Int.J.Curr.Microbiol.App.Sci (2020) *9*(2): 2451-2474

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 2 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.902.280

Half Diallel Analysis for Estimation of Heterosis for Phonological Traits in Linseed (*Linum usitatissimum* L)

Divya Mahto[1*], P. K Singh[2] and Shailesh Marker[1]

[1]*Department of Genetics & Plant Breeding, Sam Higgionbottom University of Agriculture, Technology and Sciences, Allahabad - 211007 (U.P.), India*
[2]*Department of Plant Breeding and Genetics, Bihar Agricultural University Sabour, Bhagalpur (Bihar), India*

**Corresponding author*

Keywords

Heterosis, Combining ability, Seed Yield and Linseed (*Linum usitatissimum*L.)

Article Info

Accepted: 18 January 2020
Available Online: 10 February 2020

A B S T R A C T

The research consisted of eight parents of linseed which were crossed as per half diallel analysis (Griffing 1956 Model 1 and Method 2) in Rabi 2010-11 to generate 28 crosses (excluding reciprocals). These 28 crosses were assessing along with eight parents and three checks viz: T-397, Neelum and Allahabad Local in RBD having three replications during 2011-12 at the Field Experimentation Centre of Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad. The data were recorded on ten characters to study the heterosis. The significant mean sum of squares for all the ten characters indicated the presence of a considerable amount of variability. *Per se* performance for seed yield and its components depicted that cross M-42(169) × POLF-19(1765) was found to be best. Estimate of heterosis (ha) showed that the highest average Heterosis , heterobeltiosis and economic heterosis for seed yeild plant was observed by cross PbD2-42(2789) X GS-129(1018).

Introduction

Linseed (*Linum usitatissimum* L.) is annual self-pollinated diploid (2x=2n=30) oilseed crop belonging to *Linaceae* family and it as an earliest domesticated and economically important industrial non edible oilseed crop which is being cultivated for seed and its fiber since centuries. It is also known as 'Alsi' or 'Tisi', and mainly cultivated for fibre (Flax fibre) and seed oil (Linseed) or both (dual purpose linseed), essential poly unsaturated fatty acids such as alpha-linolenic acid and rich supply of soluble dietary fiber. Flaxseed oil is used as an industrial drying oil due to its high linolenic acid content Omega-3 fatty acids lower levels of triglycerides in the blood, thereby reducing heart disease, and also show promise in the fighting against Inflammatory diseases such as rheumatoid arthritis.. The average seed yield of linseed in India is 403 Kg/ha which is comparably very low in comparison with world average seed yield that is 943 Kg/h.

In India, linseed occupied 3.59 lakh hectare area with 1.46 lakh tonnes production and productivity of 408kg/ha in 2011-12 (FAOSTAT, 2012).The low seed yield is chiefly due to limited resources available to poor farmers along with non-availability of high-yielding cultivars.

So, the development of high-yielding varieties/lines is needed to compete with other linseed growing countries. Such lines/varieties can easily be developed through suitable hybridization and selection programmes to isolate superior segregants.

Combining ability provides an important tool for selection of desirable parents and to get required information regarding the nature of gene action controlling desirable trait degree of heterosis provides a basis for genetic diversity and guideline to the choice of desirable parents for developing superior F1 hybrids so as to exploit hybrid vigor and for building gene pool for 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).Development of better hybrids using stable high yielding lines shall increase the yield of this crop.

In order to achieve high yielding cross combination, it is essential to evaluate available promising diverse lines in their hybrid combinations for yield and its components. Keeping the above facts in mind, the present investigation was carried out to study the extent of heterosis in 28 F1 hybrid over better-parent and standard variety in a half diallel cross set of 8 diverse parents.

This study reveals good scope for isolating suitable parents for hybrid development and to select potent transgressive segregants which can be further evaluated to increase the yield potential.

Materials and Methods

The details of the materials and methods adopted in the present study entitled “Half diallel analysis for estimation of heterosis for phenological traits in linseed (*Linum usitatissimum* L.)” was carried out to derived informations on heterosis in linseed during Rabi 2011-12 at the Field Experimentation Centre of the Deptt. of Genetics and Plant Breeding, Allahabad School of Agriculture, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS) formerly Allahabad Agricultural Institute Allahabad (U.P)

The experimental materials consisted of 8 parents which were crossed as per diallel analysis (Griffing 1956 Model 1 and Method 2) in Rabi 2010-11 to generate 28 crosses (excluding reciprocals). These 28 crosses were evaluated along with 8 parents and 3 checks *viz*: T-397, Neelum and Allahabad Local so, total experimental material consisted of 39 entries (8 parents + 28 crosses + 3 checks), planted in a Randomized Block design and Observations for the ten characters were recorded on five randomly selected plants for all the traits except for days to 50% flowering and days to maturity, where the observations were recorded on plot basis. The estimation of heterosis, heterobeltiosis and standard heterosis are presented under following heads **:**

Estimation of Heterosis

Heterosis is expressed as percent deviation from the mid parent. In the present experiment heteorsis was estimated for 18 hybrids for the 10 characters studies, (Turner 1953).

$$\text{ha (\%)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Testing the significance, critical difference

$$\text{C. D. (heterosis)} = (\overline{F_1} - \overline{MP}) \times t_{0.05}$$

Where,

$\overline{F_1}$ = mean of F_1

$\overline{MP}$ = mean of parents of respective F_1

$(\overline{F_1} - \overline{MP}) = \sqrt{(2MS_e / r)}$

Where,

MSe = mean sum of square due to error

r = number of replications

Estimation of heterobeltiosis

Heterobeltiosis is expressed as percent deviation towards desirable side *i.e* may be increase or decrease in performance over better parents.

$$\text{hb (\%)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Its significance was tested using critical difference *i.e.* C. D.

$$\text{CD (BP)} = \text{SE } (\overline{F_1} - \overline{BP}) \times t_{0.05}$$

Where,

$\overline{BP}$ = mean of the desirable better parent

$$\text{SE } (\overline{F_1} - \overline{BP}) = \sqrt{(2MS_e / r)}$$

Where

MSe = mean sum of square due to error

r = number of replications

Estimation of standard heterosis

Standard heterosis was expressed as percentage increase or decrease towards desirable side observed in F_1 over standard check.

$$\text{hc (\%)} = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Critical difference was applied for testing is significance

$$\text{CD (SH= SE } (\overline{F_1} - \overline{SC}) \times t_{0.05}$$

Where,

SC = mean of high yielding standard check

$$\text{SE } (\overline{F_1} - \overline{SC}) = \sqrt{(2MS_e / r)}$$

Where,

MSe = mean sum of square due to error

r = Number of replications

Results and Discussion

The mean value for ten characters of F_1 hybrid and parents were compared. Magnitude of heterosis, heterobeltiosis and economic heterosis for different quantitative traits expressed as percentage increase or decrease are presented in Table –1 and Table-2 and described character wise as under:

Analysis of variance

The mean sum of squares for 10 characters is presented in Table 1.1. The mean sum of squares due to treatments, parents, hybrids and parents V/s hybrids were significant for all the characters except for days to 50% flowering due to parents V/s hybrids. The analysis of variance revealed the presence of significance amount of variability among parents, their crosses (F_1) and among parents V/s crosses (F_1) for all the characters studied.

This suggested that the parental lines selected were quite variable, considerable amount of variability existed among the hybrids and presence of overall heterosis for most of the characters under study was present.

Similar trends for variance and its components were also reported by Rai and Das (1974), Govind and Murty (1979), Kumar *et al.*, (1980), Patil and Chopde (1983), Singh and Sindhu(1986), Thakur *et al.*, (1986), Dakhore *et al.*, (1987), Singh *et al.*, (1987), Goray *et al.*, *(*1990), Mishra and Rai (1993), Saraswat *et al.*, (1993), Verma *et al.*, *(*1993), Pillai *et al.*, *(*1995), Mishra and Rai (1996), Verma and Mahta (1996), Yadav (1997), Bhateria *et al.*, (2001), Kumar *et al.*, (2002), Ratnaparkhi *et al.*, *(*2004), Sharma *et al.*, (2005), Bhateria *et al.*, (2006), Sood *et al.*, (2006), Pant *et al.*, (2007) and Pant *et al.*, (2008) in linseed.

Mean performance of parents and their hybrids

The mean values, range, grand mean (GM), standard error of mean (SEm), critical difference (CD) of parents and their crosses in F_1 generation along with check for all the characters are presented in Table 4.2.

Days to 50 percent flowering (Table 1.2)

The days to 50 per cent flowering varied among hybrids from 82.00 days (FRW-6(973) × GS-129(1018)) to 98.67 days (FRW-6(973) × POLF17(1704)), among parents from 78.67 days (GS-234(1703)) to 89.00 days (M-42(169)) and among checks from 78 days (Allahabad local) to 88.00 days (Neelum).

The hybrid FRW-6(973) × GS-129(1018) (82.00) was found statistically *at par* with M-42(169) × C-91538(456) (83.0) and FRW-6(973) × GS-129(1018) (82.0).

Days to maturity (Table 1.2)

The data revealed that days to maturity ranged among hybrids from 140.00 days (FRW-6(973) × PbD2-42(2789)) to 151.0 days (M-42(169) × FRW-6(973)), among parents 133.00 days (POLF-19(1765)) to 148.00 days (C91538(456)) and among checks 128.33 days (T-397) to 135.0 days (Neeluum) .

The hybrid FRW-6(973) × PbD2-42(2789) (140) was found statistically *at par* with M-42(169) × POLF-19(1765) (141.0), M-42(169) × PbD2-42(2789) (140.66), FRW-6(973) × C91538(456) (142.0), FRW-6(973) × POLF19(1765) (141.67), FRW-6(973) × PbD2-42(2789) (140), FRW-6(973) × GS-234(1703) (142.33) and FRW-6(973) × GS-129(1018) (140).

Plant height (cm) (Table 1.2)

The plant height ranged among hybrids from 59.33 cm (GS-234(1703) × GS-129(1018)) to 81.77cm (M-42(169) × GS-129(1018)), among parents from 63.97 (POLF-17(1704)) to 76.33cm (M-42(169)) and among checks from 57.3 cm (Allahabad local) to 76.16 cm (T-397).

The hybrid GS-234(1703) × GS-129(1018) (59.33) was found statistically *at par* with FRW-6(973) × POLF17(1704) (61.13) and POLF-19(1765)× POLF-17(1704) (58.66).

Number of primary branches per plant (Table 1.2)

The number of primary branches per plant varied among hybrids from 3.66 (M-42(169) × GS-234(1703)) to 9.16 (C91538(456)× POLF19(1765)), among parents from 4.20 (GS-234(1703)) to 6.33 (C91538(456)) and among checks from 4.67 (Neelum) to 13.0 (T-397).

The hybrid C91538(456)× POLF19(1765) (9.16) was found statistically *at par* with FRW-6(973) × PbD2-42(2789) (7.16), C91538(456) × POLF19(1765) (9.16), C91538(456) × PbD2-42(2789) (8.16), C91538(456) × GS-234(1703) (7.16), POLF-19(1765)× POLF-17(1704) (8.16), and POLF-17(1704) × GS-234(1703) (8.9).

