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Studies of heterosis and inbreeding depression in linseed (*Linum usitatissimum* L.)

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Abstract
An experiment was conducted during 2017-18 at Experimental Research farm BAU, Ranchi, to estimate the heterosis and inbreeding depression in six crosses of linseed for different characters. Significant heterosis over better parent was observed for days to 50% flowering, technical height, plant height, seed yield per plant, 1000-seed weight and oil content. The heterosis over economic parent-I (Parvati) showed significant desirable for days to 50% flowering, days to maturity, technical height, plant height, number of capsules per plant, number of seeds per capsule, seed yield per plant, 1000-seed weight and oil content in different crosses. Heterosis over check variety-2 (T-397) was observed significant and in desirable direction for number of capsules per plant, capsule diameter, seed yield per plant and 1000- seed weight and oil content in various crosses. Significant and desirable inbreeding depression was seen for days to 50% flowering, days to maturity, technical height, plant height, number of seeds per capsule, and oil content in different crosses.

Keywords: Heterosis, Inbreeding depression, Linseed.

Introduction

Linseed, a self-pollinated, is being raised for both oil and fiber which belongs to the family Linaceae having 14 genera and over 200 species. Out of these only *Linum usitatissimum* is the only cultivated species of genus *Linum*. All other species in this genus are wild and are less important economically. India is considered as centre of origin of linseed, from where it spread to other parts of the world including Ethiopia (Wakjira *et al*., 2004) [1]. Oil content in linseed ranges from 33-45 % with protein content of 24% (Gill, 1987) [2]. Singh and Marker (2006) [3] reported that its oil is high in omega-3 fatty acid which is believed to be helpful in lowering cholesterol level when included in the diet chain. Linseed cake containing 3 per cent oil and 36 per cent protein serves as a superior supplement for the dairy cattle due to its excellent palatability. In crop improvement programme, heterosis breeding is a quick and convenient way of combining desirable traits in the production of F_1 hybrids (Ramesh *et al*., 2013 [4] and Jhajharia *et al.*, 2013 [5]). Magnitude of heterosis provides a basis for genetic diversity and guideline to the choice of desirable parents for developing superior F_1 hybrids so as to exploit hybrid vigour and for building gene pool to be exploitation in population improvement. Exploitation of heterosis in linseed in the form of hybrid varieties is a breakthrough in the field of linseed improvement (Pali and Mehta, 2014) [6]. Heterosis is superiority of the hybrid over the mid parent or better parent as standard variety and is result of allelic or non allelic interaction of gene under the influence of particular environment. Among the various technological option heterosis breeding approach is most successful one and has already been intensively exploited in self pollinated plant like Linseed, the as utilization of heterosis depend upon direction and magnitude of heterosis and feasibility and type of gene action involved. In present investigation heterosis in six F_1 crosses over mid parent, better parent and over economic checks (Parvati and T-397) and inbreeding depression in F_2 were studied. This study reveals good scope for isolating suitable parents for hybrid development and to select potent transgressive segregants which can be further evaluated for enhanced yield potential.

Materials and Methods

The basic materials for the present investigation comprised of the parents (P1 and P2), the F1s, F2s and of F3s of each of the six crosses viz., Himalshi-2 x SLS-61, Himalshi-2 x BAU-13-1, Himalshi-2 x Meera, Mukta x SLS-61, Mukta x BAU-13-1 and Mukta x Meera. The experiment was carried out at the experimental area of the Department of Plant Breeding and Genetics, BAU, Kanke, Ranchi during *Rabi* 2017-18 with a spacing of 30 cm and 10 cm between and within the rows respectively with 3 meter row length. The non-segregating generations (Parents, F_1s and Checks) were grown in 3 rows, the segregating F_2 generations were grown in 10 rows and F_3s were grown in 20 rows. The observations were recorded from 10 randomly selected plants from P_1, P_2, F_1s and check, 20 plants from F_2s and F_3s from each plots and generation for eleven characters. Heterosis over standard variety (Parvati / T-397) [standard heterosis] was calculated as given by Meredith and Bridge (1972) [7], over better parent [heterobeltiosis] by Fonseca and Patterson (1968) [8] and mid-parent [relative heterosis] by Turner (1953)[9}. The cause of decrease in fitness and vigor *i.e*. Inbreeding depression was estimated in per cent with the help of F_1 and F_2 populations of the each six crosses.

