 3 Inbreeding depression of crosses for eight characters of F_2 generation in linseed.

Characters Cross	Days to 50% flowering	Days to maturity	Plant height (cm)	Technical height (cm)	Number of capsule/ plant	Capsule diameter cm)	Number of seeds/ capsule	1000-seed weight (g)
Meera X Padmini	14.20**	7.00	-4.46	-15.36	17.97*	8.44	3.57*	7.27 **
Meera X LMS-149-4	9.23	7.53	-3.07	-7.46	18.87**	4.02	0.00	9.51 **
Meera X JLS-9	9.62	8.06	3.87	-8.26	32.14***	5.00	-3.57	6.81 *
Meera X LMS-153-3	7.91	7.80	-2.16	-28.26**	15.70*	7.93	0.00	0.24
Meera X RLC-76	21.34**	-7.27	0.96	-13.86	17.39*	0.93	0.00	1.21
Meera X KL-221	17.04 *	8.59	1.30	2.84	20.37*	12.39	0.00	10.74 **
Meera X LC-185	-9.99	9.39**	21.96*	19.99**	18.99***	21.80**	0.00	21.17 ***
Padmini X LMS-149-4	13.01 *	7.00	-7.10	-17.55*	15.06**	15.85 *	-3.45	4.69 *
Padmini X JLS-9	8.85	8.07	6.42	-12.43	15.21**	15.14 **	0.00	0.93
Padmini X LMS-153-3	10.34	7.54	-2.21	-6.25	13.09**	13.75 *	3.45*	7.52 **
Padmini X RLC-76	8.42	9.66**	-1.42	-11.44	17.22*	15.92 **	0.00	8.48 *
Padmini X KL-221	-8.46	-9.46**	-1.73	-10.02	22.02*	14.75 *	0.00	10.11 **
Padmini X LC-185	12.53	8.35	1.71	-7.33	19.23***	11.67 *	0.00	12.62 **
LMS-149-4 X JLS-9	9.79	-9.42**	-8.44*	-20.13**	21.61*	16.39 *	0.00	7.00 **
LMS-149-4 X LMS-153-3	-8.93	9.13	-6.48	-7.17	29.57**	16.46 **	0.00	10.21 *
LMS-149-4 X RLC-76	10.21	9.18**	-2.14	-8.79	7.88	10.73	0.00	9.63 **
LMS-149-4 X KL-221	-9.38	10.47**	7.66	-19.57*	46.20**	12.97 *	-7.14*	9.95 **
LMS-149-4 X LC-185	-12.70*	-8.60	1.07	-14.06*	23.98**	11.52	0.00	17.12 **
JLS-9 X LMS-153-3	-13.25	-8.95	1.81	-6.31	6.024	6.67	0.00	7.90 **
JLS-9 X RLC-76	-8.43	9.94**	6.84	-1.39	25.93**	4.00	0.00	5.48 *
JLS-9 X KL-221	-12.95	7.27	0.49	-12.25	24.50***	7.49	0.00	9.86 **
JLS-9 X LC-185	8.41	8.88	13.20**	10.91*	16.67*	-16.13 **	0.00	8.35 **
LMS-153-3 X RLC-76	8.74	10.20**	10.84*	-1.72	26.22***	17.56 **	0.00	12.72 ***
LMS-153-3 X KL-221	9.28	9.11	19.06*	14.82*	26.09***	3.29	6.90*	13.35 **
LMS-153-3 X LC-185	9.33	9.13	9.77*	5.87	21.74**	9.35 *	-3.57	2.55
RLC-76 X KL-221	8.40	18.34**	0.37	12.52*	2.56	3.33	0.00	25.94 ***
RLC-76 X LC-185	-7.00	-9.38**	-7.46*	7.10	27.67**	-3.50	0.00	4.38
KL-221 X LC-185	-18.57 **	-7.80	3.23	5.24	8.50	6.06	-23.08 *	23.79 ***
Average	7.29	7.01	2.75	-4.35	20.41	9.30	-0.50	9.47

*,**,***: Significant at 5%, 1% and 0.1% levels, respectively

Table 3a Inbreeding depression of crosses for seven characters of F_2 generation in linseed.

