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Genetic analysis of yield and yield attributing characters in linseed (*Linum usitatissimum* L.)

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A field experiment was conducted at Oilseed Research Area, Department of Plant Breeding and Genetics, IGKV, Raipur (CG) during *Rabi* 2004-05 to estimate heterosis, Inbreeding depression, hereitability, genetic advance and genetic analysis of seed yield and its components in four crosses of linseed. The experimental material comprised of five parents namely, Solan, Kiran, R 552, LCK 88062, Polf 22 and SIKO 10 and their F_1, F_2 and F_3 generations of four different crosses namely, Solan x R 552, Solan x LCK 88062, Solan x Polf 22, Solan x SIKO 10. The hybrids F_1, F_2, F_3 were evaluated along with their parents in randomized complete block design with four replications. The observations were recorded for aforesaid studies. The analysis revealed that significant positive heterosis were observed for Days to 50% flowering, plant height, no. of secondary branches per plant, no. of capsule per plant and seed yield per plant. High heritability estimate coupled with high genetic advance as percentage of mean for number of primary branches per plant, number of secondary branches per plant, number of capsules per plant, number of seeds per plant and seed yield per plant indicated contribution of additive gene effects for the expression of these traits. Hence, selection on these characters for improvement would be effective. The relative comparison of main gene effect revealed major contribution of dominance effects associated with dominance x dominance type of interaction effects in the expression of all the characters in the crosses. Duplicate type of epistasis played a major role in the expression of most of the characters studied in the crosses.

Key words : Linseed, Genetic analysis, Yield and its components, Variability analysis

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INTRODUCTION

Linseed (*Linum usitatissimum* L.) is an ancient plant, which is also known as flax. In India, the crop is mainly cultivated in the states like Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Maharashtra, Rajasthan, West Bengal, Karnataka, Orissa and Bihar. Chhattisgarh is one of the important linseed growing states of India, which account 112.52 thousand hectare area and 34.20 thousand metric tones production. Success in yield improvement programme largely depends on the nature and magnitude of genetic variability already present in the germplasm. Selection of parents based on phenotypic performance of quantitative characters is not much effective due to presence of genotypic-environment interaction. Hence, knowledge of heterosis for yield and its components give an idea about the possibility for the improvement of seed yield either by developing hybrids or to isolate desirable lines out of segregating population of high heterotic hybrids. The knowledge of variability, heritability and genetic advance become important for an efficient breeding programme. The estimates of gene effects have direct bearing on the method of hybridization and selection may be adopted in a variety of specific breeding programme. Since yield is a complex quantitative character and is governed by a number of other traits, the exact association between these characters with yield must be known for effective selection. Thus, the present investigation has been carried out to understand the genetic architecture of yield and its components.

RESEARCH METHODOLOGY

The experiment was conducted at Oilseed Research Area, Department of Plant Breeding and Genetics, Indira Gandhi Krishi Vishwavidyala, Raipur with five parents namely, Solan, R 552, LCK 88062, Polf 22 and SIKO 10 and their F_1, F_2 and F_3 generations of four different crosses namely, Solan x R 552, Solan x LCK 88062, Solan x Polf 22, Solan x SIKO 10. The hybrids (F_1), F_2, F_3 were evaluated along with their parents in randomized complete block design with four replications. The above said material was employed in the estimation of genetic parameters for days to 50 per cent flowering, days to maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of capsules per plant, number of seeds per capsule, number of seeds per plant and 1000 seed weight. Single row of 4 m length and 30 cm apart were planted for each generation *i.e.*, P_1, P_2 and F_1 whereas F_2 and F_3 generation were grown in 4 rows. The plant-to-plant distance was maintained at 10 cm. Each cross and its generations were surrounded by border rows of linseed variety LMH-62 with same spacing between plants and rows. Observations were recorded on single plant basis for each and every character four crosses under study. Five single competitive plants were observed for P_1, P_2 and F_1 but for F_2 and F_3, 20 plants were observed. The mean data were subjected to heterosis, inbreeding depression, heritability, genetic advance and partitioning of generation mean through five parameter model.

RESULTS AND ANALYSIS

Analysis of variance carried out for yield and yield contributing attributes are presented below:

Variability analysis:

The analysis of variance for five generations of four crosses showed significant difference indicated the existence of considerable amount of genetic variability for yield and its components (Table 1). Naik and Satapathy (2002), Adugna and Labuschagne (2004) and Awasthi and Rao (2005) also reported high magnitude of variability of various characters in linseed.

