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GENETIC ANALYSIS OF YIELD AND YIELD CONTRIBUTING TRAITS IN LINSEED (*LINUM USITATISSIMUM* L.)

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ABSTRACT
Twelve hybrids of linseed generated by crossing of 4 lines and 3 testers in line × tester mating design were sown along with their seven parental lines to assess the extent of standard heterosis over standard check i.e. Nagarkot for yield and eleven component traits. Dominance genetic variance varied from 0.36 (straw yield per plant) to 315.13 (seed yield per plot) and higher than additive genetic variance for all traits except technical height. Out of 12 F_1 hybrids, seven crosses T-397 x Nagarkot (34.24%), T-397 x Himalsi-1 (8.31%), Chambal x Nagarkot (43.56%), Chambal x HimAlsi-1 (21.53%), Chambal x EC-541194 (22.54%), HimAlsi-2 x HimAlsi-1 (37.29 %) and HimAlsi-2 x EC-541194 (40.17 %) exhibited significant positive standard heterosis. for seed yield per plant which could be an excellent source for developing high yielding linseed genotypes.

INTRODUCTION

Linseed (*Linum usitatissimum* L.) is one of the oldest crops under cultivation. It belongs to the family Linaceae and is presumed to be originated in southwest Asia particularly in India (Vavilov, 1935; Richharia, 1962). The Genus *Linum* comprises over 200 species (Gill, 1987) of which only *Linum usitatissimum* L. is of economic importance. It has somatic chromosome number 2n = 30 and varies from 16 to 86 in other species. Two morphologically distinct cultivated species of linseed are recognised, namely Flax and Linseed. The flax types are commercially grown for the extraction of fibres, whereas the linseed is meant for the extraction of oil from seeds. The linseed oil is rich in fatty acids alpha linolenic acid (ALA) an essential Omega-3 fatty acid and lignin oligomers accounting for 57 % of total fatty acids in its biochemical composition (Reddy *et al.,* 2013) Across the world it covers 2270.35 thousand hectare area with production of 2238.94 thousand tons having productivity of 986.16 kg per hectare, where as in India it covers 338 thousand hectares area and a production of 147 thousand tons with the productivity of 434.91 kg per hectare, (Anonymous, 2013). The average productivity is very low as compared to other countries where it is grown. Hence, there is an urgent need to increase the productivity by breaking the present yield barrier and developing hybrids with high yield potential (Ramesh *et al.,* 2013 and Jhajharia *et al.,* 2013).

Genetic improvement of any trait largely depends on the magnitude and direction of available heterosis. The phenomenon of heterosis has proved to be the most important genetic tool in boosting the yield of self as well as cross pollinated crops and is recognized as the most important breakthrough in field of crop improvement. The best hybrids for yield and related traits can be achieved by evaluating the promising diverse lines and their cross combinations. (Singh *et al.,* 2006). The study on the magnitude of heterosis would help in identifying promising cross combinations for exploitation of heterosis for genetic improvement of quantitative traits and genetic information on heterosis is useful for developing breeding strategies to meet the demands of increased population. It is necessary to have detailed information about the desirable parental combination in any breeding program which can reflect a high degree of heterotic response. It has become a common practice of the plant breeder working with crop plants to obtain genetic information of the diverse breeding material from line x tester technique developed by Kempthorne (1957). Therefore, heterotic studies can provide the basis for the exploitation of valuable hybrid combinations in future breeding programs as earlier reported by Pali and Mehta (2014); Reddy *et al.* (2013); Ratnaparkhi *et al.* (2005); Sharma *et al.* (2005); Saraswat *et al.* (1993); Foster *et al.* (1998) and Rede (1999). The present investigation was undertaken with an objective to measure the magnitude of heterosis in hybrids over standard check (Nagarkot) for seed yield and associated traits in linseed

MATERIALS AND METHODS

The experimental materials comprising of 19 treatments, seven parents (four lines and three testers Table 1) and their twelve F_1 crosses were produced using Line x Tester fashion proposed by Kempthorne (1957). Twelve crosses in line × tester fashion were made at experimental farm of Department of Crop Improvement, CSK, Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India situated at 1290.8 meters amsl and at 32º8´ N and 76º3´ E longitude during *rabi* 2012–2013.

The experimental materials were evaluated in randomized complete block design with three replications during *rabi* 2013-2014. The recommended agronomical practices and plant protection measures were adopted for raising a good crop. Data were recorded on five randomly selected plants of each treatment in each replication for plant height(cm), technical height (cm), primary branching, secondary branching, capsules per plant, seeds per capsule, biological yield (g), straw yield (g), seed yield per plant (g), 1000 seeds weight (g) and harvest index (%). Seed yield per plot (g) was calculated from whole plot.

The recorded data was subjected to statistical analysis, the percent increase (+) or decrease (-) of F_1 cross over standard check was calculated to observe heterotic effects of all the parameters.

Estimation of heterosis over the standard check

Heterosis over standard check was calculated as per the following formula given by Shull (1908).

$$\text{Heterosis over standard check (\%)} = \frac{\overline{F1} - \overline{SC}}{\overline{SC}} \times 100$$

SE for testing heterosis over SC = $\pm \sqrt{2Me/r}$ = SE (H)

Test of significance for heterosis (Dabholkar, 1992).

$$\text{Heterosis over SC} = \frac{\overline{F1} - \overline{SC}}{SE\ (H)} = \text{'t' Calculated value}$$

These calculated't' values for for heterosis over standard check were compared with Table't' value at error degrees of freedom at P=0.05 and P=0.01.