Characters cross	Seed yield/ plant	Oil content (%)	Palmitic acid (%)	Steric acid (%)	Oliec acid (%)	Linoleic acid (%)	Linolenic acid (%)
Meera X Padmini	0.45	21.80 ***	-33.01 ***	-38.45***	32.78***	-2.86**	-1.40***
Meera X LMS-149-4	27.73 *	4.74 *	-32.23 ***	-35.29***	22.56***	-2.61**	-4.37***
Meera X JLS-9	-46.94 ***	-0.40	-32.68***	-36.98***	20.54***	-2.20*	-4.68***
Meera X LMS-153-3	-3.53	-3.07	-49.02***	-46.10***	24.31***	-12.08***	-2.88***
Meera X RLC-76	2.49	-14.84 ***	-36.45***	-69.24***	22.21***	-3.96***	-1.58***
Meera X KL-221	5.77	24.49***	-32.66***	-34.71***	23.58***	-13.53***	-2.85***
Meera X LC-185	14.95*	12.41 ***	-33.44***	-48.87***	18.04***	-0.83	-5.71***
Padmini X LMS-149-4	17.34 *	4.37 *	-42.42***	-12.55***	19.10***	9.49***	-36.06***
Padmini X JLS-9	31.90 **	2.13	-44.01***	-8.47***	28.43***	25.69***	-34.05***
Padmini X LMS-153-3	-13.34*	5.38 *	-21.90***	-44.35***	-3.72***	-3.46***	-5.96***
Padmini X RLC-76	-17.32*	-0.32	-22.52***	-34.38***	-3.88***	-2.52*	-5.75***
Padmini X KL-221	-20.49*	-8.96 **	-31.21***	-26.03***	-4.95***	-6.71***	-7.20***
Padmini X LC-185	15.87 *	-22.50 ***	-28.39***	-30.18***	-1.16*	-17.73***	-8.34***
LMS-149-4 X JLS-9	23.74 *	17.80 ***	0.00	-27.81***	6.13***	-10.54***	-0.16
LMS-149-4 X LMS-153-3	9.04	12.14 ***	-10.86***	-18.78***	3.42***	-16.15***	-0.51**
LMS-149-4 X RLC-76	17.73 *	17.77 ***	13.08***	-18.30***	8.37***	3.21***	0.21
LMS-149-4 X KL-221	20.31 *	14.57 ***	33.01***	27.64***	-15.54***	0.62	-1.62*
LMS-149-4 X LC-185	28.72 **	14.55 ***	25.75***	34.43***	-4.75***	-10.46***	-2.46***
JLS-9 X LMS-153-3	-1.34	15.82 ***	21.50***	39.31***	-4.99***	-8.03***	0.17
JLS-9 X RLC-76	36.93 *	2.31	-12.26***	44.38***	-4.84***	-6.14***	1.42***
JLS-9 X KL-221	20.93 **	0.80	17.73***	44.43***	-11.06***	6.98***	21.24***
JLS-9 X LC-185	-3.72	13.23 ***	19.44***	42.67***	-16.87***	3.10***	20.66***
LMS-153-3 X RLC-76	35.75 *	14.50 ***	-40.00***	-14.10***	18.65***	25.69***	-10.81***
LMS-153-3 X KL-221	6.01	-0.73	-35.31***	1.67	15.04***	9.90***	-10.55***
LMS-153-3 X LC-185	10.02 *	-9.81**	-32.75***	0.57	18.56***	4.64***	-6.92***
RLC-76 X KL-221	20.51*	-18.33 ***	-9.16***	12.34***	-6.76***	11.10***	2.10***
RLC-76 X LC-185	34.19 **	-12.64 ***	-11.98***	15.83***	-8.32***	9.00***	0.04
KL-221 X LC-185	23.21*	12.68 ***	-12.13***	18.55***	-5.70***	11.86***	-3.86***
Average	**13.48**	**5.24**	**-13.47**	**-7.16**	**8.19**	**0.96**	**-3.42**