Heterosis and inbreeding depression:

Significant positive heterosis for Days to 50% flowering, plant height, no. of secondary branches per plant, no. of capsule per plant and seed yield per plant were observed in most of the crosses. Cross, Solan x LCK 88062 showed significant negative inbreeding depression for days to 50 per cent flowering. This showed that hybrid of this crosses flowered earlier than their parents (Table 2). Crosses, Solan x LCK 88062, Solan x Polf 22 and Solan x SIKO showed significant negative inbreeding depression for days to maturity. This may be due to the occurrence of segregate in delayed maturity in the F_2 population of these crosses. Cross Solan X Polf 22 showed positive heterosis and inbreeding depression for plant height. This population will provide much scope for selection of dwarf type. For number of secondary

Table 1 : [illegible]

Source	d.f.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Solan x [illegible]											
Replication	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Treatment	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Error	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Solan x LCK [illegible]											
Replication	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Treatment	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Error	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Solan x [illegible]											
Replication	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Treatment	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Error	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Solan x [illegible]											
Replication	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Treatment	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Error	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2: Estimation of heterosis and inbreeding depression in linseed

Crosses	Mean					Heterosis (%)		Inbreeding depression (%)
	P_1	P_2	F_1	F_2	F_3	MP	BP	
Days to 50 per cent flowering								
Solan x R 552	57.16	51.66	58.65	56.21	54.14	7.79*	13.53*	4.16*
Solan x LCK 88062	57.08	63.12	60.92	62.33	57.81	1.36*	6.73*	-2.31*
Solan x Polf 22	58.15	52.29	58.02	55.27	54.05	5.07*	10.96*	4.74*
Solan x SIKO 10	57.94	60.30	61.19	57.15	57.91	3.50*	5.61*	6.60*
Days to maturity								
Solan x R 552	99.64	103.06	105.22	104.54	99.54	3.82*	5.60*	0.65*
Solan x LCK 88062	100.04	106.76	104.15	104.63	103.19	0.73*	4.11*	-0.46*
Solan x Polf 22	99.89	99.62	99.04	103.21	99.04	-0.72*	-0.58*	-4.21*
Solan x SIKO 10	100.08	102.99	104.11	104.71	101.55	2.54*	4.03*	-0.58*
Plant height (cm)								
Solan x R 552	58.58	61.18	65.15	66.49	66.63	8.80*	11.22*	-2.06*
Solan x LCK 88062	59.01	69.08	67.78	70.74	66.86	5.83*	14.86*	-4.37*
Solan x Polf 22	59.48	52.03	63.85	61.77	52.42	14.52*	22.72*	3.26*
Solan x SIKO 10	59.20	70.77	60.78	61.85	58.35	-6.47*	2.67*	-1.76*
Number of primary branches per plant								
Solan x R 552	3.86	4.11	4.47	3.42	2.72	12.17*	8.76*	23.49*
Solan x LCK 88062	3.85	1.51	2.91	3.23	2.92	8.58*	-24.42*	-11.00*
Solan x Polf 22	4.02	3.53	4.68	5.71	3.19	23.97*	16.42*	-22.01*
Solan x SIKO 10	4.00	2.07	3.47	3.07	3.16	14.33*	-13.25*	11.53*
Number of secondary branches per plant								
Solan x R 552	9.74	14.66	23.60	13.59	9.52	93.44*	60.98*	42.42*
Solan x LCK 88062	10.03	12.03	16.59	15.31	15.50	50.41*	37.91*	7.72*
Solan x Polf 22	10.44	17.48	19.46	18.16	16.15	39.40*	11.33*	6.68*
Solan x SIKO 10	10.41	13.79	14.88	13.78	14.69	22.98*	7.90*	7.39*
Number of capsules per plant								
Solan x R 552	31.22	51.18	71.94	47.95	32.45	74.61	40.56	33.35*
Solan x LCK 88062	31.88	46.07	50.78	47.39	46.22	30.29*	10.22*	6.68*
Solan x Polf 22	33.22	42.75	60.22	50.82	44.74	58.54	40.87*	15.61*
Solan x SIKO 10	34.96	45.14	38.15	36.81	37.33	4.74*	15.49*	3.51*
Number of seeds per capsule								
Solan x R 552	6.55	7.07	5.88	6.93	6.61	-13.66*	-16.83*	-17.86*
Solan x LCK 88062	6.66	7.26	6.77	6.77	6.59	-2.73*	-6.75*	1.01
Solan x Polf 22	6.65	6.71	5.94	6.23	6.31	-11.08*	-11.48*	-4.88*
Solan x SIKO 10	6.71	7.72	7.09	7.03	6.78	-1.73*	-8.16*	0.85*
Number of seeds per plant								
Solan x R 552	203.18	355.97	425.08	331.04	215.20	52.05	19.41	22.12*
Solan x LCK 88062	212.37	345.30	334.82	323.00	314.85	20.08	-3.04	3.53*
Solan x Polf 22	220.59	266.49	353.19	314.93	278.22	45.02*	32.53*	10.83*
Solan x SIKO 10	224.77	238.74	255.44	249.51	245.37	10.22*	7.00	2.32*
1000 seed weight (g)								
Solan x R 552	5.69	6.29	6.11	5.86	5.92	2.00*	-2.86*	4.09*
Solan x LCK 88062	5.66	7.19	6.82	6.81	6.82	6.15*	-5.15*	0.15*
Solan x Polf 22	5.73	7.07	6.79	6.67	6.45	6.09*	-3.96*	1.77*
Solan x SIKO 10	5.69	8.49	6.60	6.45	6.81	-6.91*	-22.26*	2.27*
Seed yield per plant (g)								
Solan x R 552	1.26	2.27	2.59	1.95	1.39	46.74*	14.10*	24.71*
Solan x LCK 88062	1.24	2.36	2.64	2.20	2.15	46.67*	11.86*	16.67*
Solan x Polf 22	1.30	1.81	2.44	2.13	1.81	56.91*	34.81*	12.70*
Solan x SIKO 10	1.30	2.02	1.57	1.64	1.65	-5.42*	-22.28*	-4.46*

