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PL Chaure
M.Sc. Student,
Department of Agricultural Botany, College of Agriculture, Latur, Maharashtra, India

PU Dhone
M.Sc. Student, Department of Agricultural Botany, College of Agriculture, Parbhani, Maharashtra, India

Mahesh M Mahajan
M.Sc. Student Biotechnology Laboratory, ICAR-NRC on Plant Biotechnology, New Delhi, India

AM Misal
Groundnut Breeder,
Oilseed Research Station,
Latur, Maharashtra, India

Correspondence
PL Chaure
M.Sc. Student,
Department of Agricultural Botany, College of Agriculture, Latur, Maharashtra, India

Studies on heterosis for yield and yield components in linseed (*Linum usitatissimum L.*)

PL Chaure, PU Dhone, Mahesh M Mahajan and AM Misal

Abstract
A study was made in linseed (*Linum usitatissimum* L.) to assess the extent of heterosis in 25 F_1 hybrids derived from line X tester fashion. The 25 F_1 hybrids and their ten parents (5 lines X 5 testers) were used to estimate the heterosis ten traits including seed yield. The derived twenty five crosses were studied to investigate heterosis over standard checks RLC-4 and NL-260. The best crosses based on heterosis and sca effect per se performance were OL-98-13-01 x LMS-210-01-27, RL292-02 x T-397, NL-97 x SHARDA, SLS-89 x SHARDA, and OL-98-03-01 x SHARDA, was identified as the best crosses combination. These better performing hybrids can be used for exploiting hybrid vigour.

Keywords: Linseed, heterosis, L x T

Introduction
Linseed, (*Linum usitatissimum* L. (n=15), also called flax is an important oilseed crop grown for both seeds and fibers which belongs to the family linaceae having 14 genera and over 200 species. Linseed, also called common flax, is an annual herbaceous plant and grown to a height of 30 to 120 cm. Linseed is generally confined to sea level or low elevation and the plains. As seed crop, it can be grown at higher altitude also. It is cool season crop and requires moderate to cool temperature during the growing season. Various parts of the plant have been used to make fabric, dye, paper, medicines, fishing nets, hair gels and soap. Nutritional value per 100g flax seed is Energy 530 kcal, Carbohydrates- 28.98g, Sugars-1.55g, Dietary fiber-27.3g, Fat-37.1g, Protein-20.3g, Thiamine -0.23mg, riboflavin- 0.07mg, Niacin-1.0mg, Pantothenic acid (B5)-0.985mg (20%), Vitamin B6- 0.473mg (36%), Vitamin C-0.6mg (1%), Calcium-170mg (26%), Iron- 3.70mg (46%), Magnesium-392mg (106%), phosphorus-642mg (92%), Potassium-813mg (17%), Zinc-4034mg (43%).
Discovery of hybrid vigour by Shull (1908) [10] has given birth to heterosis breeding. The phenomenon of heterosis has provided an important genetic tool in improving the yield of self and cross fertilized crops plants. Commercial exploitations of heterosis and possibility of developing hybrids in Wheat, Athwal and Borlaug (1967) [2] suggested self and cross fertilized plants are similar in their heterotic response and use of heterosis should carefully be considered in all plants irrespective of their breeding system.

Material and methods
The present investigation on linseed was conducted at the department of Agricultural Botany; experimental farm, Oilseeds Research Station Latur during *Rabi*-2013. The present material consisting of five line and five testers were crossed in a line X testers mating design resulting in twenty five hybrids with two standard checks *viz;* RLC-4 and NL-260. Twenty five hybrids and their ten parents were sown in rows with spacing 30 cm between row and 15 cm between plants in row during October- 2013. The experiment was conducted in randomized block design with two replications. A fertilizer schedule of 25:50:00 kg of NPK per hectare was followed a long with the recommended cultural operations and plant protection measures. Observations were recorded on ten biometrical traits viz; days to first flowering, days to 50 percent flowering, days to maturity, plant height (cm), number of branches per plant, number of capsule per plant, number of seed per capsule, 1000 seed weight(g), oil content and seed yield per plant(g). The estimation of heterosis was done based on the method developed by Rai, (1979) [6] and the analysis of variance for combining ability was done based on the method developed by Kempthorne (1957) [3] on five randomly selected plants.