*,**,***: Significant at 5%, 1% and 0.1% levels, respectively

In case of stearic acid content only seven crosses over better parent showed highly significant negative heterosis. The cross LMS-153-3 X KL-221 recorded maximum heterosis over better parent (-42.07 percent) as well as over standard check variety (-29.61 percent), while, three other crosses recorded significant and negative heterosis over the standard variety. The present finding is in agreement with negative heterosis for this trait was also reported by Kumar *et al* (2013). In case of oliec acid content only three crosses were recorded highly significant positive (desirable) heterosis better parent. The cross LMS-149-4 x RLC-76 recorded maximum heterosis over better parent (7.96 percent), while, none of the crosses recorded significant and positive heterosis over the standard variety. Similar results were also reported by Kumar *et al* (2013). In case of linoliec acid content a total of eleven crosses was recorded highly significant positive heterosis over better while all the twenty eight crosses recorded highly significant positive heterosis over the standard variety T-397. The cross LMS-153-3 X RLC-76 recorded maximum heterosis over better parent (45.71 percent) as well as over the standard variety (71.89 percent). Kumar *et al* (2013) also reported similar trends for this character. As per the concern of linolenic acid content thirteen crosses were recorded highly significant negative (desirable) heterosis over better parent showed highly significant negative heterosis. However, only two crosses recorded highly

Table 4 Range of *per se* performance, heterobeltiosis (BP), standard heterosis (SH), and inbreeding depression (ID), along with variety. The cross LMS-153-3 X KL-221 recorded maximum and negative heterosis over better parent most heterotic crosses and inbreeding depression for 16characters in Linseed.

Character	Range						Better parents based on *per se* performance	Number of hybrids with significant heterosis and inbreeding depression					
	Per se performance			Heterosis		ID (%)		Over better parent		Over standard check		Inbreeding depression	
	Parents	Crosses F_1	Crosses F_2	BP (%)	SH (%)			+ve	-ve	+ve	-ve	+ve	-ve
Days to 50% Flowering	68.00-82.33	67.33-83.00	67.33-80.33	13.77 to 8.26	10.22 to 10.67	-18.57 to 21.34	JLS-9 X KL-221	2	15	3	19	4	2
Days to Maturity	119.00-127.00	119.67-126.67	119.67-127.00	3.94 to 2.50	1.10 to 4.68	-9.46 to 10.47	JLS-9 X LMS-153-3	2	7	12	6	8	3
Plant Height (cm)	51.59-69.82	51.02-72.57	52.15-63.13	19.00 to37.89	21.69 to 11.38	-7.46 to 21.96	Padmini X LMS-153-3	3	9	1	14	5	2
Technical Height (cm)	26.87-41.87	26.15-41.17	27.78-36.89	33.74 to 31.07	26.69 to 15.44	- 28.26-19.99	Padmini X LMS-153-3	1	20	1	19	4	5
Number of Capsule/Plant	39.00-63.00	42.67-76.67	30.67-61.33	14.29 to 76.92	11.72 to 58.62	7.88 to 46.20	LMS-149-4 X LMS-153-3	19	9	25	1	24	0
Capsule Diameter (cm)	0.58-0.76	0.66-0.84	0.55-0.84	10.09 to 15.14	0.00 to 26.77	-16.1 to 21.80	Padmini X JLS-9	9	4	22	0	11	1
Number of Seeds capsule	6.00-11.00	8.67-10.33	6.33-10.67	21.21 to 38.10	13.33 to 3.33	-23.08 to 6.90	Meera X RLC-76	5	7	4	5	3	2
1000-seed Weight (g)	5.22-8.59	6.54-10.26	5.30-9.40	16.33 to 29.87	9.60 to 71.86	-2.55 to 25.94	JLS-9 XLC-185	17	3	26	2	23	0
Yield/ Plant	1.99-3.04	2.45-6.05	2.18-4.79	8.87 to 137.08	1.87 to 142.46	-46.94 to 35.75	JLS-9 X KL-221	24	0	23	0	16	4
Oil Content (%)	34.62-41.70	33.53-44.84	33.73-42.47	19.58 to 17.16	15.07 to 13.57	-22.50 to 24.94	Meera X KL-221	12	13	13	13	15	6
Palmitic Acid (%)	5.21-7.81	5.95-10.63	6.25-9.65	21.87 to 70.31	11.83 to 99.75	-49.02 to 33.01	Meera X RLC-76	5	22	28	0	6	21
Steric Acid (%)	3.80-9.33	5.25-13.05	5.14-15.72	42.07 to 112.52	24.02 to 208.19	-48.87 to 44.43	LMS-153-3 X LC-185	21	7	24	4	9	17
Oliec Acid (%)	24.62-33.92	19.44-31.57	16.24-24.42	40.58 to 7.36	42.69 to 6.94	-16.87 to 37.78	Meera X Padmini	2	24	1	25	15	12
Linoleic Acid (%)	9.59-15.13	10.76-16.49	10.86-14.55	25.80 to 45.71	12.20 to 71.89	-17.73 to 25.69	LMS-153-3 X RLC-76	11	17	28	0	11	15
Linolenic Acid (%)	45.23-51.74	44.33-65.27	48.33-68.12	10.47 to 34. 41	1.99 to 44.32	-36.06 to 20.66	LMS-153-3 X RLC-76	13	14	26	2	4	20