Number of capsule per plant (Table 1.2)

The data revealed that number of capsule per plant ranged among hybrids from 52.4 (FRW-6(973) × GS-129(1018)) to 265.7 (FRW-6(973) × C91538(456)), among parents from 47.33 (PbD2-42(2789)) to 153.67 (FRW-6(973)) and among checks from 110.36 (Neelum) to 387.00 (T-397).

The hybrid FRW-6(973) × C-91538(456) (265.7) was found statistically *at par* with FRW-6(973) × C91538(456) (265.7).

Number of seeds per capsule (Table 1.2)

The mean values for number of seeds per capsule varied among hybrids from 5.00 (FRW-6(973) × C91538(456)) to 9.3 (M-42(169) × C91538(456)), among parents from 8.2 (GS-234(1703)) to 9.6 (M-42(169)) and among checks from 4.53 (Neelun) to 9.1 (Allahabad local).

The hybrid M-42(169) × C91538(456) (9.3) was found statistically *at par* with M-42(169) × FRW-6(973) (9.6), FRW-6(973) × GS-234(1703) (8.3), C91538(456)× POLF17(1704) (8.2), C91538(456) × GS-129(1018) (9.2) and POLF-17(1704) × GS-234(1703) (8.7).

1000-grain weight (g) (Table 1.2)

The1000-grain weight ranged among hybrids from 4.9g (M-42(169) × POLF-17(1704)) to 8.8g (FRW-6(973) × POLF17(1704)), among parents from 6.22g (M-42(169)) to 7.47g (GS-234(1703)) and among checks from 7.2g (T-397) to 7.7g (Allahabad local).

The hybrid M-42(169) × POLF-17(1704) (8.8) was found statistically *at par* with M-42(169) × PbD2-42(2789) (7.25), FRW-6(973) × C91538(456), FRW-6(973) × POLF19(1765) (7.6), FRW-6(973) × POLF17(1704) (7.4) and PbD2-42(2789) × GS-234(1703) (7.5).

Biological yield per plant (g) (Table 1.2)

The mean values for biological yield per plant ranged among hybrids from 9.09g (M-42(169) × PbD2-42(2789)) to 29.22g (FRW-6(973) × C91538(456)), among parents from 11.66g (GS-129(1018)) to 15.26g (M-42(169)) and among checks from 14.39g (Neelum) to 27.57 g (T-397).

Hybrid FRW-6(973) × C-91538(456) (29.22) was found statistically *at par* with FRW-6(973) × GS-234(1703) (31.18)

Harvest index (%) (Table 1.2)

The harvest index varied among hybrids from 17.18% (C91538(456) × GS-234(1703)) to 41.50% (POLF-17(1704) × GS-234(1703)), among parents from 20.97 %(GS-234(1703)) to 33.38% (FRW-6(973)) and among checks from 22.34% (Neelum) to 32.37% (Allahabad local).

The hybrid POLF-17(1704) × GS-234(1703 (41.5%) was found statistically *at par* with M-42(169) × FRW-6(973) (39.38).

Seed yield per plant (g) (Table 1.2)

The data revealed that seed yield per plant ranged among hybrids from 2.96g (M-42(169) × PbD2-42(2789)) to 7.9g (M-42(169) × POLF-19(1765)), among parents from 2.86g (PbD2-42(2789)) to 4.25g (M-42(169)) and among checks from 3.21g (Neelum) to 8.35g (T-397).

The hybrid M-42(169) × POLF-19(1765) (7.9) was found statistically *at par* with M-42(169) × FRW-6(973) (5.25), M-42(169) × POLF-19(1765) (7.90), FRW-6(973) × POLF19(1765) (7.19), FRW-6(973) × GS-234(1703) (6.28), FRW-6(973) × GS-129(1018) (6.28) and POLF-19(1765)× POLF-17(1704) (6.51).

The *Per se* performance was advocated by Genter and Alexander (1962) as one of the useful methods in evaluating parents for heterosis breeding in cross pollinated crop like maize.

A perusal of mean value of yield and yield contributing characters revealed that among parents genotype M-42(169) (4.25g/plant) and POLF-19(1765) (3.97g/plant) exhibited maximum value of seed yield per plant along with other contributing traits viz: number of seeds per capsule (9.6 and 8.7), number of capsules per plant (85.33 and 60.0), number of primary branches per plant (5.7 and 5.2), days to 50% flowering (89.0 and 86.0) and days to maturity (147.0 and 133.0).

Among the hybrids cross M-42(169) × POLF-19(1765) exhibited maximum value of seed yield per plant (7.9g) along with number of capsules per plant (61.6) and 1000-grain weight (6.56), whereas the hybrid FRW-6(973) × C91538(456) exhibited next higher value for seed yield per plant (7.86g) along with number of seeds per capsule (5.0) and primary branches per plant (5.96).

On the basis of *Per se* performance for seed yield per plant, five best high yielding identified hybrids are, M-42(169)×POLF-19(1765), FRW-6(973)×C91538(456), PbD2-42(2789)×GS-129(1018), FRW-6(973)×POLF-19(1765) and FRW-6(973)×GS-234(1703). (Table 4.3)

The recent trend in breeding linseed has been to evolve varieties with early flowering and early maturity because in late maturity types oil synthesis get adversely affected by temperature and time and later developed capsules do not bear well developed seeds.

Further the late maturing linseed does not fit well in multiple cropping system. Therefore, an attempt was made in present investigation to identity early maturing linseed genotypes.

Genotypes shows early maturity thus can be on immense use in the future breeding programme. These findings are in conformity with the findings of Singh and Singh(1979), Kumar *et al.*, *(*1980), Singh *et al.*, (1987), Saraswat *et al.*, *(*1993), Verma *et al.*, (1993), Mishra and Rai (1996), Patel *et al.*, (1998), Ratnaparkhi *et al.*, (1998), Kumar *et al.*, (2000), Yadav and Srivastava (2002), Swarnakar *et al.*, (2003), Ratnaparkhi *et al.*, (2004), Sharma *et al.*, (2005), Bhateria *et al.*, (2006) Sood *et al.*, (2006), Pant *et al.*, (2007) and Pant *et al.*, (2008).

Heterosis, heterobeltiosis and economic heterosis

In the present study, the magnitude of estimates of relative heterosis (MP), heterobeltiosis (BP) and standard heterosis (economic heterosis) have been expressed as percent increases in hybrid performance in relation to mid parent, better parent and best standard check, respectively.

The character wise heterosis, heterobeltiosis and economic heterosis are presented in table 2.2. The character wise results are summarized as under.

Table.1.1 Analysis of variance for ten yield attributing traits in Linseed

S.No.	Characters	Mean Sum of Squares						
		Replications	Treatments	Parents	Hybrids	P v_s Hy	Error	Total
		2	35	7	27	1	70	107
1	Days to 50% flowering	1.23	43.94**	32.95**	44.48**	106.35**	0.88	14.97
2	Days to Maturity	0.19	55.89**	120.38**	24.81**	443.63**	1.65	19.36
3	Plant height	0.13	88.53**	50.34**	100.36**	36.66**	0.13	29.04
4	Number of Primary branches per plant	0.19	5.10**	1.13**	6.13**	5.09**	0.10	1.74
5	Number of Capsules per plants	0.35	11101.44**	3512.47**	11065.58**	65192.55**	0.18	3631.13
6	Number of Seeds per capsule	0.08	3.92**	0.47**	4.38**	15.79**	0.03	1.31
7	1000 grain weight	0.02	1.59**	0.60**	1.86**	1.02**	0.01	0.53
8	Biological yield per plant	0.25	100.39**	6.50**	119.98**	228.89**	0.19	32.96
9	Harvest index	1.84	98.73**	67.14**	107.07**	94.84**	1.85	33.54
10	Seed yield per plant	0.04	6.74**	0.93**	7.56**	25.09**	0.02	2.22

**significant at 1% level of significance respectively

Table.1.2 Mean performances of parents and hybrids for different characters in linseed

S.No	Genotype	Days to 50% flowering	Days to maturity	Plant height (cm.)	primary branches per plant	Capsules per plant	Seeds per capsule	Biological yield per plant (gm.)	Economic yield per plant (gm.)	1000 grain weight (gm.)	Harvest index (%)
1.	M-42(169)	89.00	147.00	76.3333	5.7000	85.3333	9.6000	15.2667	4.2533	6.2233	27.8560
2.	M-42(169)×FRW-6(973)	85.00	151.66	75.3667	3.9000	145.6000	9.1667	13.3300	5.2500	5.9500	39.3800
3.	M-42(169)×C91538(456)	83.00	145.33	64.8000	5.6333	145.0667	9.3000	9.0967	3.1267	6.3600	34.3667
4.	M-42(169)×POLF-19(1765)	86.00	141.00	66.8000	5.2000	61.6000	8.8000	26.0400	7.9033	6.5600	30.3467
5.	M-42(169)×POLF-17(1704)	84.00	147.00	81.2000	4.2000	97.2000	8.8000	18.7500	3.9967	4.9667	21.3133
6.	M-42(169)×PbD2-42(2789)	85.00	140.66	68.6667	4.1667	93.8000	9.1333	9.0967	2.9567	7.2567	32.5033
7.	M-42(169)×GS-234(1703)	86.00	144.00	75.9667	3.6667	56.0667	7.8000	8.2933	3.0067	5.7500	36.2700
8.	M-42(169)×GS-129(1018)	87.00	145.00	81.7667	4.6667	60.0000	8.6000	12.5333	3.3300	6.4333	26.5667
9.	FRW-6(973)	86.66	134.00	73.6333	5.6667	153.6667	9.1000	11.8133	3.9433	6.2300	33.3800
10.	FRW-6(973)×C91538(456)	94.00	142.00	72.7667	5.9667	265.7000	5.0000	29.2233	7.8667	7.6000	26.9133
11.	FRW-6(973)×POLF-19(1765)	95.00	141.66	69.0667	5.2000	172.6667	6.0667	25.0000	7.1900	7.4667	28.8067
12.	FRW-6(973)×POLF-17(1704)	98.66	144.00	61.1333	6.3000	253.6000	6.6000	17.6333	4.7400	8.8000	26.8767
13.	FRW-6(973)×PbD2-42(2789)	93.00	140.00	67.0667	7.1667	165.2000	6.7000	15.7133	4.9333	7.1233	31.3933
14.	FRW-6(973)×GS-234(1703)	92.00	142.33	70.0000	5.6333	156.8000	8.3000	31.1867	6.2867	8.0333	20.1533
15.	FRW-6(973)×GS-129(1018)	82.00	140.33	65.6667	5.3333	52.4000	9.0000	16.6600	6.2800	6.8200	37.6897
16.	C91538(456)	87.00	148.00	68.0667	6.3333	102.6667	9.0667	14.0400	3.2333	6.5800	23.0233
17.	C91538(456)×POLF-19(1765)	85.00	146.33	73.7667	9.1667	232.0667	8.8000	16.2400	4.1333	6.5567	25.4533
18.	C91538(456)×POLF-17(1704)	87.00	146.00	65.6667	5.8667	211.3333	8.2333	13.7500	3.2667	7.1200	23.7600
19.	C91538(456)×PbD2-42(2789)	89.00	145.00	62.3333	8.1667	150.0667	9.0667	10.0000	3.3733	6.7467	33.9300
20.	C91538(456)×GS-234(1703)	88.00	143.66	72.6667	7.1667	232.0667	6.2000	25.0000	4.2867	6.6000	17.1867
21.	C91538(456)×GS-129(1018)	84.66	144.00	67.6667	6.3333	100.7667	9.2000	11.0367	3.0500	6.3500	27.6313
22.	POLF-19(1765)	86.00	133.00	69.1667	5.2000	60.0000	8.7000	12.0133	3.9700	6.5600	33.0400
23.	POLF-19(1765)×POLF-17(1704)	85.33	146.00	58.6667	8.1667	152.6667	8.6000	20.0000	6.5133	7.4600	32.6200