Result and discussion
The analysis of variances for various economic traits is presented in table (1a). Analysis of variance showed significant differences among parents for all ten traits studied.

This revealed the presence of significant variability in the experimental material. Earliness in the flowering is highly desirable. The crosses exhibiting significant negative heterosis effects for days to first flowering, days to 50 percent flowering and days to maturity are considered as desirable. The range heterosis for days to first flowering was from (-21.29) RLC-133 x GS-61 to (-0.72) RL-292-02 x SHARDA over mid parent From (-27.38) RLC-133 x GS-61 to (-2.82) RL-292-02 x Sharda over better parent and (-30.68) RLC-133 x GS-61 to (-21.79) RLC-133 x GS-61 over standards checks NL-260 and RLC-4 respectively. Among the crosses RLC-133 x GS-61 (-21.29) exhibited highest significant negative heterosis over mid parent followed by SLS-89 x GS-61 (-19.75). The cross RLC-133 x GS-61 (-27.29) exhibited highest significant negative heterosis over better parent followed by SLS-89 x GS-61 (-22.62) earlier result obtained by Sharma *et al*. (2005) [8], Mohammadi (2010) [4].

The range of heterosis for days to 50% flowering was from (-17.77) SLS-89 x LMS-210-01-27 to (1.10), OL-98-13-01 x GS-61 over mid parent, from (-18.80) SLS-89 x LMS-210-01-27 to (-5.43) NL-97 x Sharda over better parent and (-20.59) SLS-89 x LMS-210-01-27 to (5.75) OL-98-13-01 x GS-61 over standards checks NL-260 and RLC-4. Among the crosses SLS-89 x LMS-210-01-27 (-17.77) exhibited highest significant negative heterosis over mid parent followed by SLS-89 x JLS-9 (-15.42). The cross SLS-89 x LMS-210-01-27 (-18.18) exhibited highest significant negative heterosis over better parent followed by SLS-89 x JLS-9 (-17.48).

The range of heterosis for days to maturity was from -11.94 (OL-98-13-01 x Sharda) to 1.87 (OL-98-13-01 x LMS-210-01-27) over mid parent from -12.63 (OL-98-13-01 x sharda) to 1.60 (OL-98-13-01 x LMS-210-01-27) over better parent such result obtained by Patel (1999) [5], Sharma *et al* (2005) [8] and Ram Jeet and Singh (2010) [7].

The plant height is highly desirable for this positive heterosis effects are desirable. The cross RL-292-02 x Sharda (15.00) exhibited the highest significant positive heterosis over mid parent followed by NL-97 x GS-61 (10.14), NL-97 x LMS-210-01-27(10.14) and NL-97 x LMS-210-01-27 (8.52). The cross NL-97 x LMS-210-01-27 (6.14) exhibited the highest significant positive heterosis over better parent followed by RL-292-02 x Sharda (5.50). The Number of branches per plant ranged between -12.50. (SLS-97 x T-397) to 45.45 (RL-292-02 x JLS-9) over mid parent, from -20.00 (OL-98-13-01 x Sharda) to 37.50 (SLS-89 x Sharda) over better parents, from -12.50 (SLS-89 x T-397) to 37.50 (SLS-89 x Sharda) over the check NL-260 and from 40.00 (SLS-89 x T-397) to 120.00 (SLS-89 x sharda) over the standard check RLC-4.

For number of capsule per plant the cross SLS-89 x sharda (82.56) exhibited the highest significant positive heterosis over mid parent followed by RL-292-02 x JLS-9 (67.79), RLC-133 x T-397 (62.50), NL-97 x T-397 (48.86) and RL-292-02 x T-397 (48.34). The cross SLS-89 x sharda (82.56) exhibited the highest significant positive heterosis over better parent followed by RLC-133 x T-397 (54.76), RL-292-02 x JLS-9 (52.44), and NL.97 x T-397 (42.39). Result showed that and Shikha Tripathi *et al.* (2011) [9].