significant negative heterosis over the standard 10.07 percent), while, the cross LMS-153-3 X RLC-76 recorded maximum negative heterosis over the standard variety (-1.99). Mishra and Rai (1993) and Ameta *et al* (2005) also reported similar type of result with their findings. Inbreeding depression was calculated to know the effect of homozygosity in subsequent generation in form of loss of vigour in crosses. The results obtained from the study of inbreeding depression for different characters have been presented in Table 3. Among all the characters studied inbreeding depression was found to be desirable in negative direction for days to 50 percent flowering, days to maturity, plant height ,technical height, palmitic acid, stearic acid and linolenic acid, whereas, in other characters it was desirable in positive direction. A high degree of inbreeding depression was found in number of capsule per plant, 1000 seed weight, seed yield per plant, oil content, palmitic acid, steric acid, oleic acid, linoliec acid and linolenic acid content. Inbreeding depression of the crosses in F_2 generation for seed yield per plant varied between -46.94 percent for Meera X JLS-9 and 36.93 percent for JLS-9 X RLC-76 with an average of 13.47 percent. Whereas, for oil content it varied between -22.50 percent for Padmini X LC-185 and 24.49 percent for Meera X KL-221. High degree of heterosis followed by high inbreeding depression was found in number of capsule per plant, 1000 seed weight, seed yield per plant, palmitic acid, stearic acid and oliec acid content. This indicates the presence of non-additive gene action in those characters. The present work was corroborated with the works of Rao and Singh (1983), Saraswat *et al.* (1993), Sharma *et al* (2005), Rao (2006), Kiran and Kanojia (2014). Table 4 revealed range of *per se* performance, heterobeltiosis (BP), standard heterosis (SH), inbreeding depression (ID), along with most heterotic crosses and inbreeding depression for 16 characters in linseed.

The cross JLS-9 X KL-221 showed maximum significant positive heterosis over better parent and standard check while in oil content, the cross LMS-149-4 X RLC-76 recorded maximum heterosis over better parent and the cross Meera X KL-221 over the standard variety. Therefore, the superior segregants from the cross, JLS-9 X KL-221 may be selected for further improvement in the seed yield and Meera X KL-221 for oil content.

REFERENCES

Ameta V, Shah MA, Lakshyadeep (2005) Studies on heterosis and combining ability for fatty acids in linseed (*Linum usitatissimum*). Journal of Medicinal and Aromatic Plant Sciences 27(4): 615-618.

Anonymous (2015) Progress report of All India Coordinated Research Project on Linseed 2014-15, Coordinating Unit, CSAUAT, pp 74.

Fonseca S, Patterson F (1968) Hybrid vigour in seven parent diallel crosses in common winter wheat (*Triticum aestivum* L.). Crop Sciences 8: 85-95.

Gill KS (1987) Linseed. Indian Council of Agric Res New Delhi.

Kausal KK, Gupta SC (1981) Note on heterosis in linseed. Indian Journal of Agricultural Sciences 51(9): 680-682.

Kumar S, Kerkhi SA, Kumar A, Singh SD (2013) Combining ability and heterosis analysis in linseed (*Linum usitatissimum* L.). Annals of Agricultural Research 34(3): 197-204.