S.No	Genotype	Days to 50% flowering	Days to maturity	Plant height (cm.)	primary branches per plant	Capsules per plant	Seeds per capsule	Biological yield per plant (gm.)	Economic yield per plant (gm.)	1000 grain weight (gm.)	Harvest index (%)
24.	POLF-19(1765)×PbD2-42(2789)	90.00	148.00	67.0667	6.3333	156.6667	6.0667	14.2633	3.8700	5.7800	27.1300
25.	POLF-19(1765)×GS-234(1703)	88.00	142.66	67.2000	5.6000	111.0000	9.1333	13.6200	4.4633	7.7000	32.7667
26.	POLF-19(1765)×GS-129(1018)	86.00	144.00	70.8000	5.6333	191.6667	6.7000	17.7700	3.9900	7.2833	22.4467
27.	POLF-17(1704)	84.66	134.33	63.9667	5.1667	97.6667	8.7667	15.1767	3.9333	7.1867	25.9367
28.	POLF-17(1704)×PbD2-42(2789)	86.00	144.00	68.2000	6.2000	112.5667	7.7000	16.3000	3.9067	7.0700	23.9600
29.	POLF-17(1704)×GS-234(1703)	87.66	148.66	62.3333	8.9000	184.2000	8.7667	9.6667	4.0033	7.4633	41.5067
30.	POLF-17(1704)×GS-129(1018)	85.33	145.00	66.0667	5.9667	144.0667	8.3333	13.0000	3.0867	7.7033	23.8600
31.	PbD2-42(2789)	87.00	145.00	66.0667	5.6333	47.3333	9.0667	13.0433	2.8567	6.9600	21.8967
32.	PbD2-42(2789)×GS-234(1703)	85.00	140.00	74.6000	6.1667	55.2000	9.2000	15.6833	3.5667	7.5133	22.7167
33.	PbD2-42(2789)×GS-129(1018)	86.00	146.00	68.2000	4.6333	167.3333	7.6333	26.1167	7.6633	7.1333	29.3367
34.	GS-234(1703)	78.66	135.33	72.3333	4.2000	53.9000	8.2333	14.1167	2.9600	7.4700	20.9667
35.	GS-234(1703)×GS-129(1018)	86.66	140.00	59.3333	4.6000	134.0667	8.0667	18.0000	5.0033	7.0067	27.8633
36.	GS-129(1018)	82.00	137.00	71.6000	5.3333	87.0667	9.1000	11.6600	3.0167	6.5200	25.7967
37.	T-397(c)	85.00	128.33	76.1667	12.7667	387.3333	8.5333	27.6667	8.3600	7.2000	30.3200
38.	Allahabad local(c)	78.00	131.00	57.3000	11.9667	344.0000	9.1000	21.9967	7.0667	7.7000	32.3767
39.	Neelum(c)	88.00	135.000	65.8667	4.7000	110.3667	4.5333	14.3933	3.2167	7.5767	22.3433
	Mean	**86.72**	**142.11**	**68.8547**	**6.1179**	**143.3530**	**8.1735**	**16.5177**	**4.5603**	**6.9439**	**28.2483**
	C.V.	1.039	0.8702	0.5130	5.0889	0.3079	2.3027	2.5185	3.1388	1.6864	4.6237
	F ratio	57.908	53.90	778.39	116.7147	95254.7734	134.1050	609.4277	392.2313	113.0714	55.9087
	F Prob.	0.000	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	S.E.	0.520	0.714	0.203	0.1797	0.2549	0.1087	0.2402	0.0826	0.0676	0.7541
	C.D. 5%	1.465	2.011	2.574	2.5063	2.7178	1.3061	2.6765	2.2328	1.1904	2.1240
	C.D. 1%	1.944	2.66	2.762	2.6716	2.9522	1.4060	2.8974	2.3088	1.2526	2.8176
	Range Lowest	78.00	128.33	57.3000	3.6667	47.3333	4.5333	8.2933	2.8567	4.9667	17.1867
	Range Highest	98.66	151.66	81.7667	12.7667	387.3333	9.6000	31.1867	8.3600	8.8000	41.5067

Table.2.2 (a) Heterosis(Ha), Heterobeltiosis(H_b)and Economic Heterosis(Hc) for days to 50% flowering and days to maturity in linseed

S. No	Genotypes	Days to 50% flowering			Days to maturity		
		Ha	H_b	Hc	Ha	H_b	Hc
1	M-42(169) × FRW-6(973)	-3.23**	-4.49**	-3.41**	7.95**	3.17**	12.35**
2	M-42(169) × C91538(456)	-5.68**	-6.74**	-5.68**	-1.47*	-1.80*	7.65**
3	M-42(169) × POLF-19(1765)	-1.71*	-3.37**	-2.27*	0.71	-4.08**	4.44**
4	M-42(169) × POLF-17(1704)	-3.26**	-5.62**	-4.55**	4.50**	0.00	8.89**
5	M-42(169) × PbD2-42(2789)	-3.41**	-4.49**	-3.41**	-3.65**	-4.31**	4.20**
6	M-42(169) × GS-234(1703)	2.58**	-3.37**	-2.27*	2.01**	-2.04**	6.67**
7	M-42(169) × GS-129(1018)	1.75*	-2.25*	-1.14	2.11**	-1.36	7.41**
8	FRW-6(973) × C91538(456)	8.25**	8.05**	6.82**	0.71	-4.05**	5.19**
9	FRW-6(973) × POLF-19(1765)	10.04**	9.62**	7.95**	6.12**	5.72**	4.94**
10	FRW-6(973) × POLF-17(1704)	15.18**	13.85**	12.12**	7.33**	7.20**	6.67**
11	FRW-6(973) × PbD2-42(2789)	7.10**	6.90**	5.68**	0.36	-3.45**	3.70**
12	FRW-6(973) × GS-234(1703)	11.29**	6.15**	4.55**	5.69**	5.17**	5.43**
13	FRW-6(973) × GS-129(1018)	-2.77**	-5.38**	-6.82**	3.57**	2.43**	3.95**
14	C91538(456)× POLF-19(1765)	-1.73*	-2.30*	-3.41**	4.15**	-1.13	8.40**
15	C91538(456)× POLF-17(1704)	1.36	0.00	-1.14	3.42**	-1.35	8.15**
16	C91538(456)× PbD2-42(2789)	2.30**	2.30*	1.14	-1.02	-2.03**	7.41**
17	C91538(456) × GS-234(1703)	6.24**	1.15	0.00	1.41*	-2.93**	6.42**
18	C91538(456) × GS-129(1018)	0.20	-2.68**	-3.79**	1.05	-2.70**	6.67**
19	POLF-19(1765)× POLF-17(1704)	0.00	-0.78	-3.03**	9.23**	8.68**	8.15**
20	POLF-19(1765)× PbD2-42(2789)	4.05**	3.45**	2.27*	6.47**	2.07**	9.63**
21	POLF-19(1765) × GS-234(1703)	6.88**	2.33*	0.00	6.34**	5.42**	5.68**
22	POLF-19(1765) × GS-129(1018)	2.38**	0.00	-2.27*	6.67**	5.11**	6.67**
23	POLF-17(1704)× PbD2-42(2789)	0.19	-1.15	-2.27*	3.10**	-0.69	6.67**
24	POLF-17(1704) × GS-234(1703)	7.35**	3.54**	-0.38	10.26**	9.85**	10.12**
25	POLF-17(1704) × GS-129(1018)	2.40**	0.79	-3.03**	6.88**	5.84**	7.41**
26	PbD2-42(2789) × GS-234(1703)	2.62**	-2.30*	-3.41**	-0.12	-3.45**	3.70**
27	PbD2-42(2789) × GS-129(1018)	1.78*	-1.15	-2.27*	3.55**	0.69	8.15**
28	GS-234(1703) × GS-129(1018)	7.88**	5.69**	-1.52	2.82**	2.19**	3.70**

** and *significant at 1% and 5% level of significance respectively

Table.2.2 (b) Heterosis (H_a), Heterobeltiosis (H_b) and Economic Heterosis (H_c) for plant height and primary branches per plant in linseed

S.No	Genotypes	Plant height(cm)			Primary branches/plant		
		Ha	Hb	H_C	Ha	H_b	H_C
1	M-42(169) × FRW-6(973)	0.51	-1.27**	14.42**	-31.38**	-31.58**	-17.02**
2	M-42(169) × C91538(456)	-10.25**	-15.11**	-1.62**	-6.37	-11.05**	19.86**
3	M-42(169) × POLF-19(1765)	-8.18**	-12.49**	1.42**	-4.59	-8.77	10.64
4	M-42(169) × POLF-17(1704)	15.75**	6.38**	23.28**	-22.70**	-26.32**	-10.64
5	M-42(169) × PbD2-42(2789)	-3.56**	-10.04**	4.25**	-26.47**	-26.90**	-11.35
6	M-42(169) × GS-234(1703)	2.20**	-0.48	15.33**	-25.93**	-35.67**	-21.99**
7	M-42(169) × GS-129(1018)	10.55**	7.12**	24.14**	-15.41**	-18.13**	-0.71
8	FRW-6(973) × C91538(456)	2.71**	-1.18**	10.48**	-0.56	-5.79	26.95**
9	FRW-6(973) × POLF-19(1765)	-3.27**	-6.20**	4.86**	-4.29	-8.24	10.64
10	FRW-6(973) × POLF-17(1704)	-11.14**	-16.98**	-7.19**	16.31**	11.18**	34.04**
11	FRW-6(973) × PbD2-42(2789)	-3.98**	-8.92**	1.82**	26.84**	26.47**	52.48**
12	FRW-6(973) × GS-234(1703)	-4.09**	-4.93**	6.28**	14.19**	-0.59	19.86**
13	FRW-6(973) × GS-129(1018)	-9.57**	-10.82**	-0.30	-3.03	-5.88	13.48*
14	C91538(456)× POLF-19(1765)	7.51**	6.65**	11.99**	58.96**	44.74**	95.04**
15	C91538(456)× POLF-17(1704)	-0.53	-3.53**	-0.30	2.03	-7.37	24.82**
16	C91538(456)× PbD2-42(2789)	-7.06**	-8.42**	-5.36**	36.49**	28.95**	73.76**
17	C91538(456) × GS-234(1703)	3.51**	0.46	10.32**	36.08**	13.16**	52.48**
18	C91538(456) × GS-129(1018)	-3.10**	-5.49**	2.73**	8.57*	0.00	34.75**
19	POLF-19(1765)× POLF-17(1704)	-11.87**	-15.18**	-10.93**	57.56**	57.05**	73.76**
20	POLF-19(1765)× PbD2-42(2789)	-0.81*	-3.04**	1.82**	16.92**	12.43**	34.75**
21	POLF-19(1765) × GS-234(1703)	-5.02**	-7.10**	2.02**	19.15**	7.69	19.15**
22	POLF-19(1765) × GS-129(1018)	0.59	-1.12**	7.49**	6.96	5.62	19.86**
23	POLF-17(1704)× PbD2-42(2789)	4.90**	3.23**	3.54**	14.81**	10.06*	31.91**
24	POLF-17(1704) × GS-234(1703)	-8.54**	-13.82**	-5.36**	90.04**	72.26**	89.36**
25	POLF-17(1704) × GS-129(1018)	-2.53**	-7.73**	0.30	13.65**	11.87*	26.95**
26	PbD2-42(2789) × GS-234(1703)	7.80**	3.13**	13.26**	25.42**	9.47	31.21**
27	PbD2-42(2789) × GS-129(1018)	-0.92*	-4.75**	3.54**	-15.50v	-17.75**	-1.42
28	GS-234(1703) × GS-129(1018)	-17.55**	-17.97**	-9.92**	-3.50	-13.75**	-2.13

