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Estimation of heterosis and inbreeding depression for seed yield and disease resistance in linseed (*Linum usitatissimum* L.)

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Abstract
A study was conducted for the estimation of heterosis and Inbreeding depression involving five parents and their six F_1s and six F_2s for seed yield, morphological traits and incidence of diseases in linseed. Estimates of heterosis revealed that all the six crosses showed significant and desirable heterosis over check variety for seed yield per plant, number of capsules per plant, capsule diameter and test weight. For wilt disease, the heterosis over mid-parent, better parent and standard check was found to be significant and negative in four crosses while rust disease showed significant and negative heterosis in three crosses. Inbreeding depression in F_2 generation was estimated for the characters under study. The character test weight showed positive significant inbreeding depression of F_2 generation. The inbreeding depression was significant and negative for both wilt and rust diseases in four and all the six crosses respectively.

Keywords: Linseed, heterosis, inbreeding depression, disease resistance

Introduction

Linseed (*Linum usitatissimum* L.) is one of the most important *Rabi* oilseed crop after rapeseed mustard. Linseed (*Linum usitatissimum* L.) 2x=2n=30 is an annual self-pollinated crop. It is commonly known as 'Alsi' or 'Tisi and is mainly cultivated for fibre (flax fibre) and seed oil (linseed oil) or both (dual purpose linseed). Linseed seed contains good percentage of oil varying from 33-45 and 24% crude protein in different varieties. It has medicinal and neutraceutical properties. Recently, it has gained a new interest in the emerging market of functional food due to its high content of fatty acids, alpha linolenic acid (ALA), an essential Omega-3 fatty acid and lignin (Reddy *et al*., 2013) [7]. Linseed oil has been used for a variety of industrial purposes for manufacturing of surface coating oils, varnish, linoleum, oil cloth, printing inks etc. and the oil free meal could be fed to livestock. Omega-3 fatty acids lower levels of triglycerides in the blood, thereby reducing heart disease, and also show promise in the battle against inflammatory diseases such as rheumatoid arthritis. On global scenario, India ranks third in area (approx. 2.94 lakh hectares) and third in production with 1.54 lakh tones (Anonymous, 2017-18) [1]. In spite of vast area and varied utility of crop, country has very low productivity (525 kg/ha) against world average of 1058 kg/ha. The major part of linseed crop growing area lies in the states of Madhya Pradesh., Chhattisgarh, Uttar Pradesh, Maharashtra, Bihar, Odisha, Jharkhand, West Bengal, Nagaland and Assam accounting for more the 97% of total area of the nation. (Anonymous, 2017-18) [1].

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 and Jhajharia, *et al*., 2013) [6, 2] which depends upon the balance of additive, dominance and interaction components as well as the distribution of the genes in the parental lines. Magnitude of heterosis provides a basis for genetic diversity and guideline to the choice of desirable parents for developing superior F_1 hybrids. Exploitation of heterosis in linseed in the form of hybrid varieties is a breakthrough in the field of linseed improvement (Pali and Mehta, 2014) [5]. Genetic improvement of any trait largely depends on the magnitude and direction of available heterosis. Therefore the main objective of investigation was to identify the heterotic cross for seed yield, morphological traits and *disease* resistance in linseed using six F_{1s} crosses over mid parent, better parent and over economic check (LC-54) and inbreeding depression in six F_{2s} were studied.

Materials and Methods

The basic materials for the present investigation comprised of five improved varieties of linseed namely, Meera, Shekhar, T-397, KL - 221 and JLS -9, 6F_1s, 6F_2s and one standard check variety (LC-54). The experiment was carried out at the experimental area of ZRS, Chianki, Daltonganj under BAU. Kanke, Ranchi during *Rabi* season of 2012-13 and 2013-14 in Randomized Block Design with three replications. The observations were taken from 10 randomly selected plants per entry and per replication in case of parents and F_1s and 30 plants were selected in case of F_2s generation. Heterosis over standard check variety (standard heterosis] was calculated as given by Meredith and Bridge (1972) [11], over better parent (heterobeltiosis) by Fonseca and Patterson (1968) [10] and mid-parent (relative heterosis) by Turner (1953) [12]. 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 percentage of heterosis over mid parent, better parent and standard check variety for seed yield, morphological traits and diseases resistance are presented in Table-1. Negative and significant values of heterosis are considered to be desirable for days to 50 per cent flowering, plant height, days to maturity and incidence of diseases reaction whereas positive and significant values are considered to be desirable for rest all other yield components.