Table 3: Heritability broad sense (h^2bs) and percentage of genetic advance (G.A.) over F_2 mean for yield and its components in four crosses of linseed

Crosses	h^2_{bs}	G.A.	G.A. as percentage over F_2 mean
Days to 50 per cent flowering			
Solan x R 552	49.2	3.76	6.69
Solan x LCK 88062	88.7	5.32	8.53
Solan x Polf 22	87.8	4.99	9.03
Solan x SIKO 10	80.2	3.25	5.69
Days to maturity			
Solan x R 552	81.4	5.04	4.82
Solan x LCK 88062	93.5	5.00	4.78
Solan x Polf 22	78.4	3.21	3.11
Solan x SIKO 10	87.5	3.71	3.54
Plant height (cm)			
Solan x R 552	60.6	4.36	6.56
Solan x LCK 88062	93.2	9.23	13.05
Solan x Polf 22	78.6	9.96	16.12
Solan x SIKO 10	92.2	10.09	16.31
Number of primary branches per plant			
Solan x R 552	82.1	1.28	37.43
Solan x LCK 88062	91.8	1.73	53.56
Solan x Polf 22	93.9	2.05	35.90
Solan x SIKO 10	92.6	1.44	46.90
Number of secondary branches per plant			
Solan x R 552	75.8	10.28	75.64
Solan x LCK 88062	86.8	5.37	35.07
Solan x Polf 22	93.2	7.14	39.32
Solan x SIKO 10	79.7	3.34	24.24
Number of capsules per plant			
Solan x R 552	80.0	30.85	64.34
Solan x LCK 88062	92.2	14.74	31.10
Solan x Polf 22	92.5	20.28	39.90
Solan x SIKO 10	65.9	6.45	17.52
Number of seeds per capsule			
Solan x R 552	56.1	0.69	9.96
Solan x LCK 88062	59.6	0.41	6.06
Solan x Polf 22	80.7	0.61	9.79
Solan x SIKO 10	85.9	0.80	11.38
Number of seeds per plant			
Solan x R 552	79.5	186.40	56.31
Solan x LCK 88062	62.5	92.36	28.59
Solan x Polf 22	85.6	102.48	32.54
Solan x SIKO 10	31.4	12.19	4.88
1000 seed weight (g)			
Solan x R 552	79.1	0.43	7.34
Solan x LCK 88062	92.8	1.19	17.47
Solan x Polf 22	93.6	1.04	15.59
Solan x SIKO 10	93.4	2.12	32.87
Seed yield per plant (g)			
Solan x R 552	86.2	1.13	57.95
Solan x LCK 88062	89.5	1.08	49.09
Solan x Polf 22	90.2	0.87	40.84
Solan x SIKO 10	72.6	0.46	28.05