** and *significant at 1% and 5% level of significance respectively

Table.2.2 (c) Heterosis(Ha), Heterobeltiosis(Hb)and Economic Heterosis(Hc) for capsules per plant and seeds per capsule in linseed

S.No	Genotypes	Capsules per plant			Seeds per capsules		
		Ha	Hb	Hc	Ha	Hb	Hc
1	M-42(169) × FRW-6(973)	21.84**	-5.25**	31.92**	-1.96	-4.51**	102.21**
2	M-42(169) × C91538(456)	54.33**	41.30**	31.44**	-0.36	-3.13*	105.15**
3	M-42(169) × POLF-19(1765)	-15.23**	-27.81**	-44.19**	-3.83**	-8.33**	94.12**
4	M-42(169) × POLF-17(1704)	6.23**	-0.48	-11.93**	-4.17**	-8.33**	94.12**
5	M-42(169) × PbD2-42(2789)	41.41**	9.92**	-15.01**	-2.14	-4.86**	101.47**
6	M-42(169) × GS-234(1703)	-19.46**	-34.30**	-49.20**	-12.52**	-18.75**	72.06**
7	M-42(169) × GS-129(1018)	-30.39**	-31.09**	-45.64**	-8.02**	-10.42**	89.71**
8	FRW-6(973) × C91538(456)	107.31**	72.91**	140.74**	-44.95**	-45.05**	10.29**
9	FRW-6(973) × POLF-19(1765)	61.62**	12.36**	56.45**	-31.84**	-33.33**	33.82**
10	FRW-6(973) × POLF-17(1704)	101.80**	65.03**	129.78**	-26.12**	-27.47**	45.59**
11	FRW-6(973) × PbD2-42(2789)	64.38**	7.51**	49.68**	-26.24**	-26.37**	47.79**
12	FRW-6(973) × GS-234(1703)	51.08**	2.04**	42.07**	-4.23**	-8.79**	83.09**
13	FRW-6(973) × GS-129(1018)	-56.47**	-65.90**	-52.52**	-1.10	-1.10	98.53**
14	C91538(456)× POLF-19(1765)	185.33**	126.04**	110.27**	-0.94	-2.94	94.12**
15	C91538(456)× POLF-17(1704)	110.98**	105.84**	91.48**	-7.66**	-9.19**	81.62**
16	C91538(456)× PbD2-42(2789)	100.09**	46.17**	35.97**	0.00	0.00	100.00**
17	C91538(456) × GS-234(1703)	196.44**	126.04**	110.27**	-28.32**	-31.62**	36.76**
18	C91538(456) × GS-129(1018)	6.22**	-1.85**	-8.70**	1.28	1.10	102.94**
19	POLF-19(1765)× POLF-17(1704)	93.66**	56.31**	38.33**	-1.53	-1.90	89.71**
20	POLF-19(1765)× PbD2-42(2789)	191.93**	161.11**	41.95**	-31.71**	-33.09**	33.82**
21	POLF-19(1765) × GS-234(1703)	94.91**	85.00**	0.57	7.87**	4.98**	101.47**
22	POLF-19(1765) × GS-129(1018)	160.65**	120.14**	73.66**	-24.72**	-26.37**	47.79**
23	POLF-17(1704)× PbD2-42(2789)	55.26**	15.26**	1.99**	-13.64**	-15.07**	69.85**
24	POLF-17(1704) × GS-234(1703)	143.06**	88.60**	66.90**	3.14*	0.00	93.38**
25	POLF-17(1704) × GS-129(1018)	55.97**	47.51**	30.53**	-6.72**	-8.42**	83.82**
26	PbD2-42(2789) × GS-234(1703)	9.05**	2.41**	-49.98**	6.36**	1.47	102.94**
27	PbD2-42(2789) × GS-129(1018)	149.01**	92.19**	51.62**	-15.96**	-16.12**	68.38**
28	GS-234(1703) × GS-129(1018)	90.21**	53.98**	21.47**	-6.92**	-11.36**	77.94**

** and *significant at 1% and 5% level of significance respectively

Table.2.2 (d) Heterosis(Ha), Heterobeltiosis(Hb) and Economic Heterosis(Hc) for harvest index (%) and Seed yield per plant(g) in linseed

S.No	Genotypes	Harvest index (%)			Seed yield per plant (g)		
		Ha	Hb	Hc	Ha	Hb	Hc
1	M-42(169) × FRW-6(973)	28.62**	17.97**	76.25**	28.10**	23.43**	63.21**
2	M-42(169) × C91538(456)	35.09**	23.37**	53.81**	-16.47**	-26.49**	-2.80
3	M-42(169) × POLF-19(1765)	-0.33	-8.15*	35.82**	92.22**	85.82**	145.70**
4	M-42(169) × POLF-17(1704)	-20.76**	-23.49**	-4.61	-2.36	-6.03*	24.25**
5	M-42(169) × PbD2-42(2789)	30.66**	16.68**	45.47**	-16.83**	-30.49**	-8.08*
6	M-42(169) × GS-234(1703)	48.58**	30.21**	62.33**	-16.64**	-29.31**	-6.53
7	M-42(169) × GS-129(1018)	-0.97	-4.63	18.90**	-8.39**	-21.71**	3.52
8	FRW-6(973) × C91538(456)	-4.57	-19.37**	20.45**	119.23**	99.49**	144.56**
9	FRW-6(973) × POLF-19(1765)	-13.26**	-13.70**	28.93**	81.72**	81.11**	123.52**
10	FRW-6(973) × POLF-17(1704)	-9.38**	-19.48**	20.29**	20.36**	20.20**	47.36**
11	FRW-6(973) × PbD2-42(2789)	13.59**	-5.95	40.50**	45.10**	25.11**	53.37**
12	FRW-6(973) × GS-234(1703)	-25.83**	-39.62**	-9.80	82.13**	59.43**	95.44**
13	FRW-6(973) × GS-129(1018)	27.38**	12.91**	68.68**	80.46**	59.26**	95.23**
14	C91538(456)× POLF-19(1765)	-9.20**	-22.96**	13.92**	14.76**	4.11	28.50**
15	C91538(456)× POLF-17(1704)	-2.94	-8.39	6.34	-8.84**	-16.95**	1.55
16	C91538(456)× PbD2-42(2789)	51.07**	47.37**	51.86**	10.78**	4.33	4.87
17	C91538(456) × GS-234(1703)	-21.86**	-25.35**	-23.08**	38.43**	32.58**	33.26**
18	C91538(456) × GS-129(1018)	13.20**	7.11	23.67**	-2.40	-5.67	-5.18
19	POLF-19(1765)× POLF-17(1704)	10.62**	-1.27	45.99**	64.82**	64.06**	102.49**
20	POLF-19(1765)× PbD2-42(2789)	-1.23	-17.89**	21.42**	13.38**	-2.52	20.31**
21	POLF-19(1765) × GS-234(1703)	21.34**	-0.83	46.65**	28.81**	12.43**	38.76**
22	POLF-19(1765) × GS-129(1018	-23.70**	-32.06**	0.46	14.22**	0.50	24.04**
23	POLF-17(1704)× PbD2-42(2789)	0.18	-7.62	7.24	15.07**	-0.68	21.45**
24	POLF-17(1704) × GS-234(1703)	76.99**	60.03**	85.77**	16.15**	1.78	24.46**
25	POLF-17(1704) × GS-129(1018)	-7.76*	-8.01	6.79	-11.18**	-21.53**	-4.04
26	PbD2-42(2789) × GS-234(1703)	6.00	3.74	1.67	22.64**	20.50**	10.88**
27	PbD2-42(2789) × GS-129(1018)	23.02**	13.72**	31.30**	160.95**	154.03**	138.24**
28	GS-234(1703) × GS-129(1018)	19.17**	8.01**	24.71**	67.43**	65.86**	55.54**

** and *significant at 1% and 5% level of significance respectively

Table.2.2 (e) Heterosis(Ha), Heterobeltiosis(H_b) and Economic Heterosis(Hc) for 1000 grain weight (g) and biological yield per plant (g) in linseed

S.No	Genotypes	1000 grain weight (g)			Biological yield / plant (g)		
		Ha	H_b	Hc	Ha	H_b	Hc
1	M-42(169) × FRW-6(973)	-4.44**	-4.49**	-21.47**	-1.55	-12.69**	-7.39**
2	M-42(169) × C91538(456)	-0.65	-3.34*	-16.06**	-37.92**	-40.41**	-36.80**
3	M-42(169) × POLF-19(1765)	2.63*	0.00	-13.42**	90.91**	70.57**	80.92**
4	M-42(169) × POLF-17(1704)	-25.93**	-30.89**	-34.45**	23.18**	22.82**	30.27**
5	M-42(169) × PbD2-42(2789)	10.09**	4.26**	-4.22**	-35.74**	-40.41**	-36.80**
6	M-42(169) × GS-234(1703)	-16.02**	-23.03**	-24.11**	-43.55**	-45.68**	-42.38**
7	M-42(169) × GS-129(1018)	0.97	-1.33	-15.09**	-6.91**	-17.90**	-12.92**
8	FRW-6(973) × C91538(456)	18.66**	15.50**	0.31	126.07**	108.14**	103.03**
9	FRW-6(973) × POLF-19(1765)	16.76**	13.82**	-1.45	109.85**	108.10**	73.69**
10	FRW-6(973) × POLF-17(1704)	31.18**	22.45**	16.15**	30.67**	16.19**	22.51**
11	FRW-6(973) × PbD2-42(2789)	8.01**	2.35	-5.98**	26.43**	20.47**	9.17**
12	FRW-6(973) × GS-234(1703)	17.27**	7.54**	6.03**	140.55**	120.92**	116.67**
13	FRW-6(973) × GS-129(1018)	6.98**	4.60**	-9.99**	41.95**	41.03**	15.75**
14	C91538(456)× POLF-19(1765)	-0.20	-0.35	-13.46**	24.67**	15.67**	12.83**
15	C91538(456)× POLF-17(1704)	3.44**	-0.93	-6.03**	-5.88**	-9.40**	-4.47
16	C91538(456)× PbD2-42(2789)	-0.34	-3.07*	-10.95**	-26.15**	-28.77**	-30.52**
17	C91538(456) × GS-234(1703)	-6.05**	-11.65**	-12.89**	77.58**	77.10**	73.69**
18	C91538(456) × GS-129(1018)	-3.05*	-3.50*	-16.19**	-14.11**	-21.39**	-23.32**
19	POLF-19(1765)× POLF-17(1704)	8.54**	3.80**	-1.54	47.11**	31.78**	38.95**
20	POLF-19(1765)× PbD2-42(2789)	-14.50**	-16.95**	-23.71**	13.85**	9.35**	-0.90
21	POLF-19(1765) × GS-234(1703)	9.76**	3.08*	1.63	4.25	-3.52	-5.37*
22	POLF-19(1765) × GS-129(1018)	11.37**	11.03**	-3.87**	50.13**	47.92**	23.46**
23	POLF-17(1704)× PbD2-42(2789)	-0.05	-1.62	-6.69**	15.52**	7.40**	13.25**
24	POLF-17(1704) × GS-234(1703)	1.84	-0.09	-1.50	-34.00**	-36.31**	-32.84**
25	POLF-17(1704) × GS-129(1018)	12.40**	7.19**	1.67	-3.12	-14.34**	-9.68**
26	PbD2-42(2789) × GS-234(1703)	4.13**	0.58	-0.84	15.49**	11.10**	8.96**
27	PbD2-42(2789) × GS-129(1018)	5.84**	2.49	-5.85**	111.44**	100.23**	81.45**
28	GS-234(1703) × GS-129(1018)	0.17	-6.20**	-7.52**	39.66**	27.51**	25.06**