Estimates of heterosis showed that none of the cross exhibited significant heterosis for all characters over mid parent, better parent and check variety (LC-54) in desirable direction. 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 was observed for seed yield per plant and number of capsules per plant in four crosses each. Two crosses each exhibited significant heterosis for capsule diameter and test weight and one cross each for primary branches per plant and days to maturity while considering the significant and useful heterosis over better parent, it was observed that three crosses each showed significant and desirable heterosis for days to 50 per cent flowering and days to maturity, while two crosses each for plant height, number of capsules per plant, seed yield per plant and test weight. One cross showed significant and desirable heterosis over better parent for the character primary branches per plant. All the six crosses showed significant and desirable heterosis over check for seed yield per plant, number of capsules per plant, capsule diameter, seed yield per plant and test weight. Five crosses showed significant heterosis over check for primary braches per plant, four crosses showed significant desirable heterosis for number of seeds per capsule. Two crosses showed significant heterosis in desirable direction for oil content and days to maturity. One cross exhibited significant heterosis over check for days to 50 per cent flowering. For wilt disease, the heterosis over mid-parent, better parent and standard check was found to be significant and negative in four same crosses while rust disease showed significant and negative heterosis in three crosses for mid-parent and better parent whereas for standard check it was significant and negative in four crosses which are desirable.

The result of Singh *et al*. (1983) [8] for number of capsules per plant, 1000-seed weight and capsule size, Verma and Mahto (1996) [9] 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) [4] 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) [3] for days to 50% flowering, seed yield per plant and plant height, Kumar *et al.* (2013) [14] 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) [5] for seed yield per plant, days to 50% flowering, number of capsules per plant, and oil content, Reddy *et al.* (2013) [7] for plant height, days to 50% flowering, number of capsules per plant, 1000-seed weight and seed yield per plant, Sharma *et al.* (2018) [15] 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 and Kumar *et al.*(2019) [17] for plant height, number of capsules per plant, capsule diameter, seed yield per plant, 1000-seed weight and oil content were in conformity of the present findings.

The best crosses were Meera x T-397, Meera x KL-221 and Shekhar x T-397 for seed yield per plant. It was also found that for increasing seed yield in cross Shekhar x T-397 was mostly due to desirable heterotic response of important traits like days to 50 per cent flowering, primary branches per plant, number of capsules per plant, number of seeds per capsule and test weight.

Inbreeding depression in F_2 generation was estimated for all the twelve characters. The result indicated that five crosses showed significant positive inbreeding depression for test weight while four crosses each showed significant positive inbreeding depression for seed yield per plant and number of capsules per plant. Three crosses showed positive significant inbreeding depression for number of primary branches per plant while two crosses for number of seeds per capsule. One cross each showed significant negative inbreeding depression for days to maturity and oil content while one cross each showed positive significant inbreeding depression for plant height, days to maturity and oil content indicating detoriation in their performance in next generation. The inbreeding depression was significant and negative for both wilt and rust diseases in four and all the crosses respectively. 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) [15] 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) [16] for days to 50% flowering, plant height, number of primary branches per plant, number of capsules per plant and 1000-seed weight and Kumar *et al.* (2019) [17] for days to 50% flowering, days to maturity, plant height, number of capsules per plant, number of seeds per capsule, seed yield per plant, 1000-seed weight and oil content also reported the inbreeding depression.

Thus the crosses showing significant economic heterosis in some crosses associated with high degree of inbreeding depression, in such hybrids significant heterosis in F_1 and high degree of inbreeding depression in F_2 could be attributed to high magnitude of non-additive gene effects. In contrast, the other heterotic crosses having high economic heterosis showed negative inbreeding depression, indicating the presence of additive gene effects. These crosses may be utilized following pedigree method for the selection of desirable segregants in advanced generation.

Table 1: Estimation of heterosis over mid parent, better parent and standard check variety for seed yield and yield attributing traits in linseed (*Linum usitatissimum* L.)

Location hybrid combination	Days to 50% flowering				Plant height (cm.)				No. of Primary branches/Plant			
	MP	BP	Check	ID	MP	BP	Check	ID	MP	BP	Check	ID
Meera x T397	-6.30	-12.55*	-6.30	-4.48	-2.32	-10.46	11.23	15.45 *	-12.87	-27.47 **	57.14 **	31.82
Meera x KL-221	-3.56	-9.80*	-3.36	1.30	-5.40	-14.63 *	6.06	9.03	5.00	-7.69	100.00 **	32.14 *
Meera x JLS-9	-3.64	-11.76*	-5.46	4.00	-3.09	-19.33 **	0.22	-2.97	4.17	-17.58 *	78.57 **	20.00 *
Shekhar x T397	-1.57	-2.65	-7.56	-2.27	16.38*	6.17	9.91	7.21	57.09**	40.26 **	157.14 **	22. 22*
Shekhar x KL-221	0.45	-0.44	-5.46	4.00	0.53	-6.83	-6.83	-3.07	-1.37	-6.49	71.43**	20.83
Shekhar x JLS-9	-2.28	-5.31	-10.08*	0.93	1.51	-0.13	-14.76	-0.26	-21.54 *	-33.77 **	21.43	11.76
CD. at 5%	6.91	7.98	7.98		7.81	9.01	9.01		0.88	1.02	1.02	
CD. at 1%	9.39	10.85	10.85	–	10.61	12.25	12.25	–	1.20	1.38	1.38	–