Kumar M, Singh PK, Kumar M (2002) Heterosis in linseed (*Linum usitatissimum* L.). Annals of Agricultural Research 23(3): 506-508.

Kumar S, Kerkhi1 SA, Singh SD, Singh M, Kumar A (2013) Combining ability and heterosis analysis in linseed (*Linum usitatissimum* L.) for yield and oil quality. Annals of Agricultural Research, New Series 34(4): 298-305.

Kiran, Kanojia RK (2014) Heterosis and inbreeding depression in linseed (*Linum usitatissimum* L.) New Agriculturist 25(2): 185–188.

Meredith WR, Bridge RR (1972) Heterosis and gene action in cotton (*Gossypium hirsutum* L.) Crop Sciences 12: 304-310.

Mishra VK, Rai M (1993) Estimates of heterosis for seed yield, components of seed and oil in linseed (*Linum usitatissimum* L.). Indian Journal of Genetics and Plant Breeding 53(2): 161-164.

Mishra R, Shailesh M, Veena B, Divya M (2013) Combining ability and heterosis for seed yield and its component in linseed (*Linum usitatissimum* L.). Advances in Life Sciences 2(1): 44-47.

Pali V, Mehta N (2014) Combining ability and heterosis for seed yield and it's attributes in linseed (*Linum usitatissimum* L.). The Bioscan 9(2): 701-706.

Pant SC, Mishra V K (2008) Heterosis over Superior Parents under Diallel Cross in Linseed/Flax (*Linum usitatissimum* L.). Indian Journal of Plant Genetic Resources 21(2): 93- 97.

Rao SK, Singh SP (1983) Heterosis and inbreeding depression in linseed. Indian Journal of Agricultural Sciences 53(6): 409-417.

Rao SS (2006) Heterosis and inbreeding depression in linseed (*Linum usitatissimum* L.). Journal of Oilseeds Research 23(2): 187-190.

Ratnaparkhi RD, Dudhe MY, Gawande ND, Bhongle SA (2004) Heterosis in relation to combining ability effects in linseed. Annals of Plant Physiology 18(2): 182-186.

Reddy MP, Arsul BT, Shaik NR, Maheshwari JJ (2013) Estimation of heterosis for some traits in linseed (*Linum Usitatissimum* L.). IOSR Journal of Agriculture and Veterinary Science 2(5): 11-17.

Saraswat AV, Kumar S, Verma MM, Virk DS, Chahal GS (1993) Heterosis and inbreeding depression in some early hybrids of linseed. *In*: Heterosis Breeding in Crop Plants. Theory and Application: Short Communicati ons. *Symposium,* Ludhiana, 23–24 February, 1993, pp 52–53.

Sharma R, Tiwari SK, Singh P, Kant R (2005) Heterobeltiosis and inbreeding depression in linseed. Agricultural Science Digest 25(1): 35-37.

Tripathi S, Mishra V, Tripathi HC (2011) Heterosis and inbreeding depression in relation to other genetic parameters for yield and its attributes in Linseed (*Linum usitatissimum* L.). New Agriculturist 22(2): 207-210.

Singh SB, Marker S (2006) Linseed: A plant with many uses. Agrobios News letter 5(2): 1-3.

Singh V, Chauhan MP, Kumar K, Singh RB (2006) Heterosis for yield and yield attributes in linseed (*Linum usitatissimum* L.). Farm Science Journal 15(1): 29-31.

Singh P, Srivastava AN, Singh IB, Mishra R (1987) Heterosis and inbreeding depression in relation to *per se* performance in linseed. Farm Science Journal 2(1): 68-73.

Singh PK, Srivastava RL, Narain V, Dubey SC (2009) Combining ability and heterosis for seed yield and oil content in linseed (*Linum usitatissimum* L.). Indian Journal of Agricultural Sciences 79(3): 229-232.

Sood S, Kalia NR, Bhateria S (2011) Combining ability and heterosis studies across environments in linseed (*Linum usitatissimum* L.). Acta Agronomica Hungarica 59(1): 87-102.

Tak GM, Gupta VP (1993) Studies of heterosis in linseed. Indian Journal of Agricultural Sciences 27(4): 181-184.