** and *significant at 1% and 5% level of significance respectively

Table 1.3 First five best hybrids identified on the basis of economic heterosis for seed yield per plant

S. No	Crosses	Economic heterosis (%) over the best check	*Per se* performance for seed yield per plant(g)	Days to 50% flowering	1000-grain weight (g)	No. of capsules per plant
1	$P_{1X}P_4$(M-42(169)×POLF-19(1765))	35.82**	7.90	86.00	6.56	61.60
2	$P_{2X}P_3$ (FRW-6(973)×C91538(456))	20.45**	7.86	94.00	7.60	265.70
3	$P_{6X}P_8$ (PbD2-42(2789)×GS-129(1018))	31.30**	7.66	86.00	7.13	167.33
4	$P_{2X}P_4$ (FRW-6(973)×POLF-19(1765))	28.93**	7.19	95.00	7.46	172.66
5	$P_{2X}P_7$ (FRW-6(973)×GS-234(1703))	-9.8	6.28	92.00	8.03	156.80

Days to 50% flowering (Table 2.2.a)

Heterosis for days to 50% flowering ranged from -5.68**(M-42(169) × C91538(456)) to 15.18** (FRW-6(973) × POLF17(1704)). It was significant in 7 crosses for early flowering. Maximum significant negative heterosis was obtained in cross M-42(169) × C91538(456) (-5.68**) and M-42(169) × PbD2-42(2789) (-3.41**).

Significant heterobeltiosis for early flowering was observed in 13 crosses. Heterobeltiosis ranged from -6.74** (M-42(169) × C91538(456)) to 13.85** (FRW-6(973) × POLF17(1704)). The highest heterobeltiosis were exhibited by the hybrid M-42(169) × C91538(456) (-6.74**) followed by M-42(169) × POLF-17(1704) (-5.62**) and M-42(169) × PbD2-42(2789) (-4.49**).

Significant economic heterosis ranged from -6.82** (FRW-6(973) × GS-129(1018)) to 12.12** FRW-6(973) × POLF17(1704). It was significant in 17 cross. Highest negative economic heterosis was observed in FRW-6(973) × GS-129(1018) (-6.82**) followed by M-42(169) × C91538(456) (-5.68**) and M-42(169) × POLF-17(1704) (-4.55**) for early flowering.

Days to maturity (Table 2.2.a)

The estimates for heterosis for days to maturity ranged from – 3.65** (M-42(169) × PbD2-42(2789)) to 10.26** (POLF-17(1704) × GS-234(1703)). It was significant in 2 crosses for early maturity. Maximum significant negative heterosis was obtained in cross M-42(169) × PbD2-42(2789) (-3.65**) and M-42(169) × C91538(456) (-1.47*).

Significant heterobeltiosis for early maturity was observed in 14 crosses. It was ranged from -4.31** ((M-42(169) × PbD2-42(2789)) to 9.85** (POLF-17(1704) × GS-234(1703)). Maximum significant negative heterosis was obtained in cross M-42(169) × PbD2-42(2789) (-4.31**) and M-42(169) × POLF-19(1765) (-4.08**). Significant economic heterosis for early maturity was observed in none of crosses.

Plant height (Table 2.2.b)

The range of heterosis for plant height was –

17.55** (GS-234(1703) × GS-129(1018)) to 15.75** (M-42(169) × POLF-17(1704)). The heterotic effect was significant in 18 crosses in negative direction.

Significant heterobeltiosis for plant height was observed in 27 crosses, of which 22 crosses are significant heterobeltiosis in desired direction. It ranged from -17.97** (GS-234(1703) × GS-129(1018)) to 7.12** (M-42(169) × GS-129(1018)). The maximum significant negative heterobeltiosis was obtained in the cross GS-234(1703) × GS-129(1018) (-17.97**) followed by POLF-19(1765)× POLF-17(1704) (-15.18**) and M-42(169) × C91538(456) (-15.11**).

Economic heterosis ranged from -10.93** (POLF-19(1765)× POLF-17(1704)) to 24.14** (M-42(169) × GS-129(1018)). The maximum significant economic heterosis was obtained in the cross POLF-19(1765) × POLF-17(1704) (-10.93**) followed by GS-234(1703) × GS-129(1018) (-9.92**) and FRW-6(973) × POLF17(1704) (-7.19**).

Number of primary branches per plant (Table 2.2.b)

The heterosis over mid parent for this character varied from -31.38** (M-42(169) × FRW-6(973)) to 90.04** (POLF-17(1704) × GS-234(1703)). Out of 28 hybrids, 16 hybrids exhibited positive desirable heterotic effect. The cross combination POLF-17(1704) × GS-234(1703) (90.04**) exhibited highest heterosis followed by C91538(456)× POLF19(1765) (58.96**) and POLF-19(1765)× POLF-17(1704) (57.56**).

The heterobeltiosis ranged from -35.67** (M-42(169) × GS-234(1703)) to 72.26** (POLF-17(1704) × GS-234(1703)). Significant positive heterobeltiosis was observed in 13 crosses. Highest positive heterobeltiosis was obtained in the cross POLF-17(1704) × GS-234(1703) (72.26**) followed by POLF-19(1765) × POLF-17(1704) (57.05**) and C91538(456) × POLF19(1765) (44.74**).

Significant economic heterosis was noticed in all crosses, which ranged from -41.18** (A-202(183) X EC-12082) to 95.04**(C91538(456)× POLF19(1765)). The highest economic heterosis was observed in the cross C91538(456)× POLF19(1765) (95.04**) followed by POLF-17(1704) × GS-234(1703) (89.36**) and C91538(456)× × PbD2-42(2789) (73.76**).

Number of capsules per plant (Table 2.2.c)

The relative heterosis ranged from -56.47** (FRW-6(973) × GS-129(1018)) to 196.44** (C91538(456) × GS-234(1703)). Significant desirable heterotic effect was observed in 24 crosses. The cross combination C91538(456) × GS-234(1703) (196.44**) exhibited the highest heterosis followed by crosses C91538(456) × GS-234(1703) (191.93**) and C91538(456)× POLF19(1765) (185.33**).

The heterobeltiosis ranged from -34.30** (M-42(169) × GS-234(1703)) to 161.11** (POLF-19(1765)× PbD2-42(2789)). Significant positive heterobeltiosis effect was observed in 21 crosses. The highest positive heterobeltiosis was obtained in the cross POLF-19(1765) × PbD2-42(2789) (161.11**) followed by C91538(456) × GS-234(1703) (126.04**) and POLF-19(1765) × GS-129(1018) (120.14**).

Significant economic heterosis was noticed in all 20 crosses. It ranged from 0.57** (POLF-19(1765) × GS-234(1703)) to 140.74** (FRW-6(973) × C91538(456). The highest economic heterosis was observed in cross FRW-6(973) × C91538(456) (140.74**) followed by FRW-6(973) × POLF17(1704) (129.78**) and C91538(456)× POLF19(1765) (110.27**).

Number of seeds per capsules (Table 2.2.c)

The range of heterosis was -31.84** (FRW-6(973) × POLF19(1765)) to 7.87** POLF-19(1765) × GS-234(1703). Out of 28 crosses, 4 crosses depicted significant positive heterotic effect. The cross combination POLF-19(1765) × GS-234(1703) (7.87**) exhibited highest heterosis followed by PbD2-42(2789) × GS-234(1703) (6.36**) and POLF-17(1704) × GS-234(1703) (3.14*).

The heterobeltiosis varied from -45.05** (FRW-6(973) × C91538(456)) to 4.98** (POLF-19(1765) × GS-234(1703)). Out of 28 crosses, 3 crosses had significant positive heterobeltiosis effect. The cross combination POLF-19(1765) × GS-234(1703) (4.98**) exhibited highest heterobeltiosis followed by PbD2-42(2789) × GS-234(1703) (1.47**) and C91538(456) × GS-129(1018) (1.10**).

The economic heterosis ranged from 10.29** FRW-6(973) × C91538(456) to 105.15** (M-42(169) × C91538(456)). Out of 28 crosses, 28 crosses had significant positive economic heterosis.. The hybrid M-42(169) × C91538(456) (105.15**) exhibited highest significant economic heterosis.

Biological yield per plant (g) (Table 2.2.e)

The relative heterosis ranged from -43.55** (M-42(169) × GS-234(1703)) to 140.55** (FRW-6(973) × GS-234(1703)). Out of 28 crosses, 18 crosses had significant positive heterotic effect. The hybrid FRW-6(973) × GS-234(1703) (140.55**) exhibited highest significant heterosis followed by FRW-6(973) × C91538(456) (126.07**) and PbD2-42(2789) × GS-129(1018) (111.44**).

Heterobeltiosis varied from -45.68** (M-42(169) × GS-234(1703)) to 120.92** (FRW-6(973) × GS-234(1703)). Out of 28 crosses, 17 crosses had positive significant heterobeltiosis effect. The hybrid exhibited highest heterobeltiosis effect FRW-6(973) × GS-234(1703) (120.92**) followed by FRW-6(973) × C91538(456) (108.14**) and FRW-6(973) × POLF19(1765) (108.10**).

The economic heterosis ranged from -42.38** (M-42(169) × GS-234(1703)) to 116.67** (FRW-6(973) × GS-234(1703)). Out of 28 crosses 16 crosses had significant positive economic heterosis.. The hybrid FRW-6(973) × GS-234(1703) (116.67**) exhibited highest significant economic heterosis followed by FRW-6(973) × C91538(456) (103.03**) and PbD2-42(2789) × GS-129(1018) (81.45**).

Seed yield per plant (g) (Table 2.2.d)

The relative heterosis for seed yield per plant ranged from -2.36 (M-42(169) × POLF-17(1704)) to 160.95** (PbD2-42(2789) × GS-129(1018)). Out of 28 crosses, 20 crosses had significant positive heterotic effect. The hybrid PbD2-42(2789) × GS-129(1018) (160.95**) exhibited highest significant heterosis, followed by FRW-6(973) × C91538(456) (119.23**) and M-42(169) × POLF-19(1765) (92.22**).