The range of heterosis for number of seed per capsule was from -9.68 (RL-292-02 x GS-61) to 48.15 (NL-97 x sharda) over mid parent, from -12.50 (RL-292-02 x GS-61) to 42.86 (NL-97 x sharda) over better parents, from 7.69 (RL-292-02 x GS-61) to 53.85 (NL-97 x sharda) over the check NL-260 and from -7.69 (RL-292-02 x GS-61) to 53.85 (NL-97 x sharda) over the check RLC-4.

The cross RLC-133 x JLS-9 (31.31) exhibited the highest significant positive heterosis over mid parent followed by RL-292-2 x T-397 (23.74), SLS-89 x JLS-9 (23.20) and NL-97 x JLS-9 (21.10). The cross RLC-133 x JLS-9 (13.79) exhibited the highest significant positive heterosis over better parent followed by RL-292-02 x T-397 (11.19) and RLC-133 x LMS-210-01-27 (5.31). The cross OL-98-13-01 x LMS-210-01-27 (30.28) exhibited the highest significant positive heterosis over the check NL-260 and the crosses OL -98-13-01 x LMS-210-01-27(30.80) exhibited the highest significant positive heterosis over the check RLC-4 for 1000 seed weight.

The range of heterosis for oil content was from -2.50 (SLS-89 x LMS-210-01-27) to 3.93 (RL-292-02 x JLS-9) over mid parent, from -3.64 (RLC-133 x LMS-210-01-27) to 2.93 (RL-292-02 x JLS-9) over better parents. For seed yield per plant, among crosses (RL-292-02 x T-397) (268.03) exhibited the highest significant positive heterosis over mid parent followed by (RLC-133 x T-397) (220.43) and (NL-97 x T-397) (195.39). The cross (RL-292-02 x T-397) (260.31) exhibited the highest significant positive heterosis over better parent followed by RLC-133 x T-397 (202.03), NL-97 x T-397 (159.54) and (RL-292-02 x JLS-9) (134.78) similar result that Sharma *et al*. (2005) [8] and Sood. (2011) [11].

The cross OL-98-13-01x LMS-210-01-27 exhibited significantly high sca effects for five characters *viz*., days to maturity, number of seed capsule, 1000 seed weight, seed yield per plant and oil content.

Likewise, the best crosses identified for various yield contributing characters were RLC-133 x LMS-210-01-27, RLC-133 x GS-61, RL-292-02 x T-397, RL-292-02 x JLS-9, RL-292-02 x GS-61, SLS-89 x LMS-210-01-27,OL-98-13-01 x Sharda and RL-292-02 x Sharda for days to first flowering, days to 50 percent flowering and days to maturity. NL-97 x SHARDA, SLS-89 x T-397, RLC-133 x Sharda, and SLS-89 x JLC-8 for plant height, number of branches per plant and number of capsule per plant. OL-98-13-01 x JLS-9, OL-98-13-01 x Sharda, NL-97 x GS-61, RLC-133 x Sharda and RL-292-02 x LMS-210-01-27 for No of seed per capsule and 1000 seed weight. NL-97 x GS-61, SLS-89 x LMS-210-01-27, SLS-89 x T-397, RL-292-02 x LMS-210-01-27, RLC-133 x T-397, OL-98-13-01 x GS-61 and RLC-133 x LMS-210-01-27 for seed yield per plant and oil content on the basis of sca effects indicating suitability for exploitation of respective characters.

Table 1(a): Analysis of variance of parents and hybrids for 10 characters in Linseed.

Sr. No.	Characters	Sources of variation			
		Replication MSS	Treatment MSS	Error MSS	S.E.(±)
		d.f. (1)	d.f. (32)	d.f. (32)	
1	Days to first flowering	1.157	15.699**	1.245	0.77
2	Days to 50 % flowering	1.428	13.163**	1.516	0.89
3	Days to maturity	3.241	12.040**	3.243	1.35
4	Plant height (cm)	41.657	56.922**	20.127	2.49
5	No. of branches / plant	0.0571	0.586*	0.263	0.38
6	No. of capsule / plant	4.628	186.498**	31.363	4.06
7	No. of seed / capsule	0.70000	1.463*	0.582	0.50
8	1000 seed weight (gm)	0.00961	0.839**	0.1251	0.25
9	Oil content (%)	0.0108	0.8006**	0.0666	0.181
10	Seed yield / plant (gm)	0.00052	2.856**	0.0799	0.19

*and ** indicated the significance at 5 and 1 percent respectively.