Location Hybrid combination	No. of capsules/plant				No. of Seeds/capsule				Capsule diameter (mm.)			
	MP	BP	Check	ID	MP	BP	Check	ID	MP	BP	Check	ID
Meera x T397	14.75	8.98	41.05**	39.23 **	2.59	-0.42	21.43 **	5.46	13.81 **	6.25	29.52 **	7.35
Meera x KL-221	20.71 *	6.80	38.23**	45.85 **	7.80	1.26	23.47 **	12.81 *	2.40	0.01	21.90 **	3.91
Meera x JLS-9	20.32 *	2.53	32.70**	17.66	3.62	-4.18	16.84 *	4.80	7.32	3.13	25.71 **	18.18
Shekhar x T397	25.09 **	24.98 *	45.47**	20.47 *	5.70	4.33	22.96 **	19.09 *	10.26 *	4.88	22.86 **	1.55
Shekhar x KL-221	31.56 **	22.16 *	41.95**	15.80 *	-2.49	-6.93	9.69	5.58	-2.04	-2.44	14.29 *	-1.67
Shekhar x JLS-9	19.07	6.23	23.44*	14.43	-9.68	-15.15 *	0.01	-0.51	4.56	2.44	20.00 **	13.49
CD. at 5%	13.42	15.50	15.50		0.84	0.97	0.97		0.70	0.81	0.81	
CD. at 1%	18.25	21.07	21.07	–	1.14	1.32	1.32	–	0.96	1.11	1.11	–

Location Hybrid combination	Days to maturity				Seed yield/plant (g)				Test weight (g)			
	MP	BP	Check	ID	MP	BP	Check	ID	MP	BP	Check	ID
Meera x T397	1.77	-2.43	0.75	7.46 *	33.16 **	23.19	84.78 **	25.10	3.27	0.40	88.81 **	11.07
Meera x KL-221	2.04	-2.91	0.25	-2.75 *	19.58	9.18	63.77 **	31.86	7.72	5.16	97.76 **	24.53 **
Meera x JLS-9	4.88 **	-0.97	2.26	2.94	27.03 *	13.53	70.29 **	45.53 **	3.53	-1.19	85.82 **	23.69 **
Shekhar x T397	-0.77	-3.96 *	-2.76	-1.80	38.04 **	32.29 *	84.06 **	44.49 *	14.94 *	13.52 *	106.72 **	23.10 **
Shekhar x KL-221	-2.06	-5.94 **	-4.76 *	1.05	35.54 **	28.12 *	78.26 **	50.41 **	16.94 **	15.98 *	111.19 **	21.20 **
Shekhar x JLS-9	-4.42 **	-8.91 **	-7.77 **	0.54	20.00	10.94	54.35 **	53.05 *	9.51	6.15	93.28 **	23.55 **
CD. at 5%	4.09	4.72	4.72		1.52	1.75	1.75		0.88	1.02	1.02	
CD. at 1%	5.55	6.41	6.41	–	2.06	2.38	2.38	–	1.20	1.39	1.39	–

Location hybrid combination	Oil content (percent)				Wilt disease reaction (%)				Rust disease reaction (%)			
	MP	BP	Check	ID	MP	BP	Check	ID	MP	BP	Check	ID
Meera x T397	-0.90	-2.21	3.76	0.90	-57.14 **	-61.00 **	-56.67 **	-130.77 **	-73.41 **	-73.86 **	-77.00 **	-356.52 **
Meera x KL-221	1.12	0.01	5.63 *	4.00 *	-45.95 **	-50.00 **	-44.44 **	-78.00 *	-65.88 **	-67.05 **	-71.00 **	-296.55 **
Meera x JLS-9	1.12	0.01	5.63 *	0.00	-27.96 *	-33.00 **	-25.56 *	-56.72 **	-14.62	-17.05	-27.00 *	-98.63 **
Shekhar x T397	-0.89	-1.77	4.23	-1.35	-58.14 **	-60.00 **	-60.00 **	-202.78 **	-75.00 **	-75.29 **	-79.00 **	-600.00 **
Shekhar x KL-221	-1.57	-2.22	3.29	0.45	-9.71	-12.22	-12.22	-37.97	6.67	6.02	-12.00	-65.91 *
Shekhar x JLS-9	-2.67	2.82	-2.74	-12.93 **	-10.23	-12.22	-12.22	24.05	8.43	8.43	-10.00	-74.44 *
CD. at 5%	1.44	1.67	1.67		6.47	7.47	7.47		5.79	6.68	6.68	
CD. at 1%	1.96	2.27	2.27	–	8.79	10.15	10.15	–	7.86	9.08	9.08	–

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