Heterobeltiosis varied from -30.49** (M-42(169) × PbD2-42(2789)) to 154.03** (PbD2-42(2789) × GS-129(1018)). Out of 28 crosses, 18 crosses had positive significant heterobeltiosis effect. The hybrid PbD2-42(2789) × GS-129(1018) (154.03**) exhibited highest heterobeltiosis effect followed by FRW-6(973) × C91538(456) (99.49**) and M-42(169) × POLF-19(1765) (85.82**).

The economic heterosis ranged from -8.08* (M-42(169) × PbD2-42(2789)) to 145.70** (M-42(169) × POLF-19(1765)). Out of 28 crosses, 21 crosses had significant positive economic heterosis.. The hybrid (M-42(169)

× POLF-19(1765) (145.70**) exhibited highest significant economic heterosis followed by FRW-6(973) × C91538(456) (144.56**) and PbD2-42(2789) × GS-129(1018) (138.24**).

1000-grain weight (g) (Table 2.2.e)

The relative heterosis ranged from -25.93** (M-42(169) × POLF-17(1704)) to 31.18** (FRW-6(973) × POLF17(1704)). Out of 28 crosses, 15 crosses had significant positive heterotic effect. The hybrid FRW-6(973) × POLF17(1704) (31.18**) exhibited highest significant heterosis ,followed by FRW-6(973) × C91538(456) (18.66**) and FRW-6(973) × POLF19(1765) (16.76**).

Heterobeltiosis varied from -30.89** (M-42(169) × POLF-17(1704)) to 22.45** (FRW-6(973) × POLF17(1704)). Out of 28 crosses, 11 crosses had positive significant heterobeltiosis effect. The hybrid FRW-6(973) × POLF17(1704) exhibited highest heterobeltiosis (22.45**) followed by FRW-6(973) × C91538(456) (15.50**) and FRW-6(973) × POLF19(1765) (13.82**).

The economic heterosis ranged from -34.45** (M-42(169) × POLF-17(1704)) to 16.15** (FRW-6(973) × POLF17(1704)). Out of 28 crosses, 2 crosses had significant positive economic heterosis.. The hybrid FRW-6(973) × POLF17(1704) (16.15**) exhibited highest significant economic heterosis followed by FRW-6(973) × GS-234(1703) (6.03**).

Harvest index (%) (Table 2.2.d)

The relative heterosis ranged from -25.83** (FRW-6(973) × GS-234(1703)) to 76.99** (POLF-17(1704) × GS-234(1703). Out of 28 crosses, 13 crosses had significant positive heterotic effect. The hybrid POLF-17(1704) × GS-234(1703) (76.99**) exhibited highest significant heterosis, followed by C91538(456)× × PbD2-42(2789) (51.07**) and M-42(169) × GS-234(1703) (48.58**).

Heterobeltiosis varied from -39.62** (FRW-6(973) × GS-234(1703) to 60.03** (POLF-17(1704) × GS-234(1703)). Out of 28 crosses, 9 crosses had positive significant heterobeltiosis effect. The hybrid POLF-17(1704) × GS-234(1703) (60.03**) exhibited highest heterobeltiosis followed by C91538(456)× × PbD2-42(2789) (47.37**) and M-42(169) × GS-234(1703) (30.21**).

The economic heterosis ranged from -23.08** (C91538(456) × GS-234(1703)) to 85.77**(POLF-17(1704) × GS-234(1703)). Out of 28 crosses, 20 cross had positive economic heterosis.. The hybrid POLF-17(1704) × GS-234(1703) (85.77**) exhibited highest significant economic heterosis followed by M-42(169) × FRW-6(973) (76.25**) and FRW-6(973) × GS-129(1018) (68.68**).

The commercial exploitation of heterosis in crop plants is regarded as a major breakthrough in the realm of plant breeding. It is a phenomenon of immense practical value, as its utilization has led to considerable yield improvement of several cereal and other crops such as maize, bajra, sorghum, cotton and castor etc. A better understanding of this phenomenon might lead to important advantages, including its commercial exploitation in other crops like linseed. In linseed inspite of high hybrid vigour and availability of male sterility. Its commercial exploitation has not been possible, because the flower of the male sterile flax had a small corolla which fails to open to allow cross pollination. The aim of heterosis study in this crop is to spot out heterotic hybrids which might throw desired, segregants in the succeeding generations.

The results revealed that estimates of significant positive as well as negative heterosis and heterobeltiosis were obtained in many crosses for different character studied. The high values for heterotic effects indicated that the parents used for the study were widely diverse. Considerable high heterosis in certain hybrids and low in other revealed that the nature of gene action varied with the genetic architecture of the parents. Such nature as well as magnitude of heterosis helps in identifying superior cross combination.

In the present study out of 28 crosses, 7 crosses for days to flowering, 2 crosses for days to maturity, 18 crosses for plant height, 16 crosses for number of primary branches per plant, 24 crosses for number of capsules per plant, 4 crosses for number of seeds per capsule, 15 crosses for 1000-seed weight, 18 crosses for biological yield per plant, 13 crosses for harvest index and 4 crosses for seed yield per plant depicted significant relative heterosis in desired direction. Hybrid M-42(169) × POLF-19(1765) and FRW-6(973) × C91538(456) showed significant heterosis effect of seed yield along with earliness.

Positive significant heterosis for seed yield and other attributes in linseed were also reported by Elladi (1939), Dalal and Gill (1965), Bojeova (1966), Doucet *et al.*, (1967), Anand and Murty (1968), Hakro and Baluch (1968), Anand and Murty (1969), Anand *et al.*, (1972), Galkin (1972), Badwa and Gupta (1974), Bhatnagar (1977), Rao and Singh (1983), Dakhore *et al.*, (1987 b), Rao *et al.*, (1987), Singh *et al.*, (1987 a), Heyland and Hemker (1991), Dhakar (1994), Patel (1995), Verma and Mahto (1996), Yadav (1997), Kumar *et al.*, (2002), Ratnaparkhi *et al.*, (2004), Sharma *et al.*, (2005), Sood *et al.*, (2006), Pant *et al.*, (2007) and Pant *et al.*, (2008).

In the present study seed yield per plant had significant desired heterobeltiosis in crosses. The highest heterobeltiosis value for seed yield was recorded by the cross (PbD2-42(2789) × GS-129(1018)) (154.03**) followed by FRW-6(973) × C91538(456) (99.49**) and M-42(169) × POLF-19(1765) (85.82**).

The above findings are in agreement with the findings of Kalia (1972), Makhija (1974), Ermakov and Megoraskaya (1975), Chandra (1978), Shrivas and Singh (1982), Patil and Chopde (1983), Singh *et al.*, (1983), Dakhore *et al.*, (1987), Dubey and Dixit (1991), Verma and Sinha (1993), Saraswat *et al.*, (1993), Patel (1995), Kumar *et al.*, (2002), Sharma *et al.*, (2005) and Pant *et al.*, (2008).

In the present study, seed yield per plant had significant positive economic heterosis in 20 crosses. The highest economic heterosis value for seed yield per plant was recorded by the cross (M-42(169) × POLF-19(1765)) (145.70**) followed by FRW-6(973) × C91538(456) (144.56**) and PbD2-42(2789) × GS-129(1018) (138.24**).

Among the top economic heterotic hybrids, the hybrid (259.83**) maximum seed yield per plant along with 1000 grain weight (7.44**) and number of capsules per plant (288.02**), whereas the hybrid A-72(112) X EC-41528 exhibited second highest seed yield per plant (221.98%) along with primary branches per plant (205.88**). Significant desired economic heterosis for seed yield and other attributes in linseed were also reported by Dakhore *et al.*, (1987), Kumar *et al.*, (2002), Ratnaparkhi *et al.*, (2004) Sharma *et al.*, (2005) and Pant *et al.*, (2008).

Relative heterosis(MP) and heterobeltiosis (BP) are important parameters as they provide information about the presence of dominance and over dominance type of gene actions in the expression of various traits.

Thus for characters viz., days to flowering, days to maturity and plant height some hybrids exhibited negative significant relative heterosis, there by indicating that for these traits the genes with negative effects were dominant on the other hand for characters like seeds per capsule, number of capsules per plant, number of primary branches per plant, seed yield per plant, biological yield per plant and harvest index, majority of the hybrids exhibited positive significant relative heterosis, thereby indicating that for these characters the genes with positive effects were dominant.

Similar results on heterosis in linseed were reported by Kumar *et al.,* (1980), Patil and Chopde (1983), Singh *et al.*, (1987), Dakhore *et al.*, (1987), Saraswat *et al.*, *(*1993), Verma *et al.*, *(*1993), Mishra and Rai (1993), Ratnaparkhi *et al.*, *(*2004), Sharma *et al.*, (2005). Sood *et al.*, (2006) and Pant *et al.*, *(*2008). However, heterosis over check variety will be a better parameter for assessing superiority over existing varities and comparing heterosis effects of different crosses (Dakhore *et al.*, 1987).

In the present investigation cross M-42(169) × POLF-19(1765) showed highest economic heterosis over the best check (Neelum) followed by T-397 and local check.

References

A. R. Hallauer and J. B. Miranda(1981), *Quantitative Genetics in Maize Breeding*, Iowa State University Press Ames, Iowa, USA.

A.B.Damania,(1997) "Near-eastern crop diversity and its global migration," in *The Origin of Agriculture and Crop Domestication.Proceedings of the Harlan Symposium (ICARDA '97)*, A.

Anand, I.J. and B.R. Murty (1968). Genetic divergence and hybrid performance in Linseed. *Indian J. Genet.*,28: 178-185.

Anand, I.J. and B.R. Murty (1969 a). Serial analysis of combining ability in diallel and fractional diallel crosses in Linseed.TAG.,39; 88-94.

Anand, I.J. and B.S.Rana (1972) Estimation of Genetic variances by full-sib and half-sib analysis in linseed. *Sabrao Newssl.,* 4 :33-37.

Babwal, S.S and V.P. Gupta (1974). Heterosis and inbreeding depression in linseed. *J.Cytol. Genet.*, 7 : 63-78.

Babwal, S.S, V.P. Gupta and K.S. Gill (1972). Combining ability studies of selected world germplasm lines of linseed. *J.Res. PAU.* 9 : 383-388.

Bhateria *et al.*, (2006) Genetic analysis of quantitative traits across environments in linseed (*Linum usitatissimum* L.) *Springer Netherlands* :185-194

Bhateria, S., A. Pathania, J.K. Sharma, D. Badiyala and J.C. Bhandari (2001). Combining ability for seed yield and its components in linseed (*Linum usitatissimum L.). J.Oilseeds Res.*,18 (1) : 44-47.

Bhatnagar, S.K. (1977). Combining ability and gene action studies in the inheritance of quality and quantity of oil in linseed (*Linum usitatissimum L.).* Phd. Thesis, university of Udaipur. Udaipur.

Bojeova, V.P. (1966). Hybridization of Linseed.*Indian J. Genet.*, 40(1): 99-101.

Bruce, A. B. (1910). The Mendelian theory of heredity and the augmentation of vigour. *Sci* 32 : 627-28.

Carnahan, H.L. (19\49). The inheritance of oil content and other characters in the flax andassociation between characters in the cross of 'Dakota x Minerva' P.hd. Thesis University of Minnestola, St. Paul. Minnesota.