Results and discussion

The estimation of heterosis depicted in Table-1 revealed that none of the cross exhibited significant heterosis for all the characters over mid parent, better parent and checks verities. The degree and direction of heterotic response varied not only from character to character but also from cross to cross. In general, considerable amount of significant desirable heterosis over mid parent observed for most of the characters. Significant and desirable heterosis over mid parent was observed in two crosses (Mukta x BAU-13-1 and Mukta x Meera) for technical height, one cross (Mukta x Meera) for plant height, one cross (Himalsi-2 x Meera) for number of capsules per plant, one cross (Mukta x BAU-13-1) for capsule diameter, three crosses (Himalsi-2 x SLS-61,Himalsi-2 x BAU-13-1, Himalsi-2 x Mukta) for seed yield per plant, five crosses (Himalsi-2 x BAU-13-1, Himalsi-2 x Meera, Mukta x SLS-61, Mukta X BAU-13-1, Mukta x Meera) for 1000-seed weight and four crosses (Himalsi-2 x BAU-13-1, Himalsi-2 x Meera, Mukta x SLS-61, Mukta x Meera) for oil content.

Heterosis over better parent it was observed significant and in desirable direction for two crosses (Himalsi-2 x SLS-61and Mukta x BAU-13-1) for days to 50% flowering, five crosses (Himalsi-2 x SLS-61, Himalsi-2 x BAU-13-1, Himalsi-2 x Meera, Mukta x BAU-13-1 and Mukta x Meera) for technical height, one cross (Mukta X Meera) for plant height, two crosses (Himalsi-2 x BAU-13-1 and Himalsi-2 x Meera) for seed yield per plant, three crosses (Himalsi-2 x BAU-13-1, Mukta x SLS-61and Mukta x Meera) for 1000-seed weight and two crosses (Himalsi-2 x Meera and Mukta x SLS-61)) for oil content.

Heterosis over check variety-1 (Parvati) was found significant desirable in three crosses (Himalsi-2 x SLS-61, Mukta x SLS-61 and Mukta x BAU-13-1) for days to 50% flowering, three crosses (Himalsi-2 x SLS-61, Himalsi-2 x BAU-13-1and Himalsi-2 x Meera) for days to maturity and three crosses (Mukta x SLS-61, Mukta x BAU-13-1 and Mukta x Meera) each for technical height and plant height, three crosses (Himalsi-2 x SLS-61, Himalsi-2 x Meera and Mukta x SLS-61) for number of capsules per plant, four crosses (Himalsi-2 x SLS-61, Himalsi-2 x BAU-13-1, Himalsi-2 x Meera and Mukta x BAU-13-1) for number of seed per capsule, three crosses (Mukta x SLS-61, Mukta x BAU-13-1 and Mukta x Meera) for capsule diameter, all six crosses for seed yield per plant, five crosses (Himalsi-2 x BAU-13-1and Himalsi-2 x Meera, Mukta x SLS-61, Mukta x BAU-13-1 and Mukta x Meera) for each 1000-seed weight and oil content.

Heterosis over check variety-2 (T-397) was observed significant and in desirable direction for one cross (Himalsi-2 x SLS-61) for number of capsules per plant, three crosses (Mukta x SLS-61, Mukta x BAU-13-1and Mukta x Meera) for capsule diameter, all six crosses each for seed yield per plant and 1000- seed weight and five crosses (Himalsi-2 x BAU-13-1, Himalsi-2 x Meera, Mukta x SLS-61, Mukta x BAU-13-1and Mukta x Meera) for oil content.