Table 5 : Estimation of gene effects and their standard error of Solan x LCK 88062 cross of linseed for yield and its component

Characters	m	d	h	i	j	l	χ^2	Type of epistasis
Days to 50% flowering	62.33 ± 0.34**	3.02 ± 0.28**	11.12 ± 0.81**	4.28 ± 1.09**	27.91 ± 2.94**	16.04	D
Days to maturity	104.63 ± 0.18**	3.36 ± 0.06**	3.52 ± 0.68**	3.94 ± 0.61**	8.98 ± 1.88**	24.26	D
Plant height (cm)	70.74 ± 0.50**	5.03 ± 0.10**	8.36 ± 0.11**	5.43 ± 0.13**	28.55 ± 4.18**	142.22	D
Number of primary branches per plant	3.23 ± 0.08**	1.17 ± 0.05**	0.61 ± 0.20**	2.73 ± 0.25**	2.54 ± 0.72**	20.61	D
Number of secondary branches per plant	15.30 ± 0.51**	0.99 ± 0.16**	0.35 ± 1.53	7.20 ± 1.55**	4.45 ± 4.80	49.96	C
Number of capsules per plant	47.39 ± 0.76**	7.09 ± 0.69**	5.38 ± 2.26*	20.61 ± 2.48**	2.78 ± 7.27	28.66	C
Number of seeds per capsule	6.77 ± 0.06**	0.30 ± 0.04**	0.47 ± 0.49	0.06 ± 0.37	0.92 ± 1.07	4.86	D
Number of seeds per plant	323.00 ± 7.07**	66.47 ± 9.31**	29.60 ± 27.90	159.31 ± 30.92**	11.94 ± 98.63	3.99	D
1000 seed weight (g)	6.81 ± 0.01**	0.77 ± 0.01**	0.02 ± 0.07	1.95 ± 0.07**	0.07 ± 0.24	211.73	D
Seed yield per plant (g)	2.20 ± 0.04	0.56 ± 0.02**	0.44 ± 0.16**	1.53 ± 0.15**	0.87 ± 0.47	7.87	C

* and ** indicates significance of value at P=0.05 and P=0.01, respectively
D – Duplicate type of epistasis
C – Complementary type of epistasis

Table 6 : Estimation of gene effects and their standard error of Solan x Polf 22 cross of linseed for yield and its component

Characters	m	d	h	i	j	l	χ^2	Type of epistasis
Days to 50% flowering	55.27 ± 0.57**	2.93 ± 0.11**	5.10 ± 1.40**	8.16 ± 1.53**	0.78 ± 4.89	37.30	C
Days to maturity	103.21 ± 0.22**	0.13 ± 0.22	8.34 ± 1.40**	9.32 ± 1.30**	33.39 ± 3.83**	96.42	D
Plant height (cm)	61.77 ± 0.48**	3.72 ± 0.11**	26.31 ± 2.35**	25.67 ± 2.36**	44.34 ± 7.90**	109.81	D
Number of primary branches per plant	5.71 ± 0.04**	0.25 ± 0.04**	6.03 ± 0.25**	5.62 ± 0.21**	16.16 ± 0.59**	63.37	D
Number of secondary branches per plant	18.16 ± 0.41**	3.52 ± 0.17**	6.24 ± 0.99**	6.30 ± 1.14**	7.28 ± 3.61*	15.17	D
Number of capsules per plant	50.82 ± 0.79**	4.77 ± 0.79**	22.49 ± 3.18**	9.27 ± 3.16**	7.37 ± 8.94	2.61	D
Number of seeds per capsule	6.23 ± 0.04**	0.03 ± 0.04	0.38 ± 0.14**	0.30 ± 0.16	0.38 ± 0.43	14.93	C
Number of seeds per plant	314.93 ± 6.81**	22.95 ± 3.23**	123.41 ± 20.50**	32.15 ± 21.32	93.77 ± 65.01	4.80	D
1000 seed weight (g)	6.67 ± 0.01**	0.67 ± 0.01**	0.67 ± 0.07**	1.06 ± 0.06**	0.86 ± 0.17**	25.20	D
Seed yield per plant (g)	2.13 ± 0.05**	0.26 ± 0.01**	1.05 ± 0.16**	3.46 ± 0.16**	0.86 ± 0.49	5.96	D

* and ** indicates significance of value at P=0.05 and P=0.01, respectively
D – Duplicate type of epistasis
C – Complementary type of epistasis