Castle, W.E.(1946). Gene which devide species or produce hybrid vigours.*Proc. National Acad. U.S.A.* 32: 145-149.

Comstock, R.E., H.F. Robinson, and P.H. Harvey (1949). A breeding procedure designated to make maximum use of both general and specific combining ability. *Agron .J.* 41:360-367.

Dakhore, S.R., M.N. Narkhede and P.W. Khorgade (1987b). Combining ability for oil content in linseed. *J. of Maharastra. Agri. Univ.*12 (3): 308-310.

Dakhore, S.R., M.N. Narkhede and P.W. Khorgade (1987b). Heterosis in relation to combining ability effects in Linseed. *PKV Res. J.*,11 (1): 7-12.

Dalal, J.L. and K.S. Gill (1965) General combining ability and heterosis in some F_1 intervarietal crosses of linseed. *Indian Oilseeds J.*,9 : 61-66.

Dang, Z. H., B.D. Chen, S.C. Xin and L.Q. Zheng

(1987). Analysis of combining ability for oil contents in linseed. *Oil Crops, China,* 3 : 52-55.

Devenport, C. B. (1908). Degeneration, albinos and inbreeding. *Sci.* 28 : 454-55.

Dhakar,J.M. (1994). Studies on heterosis, combining ability and stability parameters in linseed (*Linum usitatissimum* L.). unpublished Ph.d. Thesis, R.C.A., R.A.U. Udaipur.

Donald, C.M. and Hamblin, J.(1976). .The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv.Agron.,* (28): 361-405.

Doucet, I., M. Coucet and F. Popescu (1979). Combining ability in some Flax varieties analysed by the incomplete diallel-cross method. Analele- Institutuli-de-Cercetari-pentru- cereal-si-plante-Technice-Fundulea, 44:51-62.

Doucet, M. and I. Doucet, (1967). Contribution to study of heterosis in flax. *An.Ins. certcet. Cereal Pl. Tech. Fundulea. Ser. C.,* 34 : 401-413.

East, E.M. (1936). Heterosis, Genetics, 21:375-397.

East, E.M. and H.K. Hays (1912). Heterozygotes in evolution and in -plant breeding *U.S. Dept. Agri Bur.Plant Indust. Bull.*243 : p 58.

Elladi, K. V. (1939). Inheritance of length of vegetative period in flax hybrids. *Bul. Acad. Sci. USSR. Ser. Biol,.* 37: 388.

F. L´opez Anido, V. Cravero, P. Asprelli, T. Firpo, S. M. Garc´ıa, and E. Cointry (2004), "Heterotic patterns in hybrids involving cultivar-groups of summer squash, *Cucurbita pepo* L," *Euphytica*, vol. 135, no. 3, pp. 355–360.

Fonesca, S. and Patterson, p. (1968). Hybrid vigour in a seven parent diallel cross in common winter wheat. *Crop Sci*., 8: 85-88.

Galkin, F. M. (1972). Heterosis in inter varietal hybrids of linseed (*Linum usitatissimum* L.). *Byul. Nauchntekhn inform Po. Maslichn. Kulturam* No. 3: 17-21.

Genter, G. F. and Alexander, M. N. (1962). Comparative performance of S_1 progenies and test crosses of corn, C*rop Sci*., 2: 416-419

Gill, K.S. (1967). Linseed, publication and information Division, New Delhi :I.C.A.R.

Goray, S.C., Khosla, H.K. and P.K. Nigam (1990). Analysis of combining ability in Linseed (*Linum usitatissimum* L.). *Madras Agric., Crop Sci*., 8: 77(9-12): 465-469.

Green AG (1986) Genetic control of polyunsaturated fatty acid biosynthesis in flax (Linum usitatissimum) seed oil. Theor Appl Genet 72:654-661.

Green, A. G. and D. R. Marshall (1981). Variation for oil quantity and qualtity in Linseed (*Linum usitatissimum* L.). *Australian J. Agric. Res.,*32 (4) :599-607.

Griffing, B. (1956b). Concept of general and specific combining ability in relation to diallel crossing system *Aust. J. Biol. Sci.,* 9: 463-493.

Gustafsson, A. (1936). Studies on the genetic basis of chlorophyll formation and the mechanism of inducing mutation. *Hereditas* 24 : 33-93.

Hakro, M.A. and M.A.A. Baulch (1968). Heterosis studies on plant height in linseed (*Linum usitatissimum* L.) *west Pak. J. Agril. Res.,* 7 (3): 109-116.

Hatze, G. (1989) World importance of oil crops and their products. *McGraw Hill Publishing company, New York*, 1-21.

Hayman, B.I. (1954). The analysis of variance of diallel table. *Biometrics*, 10: 235-244.

Heyland, K.U. and R. Hemker (1991). Suitability of vegetative and reproductive traits as selection criteria in breeding for Concurrent use of soil, fibre and flax., *Lein Bodenkultur.* 42 (1): 45-56.

Hull, F. H. (1945). Recurrent selection for specific combining ability in corn. *J. Amer. Soc. Agron.* 37 : 234-45.

Jeswani,L. M. (1953). Inheritance studies in varietal crosses in Linseed (*Linum usitatissimum* L.). Unpublished Assoc. Thesis I.A.R.I., New Delhi.

Jinks, J. L. (1955). A survey of genetic basis of heterosis in a variety of diallels crosses, *Heredity*, 9 : 223- 238.

Jinks, J. L. and Jones, R. M. (1958). Estimation of the components of heterosis. *Genetics*, 43: 223-234.

Kalia, N.R. (1972). Combining ability, graphical analysis and heterosis in linseed(*Linum usitatissimum* L).Unpublished M.Sc. Thesis, P.A.U. Ludhiana.

Kandil, .A.A. Sheraif A. E. , Abo-Zaied T. A. and Gamil A. (2011). Genetic divergence and heterosis in linseed(*Linum usitassimum* L.). J.Plant production mansours university vol(2)2 335-349.

Kansal, K.K. and S.C. Gupta (1981). Note on heterosis in Linseed. *Indian J.Agric. Sci.*,51 (9): 680-682

Karmuka,K.S., Tasdidawa and G.S. Shethi (1988). Combining ability analysis for oil content and iodine value in linseed. (*Linum usitatissimum* L.). *Indian J. Agric. Sci.*,58 (4):-252-254.

Karpunia, I.I. and G.P. Kornienko (1981). Combining ability of flax varieties. *Len- i- Kanaplya* ,1 35:36.

Kasim, M.H. (1964). The analysis of yield and its components and seed quality characteristics in diallel cross among ten varieties of flax.

Diss. Abstr. 25: 2719 .

Kaushal, A.K., S.R. Srinivas and U. Goswami (1974). Combining ability for oil content in Linseed. *J.Agric. Sci*., 44 (12): 859-862.

Keeble, F. and Pellow, C. (1910). The mode of inheritance in stature and of time of flowering in peas (*Pisum sativum*). *J. Genet*. 1 : 47-56.

Kumar, Mukul, P.K. Singh, M. Kumar (2000). Heterosis in Linseed. *Ann. Agric. Res*., 21(4) : 485-489.

Kumar, Mukul, P.K. Singh, N.P. Singh and M. Kumar (2002). Line x tester analysis for seed yield and its components in Linseed. *Ann. Agric. Res*., 21(4): 723-727.

Kumar, S., B.P.S. Chauhan, S.S. Jamini and Suresh Kumar (1980 a). Diallel analysis of flowering and maturity in Linseed. *Indian J. Agric Sci*., 50 (3):225-230.

Kumar, S., B.P.S. Chauhan, S.S. Jamini and Suresh Kumar (1980 b) Combining ability in Linseed. *Indian J. Genet*., 40 (1) : 216-221.

Kumar, S., B.P.S. Chauhan, Suresh Kumar (1982). Variability and combining ability in the F_2 population of a diallel in linseed. *Indian J. Agric. Sci*., 52(11) : 723-727.

Kupyanskaya, N.A. (1979). Results of estimating the combining ability of Fibre Flax cultivars specimens. *Selektisya-i-Semenovodstvo*, 4 : 17-18.

Kusalkar, A. M., B.R. Patil. S.B. Thawari and J.P. Khatod (2002). Combining ability studies in Linseed. *Ann. Of Pl. Physio*., 16 (2) : 133-137.

Lay, C.L. and C.D. Dying (1989) Oil crops of the world. Their Breeding and utilization.*McGraw Hill Publishing company, New York*, 416-430.

Lennerts, L. (1983) Oilschrote, Oelkuchen, Pflahzliche oele and Fette, Herkunft, Gewinnung, verwendung. Bonn.verlag Alfred strothe, Hannover.

M. Berti, S. Fischer, R. Wilckens, and F. Hevia, (2009) “Flaxseed response to N, P, and K fertilization in South Central Chile,”*Chilean Journal of Agricultural Research*, vol. 69, no. 2, pp. 145–153,

M. P. Chauhan, S. Singh, and A. K. Singh,(2010) “Post-Harvest uses of Linseed,” *Journal of Human Ecology*, vol. 28, pp.217–219.

M. Rai, H. Singh, and D. M. Hegde (2002), *Oilseeds and Oils research and Development Needs*, Indian Society of Oilseeds Research,Directorate of Oilseeds Research, Hyderabad, India.

Manfroni-de—Silvero-Sanz, D.H., A. A. Conde, O.I. Silvero-Sanz and D.H.M. de Silvero-Sanz (1989). Combining ability in a diallel cross of Linseed. *Boletin- Genetico-Castelar*, 15 : 9-14

Mishra *et al*., (2011). Biplot approach for identification of heterotic crosses in linseed *(Linum usitatissimum* L.*). J. of Botany*. 2011: Article ID 353102.

Mishra, V.K. and M. Rai (1996). Combining ability analysis for seed yield and quality components of seed and oil in Linseed. *(Linum usitatissimum* L.*) J. Genet.*,56 (2): 155-161.

Mishra, V.K. and Rai, M.(1993). Estimates of heterosis for seed yield, components of seed and oil in Linseed *(Linum usitatissimum* L.*) Indian J.Genet.*,53 (2) 161-164.

Mohammadi. A. A., Saeidi G., Arjani A. (2010) Genetic analysis of some agronomic traits in flax (*Linum usitatissimum* L.). *Australian J. of Crop Sci*, 4:5, 343-352.

Muir AD, Westcott ND (2003) Flax: The Genus Linum. Taylor & Francis, London

Murty, B.R. and I.J. Anand (1966). Combining ability and genetic diversity in some varieties of linseed. *(Linum usitatissimum* L.*) Indian J.Genet.*,26 :21-36.

Nie, Z. B.C. Gue, G.T. Chen and A.O. Liang (1991). Study on combining ability of the principal organic characters in Flax *(Linum usitatissimum* L.*) Ningria J. Agro. Forestry Science and Technology*, 4:7-11.

Noor-ul-Islam *et al*., (1999). Combining Ability Analysis in Linseed (*Linum usitatissimum L*.). *Pakistan J. of Biol. Sci*. 01/1999; DOI.

Pal, B.P. and Sikka, S.M., (1956). Exploitation of hybrid vigour in the improvement of crop plants, fruits and vegetables. *Indian J. Genet*. Plant Breed, 16: 95-193.