The result of Singh *et al*. (1983) [10] for number of capsules per plant, 1000-seeds weight and capsule size, Verma and Mahto (1996) [11] for days to maturity, seed yield per plant, number of capsules per plant, number of primary branches per plant, plant height and number of seeds per capsule, Kusalkar *et al.*(2002) [12] for number of capsules per plant, number of seeds per capsule, oil content, 1000-seed weight and seed yield per plant, Sharma *et al.* (2005) [13] for seed yield per plant, oil content, days to 50% flowering, number of primary branches per plant, days to maturity and 1000-seed weight, Kiran *et al.* (2012) [14] for days to 50% flowering, seed yield per plant and plant height, Kumar *et al.* (2013) [15] for number of primary branches per plant, number of capsules per plant, 1000-seed weight, seed yield per plant, plant height and number of seeds per capsule, Pali and Mehta (2014) [6] for seed yield per plant, days to 50% flowering, number of capsules per plant, and oil content, Reddy *et al.* (2013) [16] for plant height, days to 50% flowering, number of capsules per plant, 1000-seeds weight and seed yield per plant and Sharma *et al.* (2018) [17] for both days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule and seed yield per plant were in confirmity of the present finding. Dakhore *et al*. (1987) [18], Singh *et al.*(1987) [19], Wang *et al.* (1996) [20], Kusalkar *et al.* (2002) [12], Kiran *et al.* (2012) [14], Singh *et al*. (2014) [21], Reddy *et al.* (2013) [16], Sharma *et al.* (2018) [17] also reported the contribution of these components to the heterosis for seed yield per plant.

Inbreeding depression in F_2 generation was estimated for all the characters under study. The result indicted that two crosses (Himalsi-2 x Meera and Mukta x SLS-61) for days to 50% flowering, two crosses (Mukta x SLS-61 and Mukta x BAU-13-1) for days to maturity, four crosses (Himalsi-2 x SLS-61) for technical height, three crosses (Himalsi-2 x BAU-13-1, Himalsi-2 x Meera and Mukta x SLS-61) for plant height, all six crosses for each number of primary branches per plant and number of capsules per plant, five crosses (Himalsi-2 x BAU-13-1, Himalsi-2 x Meera and Mukta x SLS-61, Mukta x BAU-13-1 and Mukta x Meera) for number of seeds per capsule, all six crosses for each capsule diameter and seed yield per plant, five crosses (Himalsi-2 x SLS-61, Himalsi-2 x BAU-13-1, Himalsi-2 x Meera , Mukta x SLS-61 and Mukta x Meera) for 1000-seed weight and three crosses (Himalsi-2 x Meera and Mukta x SLS-61 and Mukta x BAU-13-1) for oil content revealed significant positive inbreeding depression indicating detoriation in their performance in next generation. It might be due to lack of segregation of desirable genes responsible for dominance effect or may be due to tight linkage of desirable genes or due to phenomenon of fixing of heterozygocity. Such crosses could prove useful in diallel selective mating system. Srivastava *et al.* (2003) [22] and Swarkar *et al.* (2003) [23] for seed yield per plant, Sharma *et al*. (2005) [13] for days to 50% flowering, number of primary branches per plant, days to maturity and 1000-seed weight, Sharma *et al.* (2018) [17] days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule and seed yield per plant, Kiran and Kanojia (2014) [24] for days to 50% flowering, plant height, number of primary branches per plant, number of capsules per plant and 1000-seed weight also reported the inbreeding depression.

Nature and magnitude of heterosis and inbreeding depression varied with crosses as well as characters. Considering the very high degree of heterosis in desirable direction and importance of non-additive genetic variance for yield and yield contributing components; two crosses viz., Himalshi-2 x Meera and Mukta x SLS-61 were identified better specific cross combination to be used for heterosis breeding programme. However, predominant role of non-additive gene action in expression of heterosis accompanied by inbreeding depression for these traits discussed above would render difficulty in the fixation and sustainability of heterotic effects in later generations.