Table 7 : Estimation of gene effects and their standard error of Solan x SIKO 10 cross of linseed for yield and its component

Characters	m	d	h	[illegible]	[illegible]	χ^2	Type of epistasis
Days to 50% flowering	57.14 ± 0.33**	1.18 ± 0.33**	0.65 ± 1.02	3.77 ± 1.07**	14.85 ± 3.13**	64.05	C
Days to maturity	104.71 ± 0.25**	1.45 ± 0.15**	8.04 ± 1.27**	2.56 ± 1.05*	18.51 ± 3.12**	50.34	D
Plant height (cm)	61.85 ± 0.75**	5.78 ± 0.19**	8.63 ± 1.91**	1.26 ± 2.04	21.55 ± 6.49**	42.11	D
Number of primary branches per plant	3.07 ± 0.06**	0.87 ± 0.02**	0.02 ± 0.20	1.52 ± 0.18**	1.56 ± 0.58**	8.10	C
Number of secondary branches per plant	13.77 ± 0.43**	1.69 ± 0.17**	1.69 ± 1.89	7.84 ± 1.63**	7.79 ± 4.85	8.92	D
Number of capsules per plant	36.80 ± 1.15**	5.09 ± 0.54**	0.50 ± 4.43	8.79 ± 4.15*	6.39 ± 12.52	3.98	D
Number of seeds per capsule	7.03 ± 0.04**	0.50 ± 0.02**	0.69 ± 0.13**	0.18 ± 0.13	1.17 ± 0.38**	83.42	D
Number of seeds per plant	249.51 ± 7.22**	6.98 ± 3.13*	44.99 ± 25.67	22.66 ± 24.62	6.24 ± 74.61	1.13	D
1000 seed weight (g)	6.45 ± 0.03**	1.39 ± 0.01**	0.86 ± 0.08**	3.16 ± 0.09**	2.31 ± 0.30**	74.06	D
Seed yield per plant (g)	1.67 ± 0.04**	0.36 ± 0.02**	7.17 ± 0.19**	0.70 ± 0.18**	0.13 ± 0.59	10.07	C

* and ** indicates significance of value at P=0.05 and P=0.01, respectively

D – Duplicate type of epistasis

C – Complementary type of epistasis

branches per plant cross, Solan x R 552 showed highest heterosis. As this character is directly correlated to the seed yield per plant, high heterosis can be utilized for improvement of seed yield. Highest heterosis coupled with negative inbreeding depression was observed in cross Solan x R 552 for plant height; in Solan x LCK 88062 for days to 50 per cent flowering, days to maturity and plant height; in Solan x Polf 22 for number of primary branches per plant; in Solan x SIKO 10 for days to maturity and plant height. This indicated the occurrence of superior segregates for these characters in linseed. However, it would be essential to avoid rapid fixation of alleles, which accompanied in self pollinated crops after the F_2 generation. The scheme of intermating in F_2 and their resulting generations may be advantageous for the improvement of these characters. These results are in agreement with the findings of Rede (1999), Kumar and Singh (2002) and Sharma *et al.* (2005).

Heritability and genetic advance:

High heritability estimate coupled with high genetic advance as percentage of mean observed in number of primary branches per plant, number of secondary branches per plant, number of capsules per plant, number of seeds per plant and seed yield per plant in mst of the crosses indicated the prevalence of additive gene effects for the expression of these traits (Table 3). Hence, improvement of these characters may be possible through simple selection. Whereas, high to medium heritability estimate coupled with low genetic advance indicated these character governed by dominance or epistatic variance in the expression of the character like number of seeds per capsule. These findings are in general agreement with the findings of Muhammad *et al.* (2003) and Adugna and Labuschagne (2004).

Gene action:

The relative comparison of main gene effect revealed major contribution of dominance effects associated with dominance x dominance type of interaction effects in the expression of all the characters in the crosses (Table 4-7). Both additive and dominance gene effects are significant for majority of crosses. Duplicate type of epistasis played a major role in the expression of days to 50 per cent flowering, days to maturity, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, number of seeds per plant and seed yield per plant. This showed their complex nature of inheritance. Improvement of these characters in a cross could be possible in later generations. The duplicate type of epistasis for most of the characters showed their complex nature of inheritance. Therefore, the breeding strategies should be designed accordingly to get desired results. Improvement of these crosses could be possible in later generation. These results are in agreement with the findings of Kumar *et al.* (2000), Yadav and Shrivastava (2002), Swarnkar *et al*. (2003) and Joshi (2004).

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