Panse, V.G, and Sukhatme, P.V. (1942). Statistical methods for agricultural workers (*2nd* Ed.)., I.C.A.R., Publications, New Delhi.

Pant *et al*., (2007) Components of Genetic Variation in Yield Traits of Linseed(*Linum usitatissimum* L.) *Indian Journal of Plant Genetic Resources.*

Pant *et al*., (2008) Heterosis over Superior Parents under Diallel Cross in Linseed/Flax (*Linum usitatissimum* L.) *Indian Journal of Plant Genetic Resources.*

Patel, A.J. (1995). Genetic analysis of seed yield and quality characters in linseed *(Linum usitatissimum* L.*)* P.hd. Thesis, R.A.U Bikaner.

Patel, A.J.,Y.K.Gupta, S.B. Patel and J.N. Patel (1997). Combining ability analysis over environments in linseed *(Linum usitatissimum* L.*) Madra Agric. J.*, 84 (4) : 188-191.

Patil, V.D. and P.R. Chopde (1981) Combining ability analysis over environments in diallel crosses in linseed *(Linum usitatissimum* L.*) Theo. and App.*

Genet 60 (6): 339-343.

Patil, V.D. and P.R. Chopde (1984) Heterosis in relation to general and specific combining ability effects in linseed *(Linum usitatissimum* L.*) Indian J. Genet.,* 43(2): 226-228.

Pillai, Beena, P.W. Khorgade and M.N. Narkhede (1995). Genetic behavior of yield and its components in Linseed. *J. Oilseeds Res.,*12(1): 5-9.

Popescu, F., I. Marinescu and I. Vasile (1998). Combining ability and heritability of important characters for improving Linseed. *Problems-de-Genetica-Teoretica- Si- Aplicata.*30 (1-2) : 105-122.

Prasad, R. (2004). Text Book of Field Crops production (1st Ed.). I.C.A.R. publication, New Delhi.

Prygun, V.S. and L.M. polonetskayaat (1985). Combining ability of Flax varieties for the main economically useful characters in a Line x Tester crossing system. *Sel' Skokhazyaistvennaya-Bidogiya,* 9 : 67-70

Rai, M. and K. Das (1974). Combining ability for components yield in linseed *(Linum usitatissimum* L.*) Indian J. Gene.,* 34 (3) : 371-375.

Rao, S.K., S.P. Singh (1983). Heterosis and inbreeding depression in linseed. *(Linum usitatissimum* L.*)J. Agric. Sci.* 53 :409-417.

Rao, S.K., S.P. Singh and M.L. Talwar (1987). Heterosis fos seed size and oil content in linseed *(Linum usitatissimum* L.*)Oilseeds Res.,*4 :242-245

Ratnaparkhi, R.D., M.Y. Dudhe, N.D. Gawande and S.A. Bhongle (2004). Heterosis in relation to combining ability effects in linseed. *Ann. Plant Physio.* 18 (2): 182- 186.

Ratnaparkhi, R.D., N.N. Kolte and P.W. Khorgade (1998). Line x Tester analysis for combining ability in Linseed. *(Linum usitatissimum* L.) *PKV Res. J.,* 22 (1) : 3-6

Rowland GG (1991) An EMS-induced low linolenic acid mutant in McGregor flax (Linum usitatissimum L.). *Can J Plant Sci* 71:393-396.

Saraswat, A. V., Kumar Satyendra, S. Kumar, M. N. Verma, D. S. Virk and G. S. Chand (1995). Heterosis and inbreeding depression in some early hybrids of linseed. Heterosis breeding in crop plants- theory and applications: Short communications: Symposium Ludhiana, 1993 : 52-53.

Schidmt, J.(1919). La valeur 1 'individu a' titre de generatour appreciee Suivant la method du crosment diallel. *Camp. Rend. Lab. Casriberg,* 14 No. 633.

Seetharam, A. and D. Srinivasachar, (1970). Mutational evidence for the origin of Indo-gangetic and peninsular types of Indian Linseed. *Current. Sci.,*39

Sharma *et al.,* (2005) Heterobeltiosis and inbreeding depression in linseed. *Agricultural Science Digest.*

Shehata, A.H. and Comstock, V.E., (1971) Heterosis and combining ability estimates in F_2 Flax populations as influenced by plant density. *Crop Sci 11 :534-536.*

Shrivastava *et al.,* (2004) Heterosis and combining ability estimates in linseed under salt affected soil. Indian Agriculturist. 48:3/4, 193-197.

Shrivastava *et al.,* (2007) Heterosis and combining ability estimates in linseed under salt affected soil. *Plant Archives.* 7: 2, 905-908.

Shull, G. H. (1908). The composition of field of maize. *Amer. Breeders Assoc. Rept*. 4 : 296-301.

Shull, G. H. (1911 a). Experiments with maize. composition of field of maize. *Bot. Goz.,* 52: 430-435.

Shull, G. H. (1911 b). The genotypes of maize. *Amer.Nat.,* 45 : 234-252.

Sikha, Tripathi, Mishra, V. and Tripathi, H. C. (2011). Combining ability analysis of yield and its components in linseed (Linum usitatissimum L.). *Current Advances in Agril. Sci*. 3: 2, 93-95.

Simmonds, N.W., (1976) Evolutions of crop plants.,*Langman Inc., New York.*

Singh *et al.,* (2008) Combining ability and gene action for Alternaria blight and powdery mildew resistance in linseed. *The Indian Journal of Genetics and Plant Breeding*.

Singh R. J., Ramakant P. K., Vimal S.C. (2010) Assessment of heterosis in linseed (*Linum usitatissimum* L.). *Agril. And Biol. Research*. 26:1,64-76.

Singh, B., J.S. Sindhu, Allah Rang and A. Rang (1990). Combining ability in Linseed. *Res. and Dev. Reporter,* 7 (1-2) : 47-52.

Singh, Brahm.G. Singh and J.S. Sindhu (1986) Combining ability and genetic architecture of oil content in Linseed. *J. Oilseeds Res*., 3 : 14-18.

Singh, K.P. and H.G. Singh(1979). Combining ability analysis for quantitative traits in Linseed.*Indian J. Agric. Sci.,* 49 (8): 573-578.

Singh, Neelam, S.P. Singh and C.B. Singh(1981). Genetic studies in linseed using partial diallel technique.*Indian J. Agric. Sci.,* 51 (12): 853-856.

Singh, P., A.N. Srivastava, I.B. Singh and R. Mishra (1987a). Heterosis and Inbreeding depression in relation to *Per se* performance in Linseed. *Farm Sci. j.,* 2 (1): 68-73.

Singh, R.K. (1973). Comparision of selection indices on selection experiments in rye. *H.A.U. J. Res.,* 2 : 145-149.

Singh, R.P., R.P. Singh, S.P. Singh and R.V. Singh (1979). Combining ability for yield components in rice. *Oryza*,, 16 : 115-118.

Singh, R.S., S. Singh and R.K. Chiudhary (1983). Heterobeltiosis in relation to *per se* performance and effects of general combining ability in linseed *(Linum usitatissimum* L.) *Precongress scientific meeting on genetics and improvement of heterotic systems :*14

Singh, V., O.P. Pachauri and S.N. Tiwari (1987 b). Combining ability studies in linseed *(Linum usitatissimum* L.) *Indian J. Genet.*, 47 (2): 171-178.

Singh. P. K., Srivastava. R. L., Narayan Ved and Dubey. S. D. (2009) Combining ability and heterosis for seed yield and oil content in linseed (*Linum usitatissimum*). *Indian J.of Agric. Sci.* Vol 79, No 3.

Sood *et al.*, (2006) Detection of genetic components of variation for some biometrical traits in *Linum usitatissimum* L. in sub-mountain Himalayan region.

Sood S., Kalina N. R., Bhatira S. (2011) Combining ability and heterosis studies across environments in linseed (*Linum usitatissimum* L.). *Acta Agronomica Hungarica*. 2011. 59: 1, 87-102. 27 ref.

Sprague, G.F. and L.A. Tatum (1942).General versus specific combining ability in single crosses of corn. *J.Amer. Sol. Agron.*, 34 923-932.

Sprague, G.F.(1966). Quantitative genetics in plant improvement in plant breeding. Ed. K.J. Frey IOWA state univ. press Ames. IOWA : 315-347.

Stadler, L. J. (1939). Some observations on gene variability and spontaneous mutation. Spragg Memorial Lectures, Michigan College. Pp. 1-15 (Read Abstr.).

Swarnakar *et al.*, (2005) Studies on combining ability and heterosis in linseed (Linum usitatissinum L.). *Farm Sci. J.* 14;1,4-6.

Swarnakar, S.K., Poonam Singh and R.L. Srivastava (2003). Combining ability analysis in linseed *(Linum usitatissimum* L.) *Progressive Agric.*, 3(1-2): 103-106.

Thakur, H.L. and N.D. Rana (1987). Combining ability in linseed *(Linum usitatissimum* L.) *Indian J. Agric., Sci.*, 57 (5) : 303-308.

Thakur, H.L. and N.D. Rana and O.P. Sood (1987). Combining ability analysis for some quantitative characters in linseed *(Linum usitatissimum* L.) *Indian J. Genet.*, 47 (1) : 6-10.

Thakur, H.L. and S. Bhateria (1991). L x T analysis for Combining ability in linseed *(Linum usitatissimum* L.) *J.Oilseeds Res.*,8 : 14-18.

Tiwari,Nalini, R.K. Dixit and H.C. Singh (2004). Combining ability analysis for seed yield and its components in linseed. *(Linum usitatissimum* L.) *J. Oilseeds Res.*,,21(2): 343-345.

Turner, J.H. (1953). A study of heterosis in upland cotton, combining ability and inbreeding effects. *Agronomy Journal*, 45 : 487-490

Vavilov, N.I. (1951). Phytogeographic basis of plant breeding. The origin,variation, immunity and breeding of cultivated plants. *Chronica Bat.*, 13 : 1- 366.

Verma, A.K. and J.L. Mahto (1966). Hybrid vigour in linseed for yield and yield attributes under rainfed and irrigated enviromments. *J. Tropical Agric.*, 34 (1) : 54-57.

Verma, A.K., P.K. Sinha. M.M. Verma, D.S. Virk and G.S. Chahal (1993). Heterosis in linseed. *(Linum usitatissimum* L.). Heterosis Breebing in crop plants- theory and applications: Short communications: Symposium Ludhiana, 1993:82-83.

Visnu Ameta Shah, Lakshyadeep M. A. (2005) Studies on heterosis and combining ability for fatty acids in linseed (*Linum usitatissimum* L.). *J. of Medicinal and Aromatic Plant Sci.* 27: 4, 615-618. 8.

Yadav, R.K. and S.B.L. Srivastava (2002). Combining ability analysis over environments in linseed *(Linum usitatissimum* L.) *Crop Res., Hissar*, 23(2) :277- 282.

Yang, W. R. and T.Y. Bo (1988). Analysis of combining ability for quantitative characters in Flax cultivars. *Shanxi Agric. Sci.*, 3 : 7-10.

How to cite this article:

Divya Mahto, P. K Singh and Shailesh Marker. 2020. Half diallel analysis for estimation of heterosis for phonological traits in linseed (*Linum usitatissimum* L). *Int.J.Curr.Microbiol.App.Sci.* 9(02): 2451-2474. doi: https://doi.org/10.20546/ijcmas.2020.902.280