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Table 1: Estimates of Heterosis (MP, BP and Checks) and Inbreeding depression in per cent for different yield attributing character in linseed.

Characters and heterosis		Himalsi-2 x SLS-61	Himalsi-2 x BAU-13-1	Himalsi-2 x Meera	Mukta x SLS-61	Mukta x BAU-13-1	Mukta x Meera	CD 5%	CD 1%
Days to 50 % flowering	MP	-0.67	2.43	0.22	-0.91	-2.25	-1.34	3.19	4.26
	BP	-6.30**	-2.52	-3.78	-4.80	-5.24*	-3.49	3.68	4.92
	C1	-6.30**	-2.52	-3.78	-8.40**	-8.82**	-7.14	3.68	4.92
	C2	-0.45	3.57	2.23	-2.68	-3.13	-1.34	3.68	4.92
	ID	-6.27**	-1.72**	7.42**	0.00**	-1.38**	-0.90**	3.68	4.92
Days to maturity	MP	3.34*	5.59**	0.26	4.58**	5.76**	4.57**	3.95	5.27
	BP	2.55	5.18**	-0.76	1.69	1.69	1.93	4.57	6.09
	C1	-7.59**	-6.67**	-10.11**	-2.99	-2.99	-2.76	4.57	6.09
	C2	9.24**	10.33**	6.25**	14.67**	14.67**	14.95**	4.57	6.09
	ID	-5.22**	-2.46**	-5.11**	1.18**	1.18**	-4.25**	4.57	6.09
Technical height (cm)	MP	-0.16	-1.22	-8.12	-8.29	-16.03*	-19.66**	3.51	4.68
	BP	-13.38*	-13.66*	-12.06*	-13.27	-21.24**	-35.77**	4.05	5.40
	C1	2.64	2.31	13.99*	-24.45**	-30.18**	-16.74*	4.05	5.40
	C2	46.31**	45.84**	62.48**	7.69	-0.47	18.68	4.05	5.40
	ID	1.71**	27.87**	27.05**	4.66**	-30.75**	-10.58**	4.05	5.40
Plant height (cm)	MP	4.38	9.85**	2.80	3.69	-7.93	-11.44**	4.00	5.33
	BP	0.21	-2.06	-3.31	-3.22	-8.75	-24.60**	4.62	6.16
	C1	0.16	-2.11	9.67*	-10.99**	-27.27**	-14.48**	4.62	6.16
	C2	29.71**	26.76**	42.03**	15.26**	-5.82	10.75*	4.62	6.16
	ID	-7.65**	26.02**	26.26**	12.11**	-11.70**	-3.95**	4.62	6.16
Number of primary branches per plant	MP	0.00	-5.88	-7.01	-16.76	-8.28	-9.32	1.02	1.36
	BP	-1.74	-16.38	-15.12	-20.11*	-20.00*	-18.89	1.18	1.57
	C1	25.19	6.67	8.15	6.67	6.67	8.15	1.18	1.57
	C2	20.71	2.86	4.29	2.86	2.86	4.29	1.18	1.57
	ID	21.89**	6.94**	11.64**	23.61**	16.66**	28.76**	1.18	1.57

*, ** --Significant at 5% and 1% level of significance respectively.MP = mid parent, BP = better parent,C1= check 1, C2= check2 and ID = inbreeding depression

Table 1 (Contd): Estimates of Heterosis (MP, BP and Checks) and Inbreeding depression in per cent for different yield and its attributing character in linseed.