Table 1(b): Range of heterosis and number of crosses showing significant heterosis in desired direction for yield & yield and yield contributing characters in Linseed.

Sr. No.	Name of the character	Heterosis (%) over MP		Heterosis (%) over BP		Heterosis (%) over SC-1		Heterosis (%) over SC-2	
		Range	No. of desired crosses	Range	No. of desired crosses	Range	No. of desired crosses	Range	No. of desired crosses
1	Days to frist flowering	-21.29 to -0.72	18	-27.38 to -2.82	23	-30.68 to -13.64	25	-21.79 to -2.56	19
2	Days to 50 percent flowering	-17.77 to 1.10	17	-18.18 to -5.43	24	-20.59 to -9.80	25	-6.90 to 1.15	1
3	Days to maturity	-11.94 to 1.87	2	-12.63 to 1.60	2	-10.75 to 2.69	2	-6.21 to 7.91	19
4	Plant height (cm)	-21.10 to 15.00	7	-24.56 to 6.14	10	-29.75 to -2.48	16	-30.33 to -0.82	17
5	Number of branches / plant	-12.50 to 45.45	2	-20.00 to 37.50	1	-12.50 to 37.50	1	40.00 to 120.00	19
6	Number of capsule / plant	-6.40 to 67.79	11	-20.14 to 67.02	8	4.40 to 53.85	12	11.76 to 84.71	19
7	Number of seed / capsule	-9.68 to 48.15	5	-12.50 to 42.86	2	7.69 to 53.85	7	7.69 to 53.85	7
8	1000 seed weight (g)	-25.22 to 31.31	13	-25.83 to 13.79	8	-6.18 to 30.28	16	-5.80 to 30.80	16
9	Oil content (%)	-2.99 to 3.93	26	-3.64 to 2.93	26	-4.09 to 1.44	21	-3.10 to 2.49	22
10	Seed yield / plant (g)	-22.96 to 268.03	23	-28.29 to 260.31	20	8.92 to 197.54	23	-31.92 to 85.96	19

Table 1(c): Information on best 5 crosses based on *per se* performance in Linseed.

Sr. No	Cross	*Per se* performance Seed yield/ plant (g/pl.)	Heterosis				GCA effects		SCA effects	Significant heterosis in desired direction for other traits
			M.P (%)	B.P (%)	SC-1 NL-97 (%)	SC-2 RLC-4 (%)	Parent I (Female)	Parent II (Male)		
1	OL-98-13-01 X LMS-210-01-27	4.84	69.06**	48.54**	197.54**	85.96**	0.588**	-0.274**	0.592**	Days to first flowers, Days to 50% flowers, days to maturity, Seed yield / plant.
2	RL-292-02 X T-397	4.72	268.3**	260.31**	190.46**	81.54**	0.202*	0.091	0.498*	Days to first flowers, No. of capsule/ plant, 1000 Seed weight, Seed yield/ plant.
3	NL-97 X Sharda	4.70	116.34**	79.73**	189.23**	80.77**	0.233*	0.568**	-0.030	Days to first flowers, Plant height, Seed yield /plant.
4	SLS-89 X Sharda	4.63	95.15**	77.06**	184.92**	78.08	-0.877**	0.568**	1.010**	1000 Seed weight, Seed yield / plant.
5	OL-98-13-01 X Sharda	4.59	56.39**	41.01**	182.46**	74.54**	0.588**	0.568**	-0.495*	Days to first flowers, Days to 50% flowers, Days to maturity, Plant height, Seed yield / plant.

* and ** indicated the significance at 5 and 1 percent respectively.

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