Characters and heterosis		Himalsi-2 x SLS-61	Himalsi-2 x BAU-13-1	Himalsi-2 x Meera	Mukta x SLS-61	Mukta x BAU-13-1	Mukta x Meera	CD 5%	CD 1%
Number of Capsules per plant	MP	24.08	26.01	29.90*	-6.33	-19.72	-3.80	36.99	49.35
	BP	17.86	1.91	13.89	-10.26	-39.43**	-22.02	42.71	56.98
	C1	80.53**	40.46	56.98**	50.04*	1.27	30.37	42.71	56.98
	C2	54.35**	20.09	34.21	28.28	-13.42	11.47	42.71	56.98
	ID	25.20**	15.80**	53.54**	49.91**	13.80**	7.87**	42.71	56.98
Number of Seeds per	MP	1.54	0.97	2.83	0.40	4.28	1.28	0.62	0.83
	BP	0.38	0.39	-0.78	-5.34	-1.16	0.00	0.72	0.96

capsule	C1	14.35**	13.04**	10.43*	7.83	11.30*	3.48	0.72	0.96
	C2	-0.38	-1.52	-3.79	-6.06	-3.03	-9.85*	0.72	0.96
	ID	-1.90**	6.92**	21.26**	15.32**	1.71**	6.72**	0.72	0.96
Capsule diameter (mm)	MP	2.02	-1.05	-1.31	3.09	5.74*	2.27	0.36	0.48
	BP	-1.12	-8.79**	-4.44	0.89	2.51	0.19	0.42	0.56
	C1	0.75	3.39	-2.44	7.37*	16.19**	6.63*	0.42	0.56
	C2	4.93	7.68	1.61	11.83**	21.02**	11.05**	0.42	0.56
	ID	7.66**	7.61**	5.56**	12.48**	6.64**	5.84**	0.42	0.56
Seed yield per plant (g)	MP	39.92**	43.66**	66.79**	-0.31	-0.35	15.68	2.08	2.77
	BP	17.71	37.31*	60.23**	-4.06	-15.68	-8.52	2.40	3.20
	C1	100.61**	75.21**	86.38**	76.81**	55.40*	68.59**	2.40	3.20
	C2	93.15**	68.69**	79.44**	70.23**	49.62*	62.32**	1.27	1.70
	ID	42.66**	34.69**	69.71**	68.77**	26.09**	25.80**	1.27	1.70
1000seeds Weight(g)	MP	-5.10*	12.084**	17.90**	17.38**	4.45*	8.37**	0.32	0.42
	BP	-16.98**	6.82**	-1.02	11.04**	3.11	4.95*	0.37	0.49
	C1	-8.77**	17.82**	16.60**	36.80**	30.38**	29.30**	0.37	0.49
	C2	21.93**	57.46**	55.83**	82.83**	74.25**	72.81**	0.37	0.49
	ID	7.34**	11.02**	6.19**	23.23**	1.04	2.86**	0.37	0.49

*, ** --Significant at 5% and 1% level of significance respectively.MP = mid parent, BP = better parent,C1= check 1, C2= check2 and ID = inbreeding depression

Table 1 (Contd.): Estimates of Heterosis (MP, BP and Checks) and Inbreeding depression in per cent for oil content (%) in linseed at Ranchi.

Characters and heterosis		Cross combinations						CD 5%	CD 1%
		Himalsi-2 x SLS-61	Himalsi-2 x BAU-13-1	Himalsi-2 x Meera	Mukta x SLS-61	Mukta x BAU-13-1	Mukta x Meera		
Oil%	MP	-18.90**	3.23*	4.32**	3.98**	2.46	7.66**	1.10	1.47
	BP	-22.04**	-3.98**	3.98*	3.95*	0.79	2.96	1.27	1.70
	C1	-21.25**	12.75**	5.04**	5.64**	16.50**	13.24**	1.27	1.70
	C2	-10.14**	28.66**	19.86**	20.54**	32.94**	29.21**	1.27	1.70
	ID	-16.49**	-1.00**	5.49**	4.17**	6.27**	-1.06**	1.27	1.70

*, ** --Significant at 5% and 1% level of significance respectively.MP = mid parent, BP = better parent, C1= check 1, C2= check2 and ID = inbreeding depression

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