Estimation of additive ($\sigma^2 A$) and dominance ($\sigma^2 D$) components of variance

For computing the additive and dominance components of variances following formulae have been used (Singh & Chaudhary, 1977).

$\sigma^2 gca = [1 + f/4]\ \sigma^2 a = ½\ \sigma^2 a$

$\sigma^2 sca = [1 + F/2]^2\ \sigma^2 D = \sigma^2 D$

where,

F = inbreeding coefficient,

$\sigma^2 A$ = additive variance, and

$\sigma^2 D$ = dominance variance.

Estimation of narrow sense heritability (%)

Heritability in narrow sense (h^2_{ns}) was calculated as per the following formula (Singh and Chaudhary, 1977).

$$\text{Heritability } (h^2 ns) = \frac{\sigma^2 A}{\sigma^2 P}$$

$$= \frac{\sigma^2 A}{\sigma^2 A + \sigma^2 D + \sigma^2 E}$$

where,

h^2_{ns} = narrow sense heritability

$\sigma^2 A$ = additive genetic variance

$\sigma^2 P$ = phenotypic variance

$\sigma^2 D$ = dominant genetic variance

$\sigma^2 E$ = environmental variance

RESULTS AND DISCUSSION

Dominance genetic variance was larger than additive genetic variance for all traits except technical height. These results are supported by the degree of dominance $(\sigma^2 D/\sigma^2 A)^{1/2}$ which takes values greater than unity (Table 2). Therefore, it appeared that the inheritance of all the studied characters except technical height was controlled by a preponderance of non-additive gene effects as earlier reported by Bhateria *et al*. (2006); Bhateria *et al*. (2001); Kumar *et al*. (2000); Mahto and Rahman (1998); Patel *et al*. (1997) and Tak (1996). Such type of gene action clearly indicated that selection of superior plants, in terms of grain yield, plant height, and duration of the vegetative growth period should be postponed to later generation, where these traits can be improved by making selections among the recombinants within the segregating populations, selection efficiency is related to the magnitude of heritability. In this study, low estimates of narrow-sense heritability were observed for all the traits under study (Table 2), as earlier reported by Bhateria *et al*. (2006), indicating non-additive type of gene action.

The percentage of heterosis over standard check for seed yield and its component characters is presented in Table 3. The estimates of heterosis expressed that none of the hybrids were found to be significantly heterotic (standard heterosis) for all the traits. The extent of heterosis for various characters was calculated as per cent increase or decrease over best check variety (Nagarkot). Small and medium plant stature in linseed crop is preferred because it prevents lodging from heavy winds; therefore, negative heterosis is useful regarding plant height. It is clear that standard heterosis ranged from -27.29 to 2.73 percent in the crosses Kangra Local x EC-541194 and Chambal x Nagarkot respectively. Nine crosses showed significant decrease in plant height over standard check, the findings of similar nature were obtained by Sheikh and Singh (2001); Anand *et al*. (1972); Badwal *et al*. (1974); Galkin (1973 b) and Wang and Feng (1997). Technical height is important for fibre quality so positive heterosis is useful regarding technical height.

Table 1: List of linseed accessions/lines and their parentage/source used in the study

S. No.	Lines/testers	Parentage/source
Lines		
1	T-397	T-491 x T-1193-2
2	Chambal	Local × RR 45
3	Kangra local	Local variety
4	HimAlsi-2	EC-21741 x LC-216
Testers		
1	Nagarkot	New river x LC-216
2	HimAlsi-1	K-2 x TLP-1
3	EC-541194	Wild species

Table 2: Estimates of genetic components for the measured characters in linseed

	σ^2A	σ^2D	$[\sigma^2D/\sigma^2A]^{1/2}$	h^2ns
Plant height(cm)	14.30	23.30	1.28	12.99
Technical height (cm)	8.05	4.77	0.77	17.53
Primary branches	0.75	2.98	2.00	10.19
Secondary branches	0.48	2.14	2.12	10.37
Capsules per plant	6.52	26.78	2.03	10.02
Biological yield per plant	1.00	2.99	1.73	13.95
Seeds per capsules	0.08	0.23	1.65	13.99
Straw yield per plant (g)	0.23	0.36	1.24	14.77
Seed yield per plant (g)	0.12	0.86	2.72	8.81
Seed yield per plot (g)	141.48	315.13	1.49	12.58
1000 seeds weight (g)	0.33	0.58	1.32	13.89
Harvest Index (%)	3.02	33.22	3.32	13.04

σ^2A :additive genetic variance, σ^2D: dominance genetic variance, $[\sigma^2D/\sigma^2A]^{1/2}$:mean degree of dominance and η^2ns : narrow sense heritability

Table 3: Percentage of heterosis over standard check for various traits in linseed

Crosses / Traits	Plant height (cm)	Technical height (cm)	Primary branches	Secondary branches	Capsules per plant	Biological yield per plant
T-397 x Nagarkot	-22.67 **	-27.31 **	29.55 **	29.17 **	-2.46 *	16.24 **
T-397 x HimAlsi-1	-21.00 **	-14.32 **	86.23 **	80.09 **	-1.71	-7.85 **
T-397 x EC-541194	-26.78 **	-38.74 **	97.81 **	84.91 **	-7.41 **	-37.60 **
Chambal x Nagarkot	2.73 **	5.73 **	11.74 **	13.89 **	- 4.51 **	12.06 **
Chambal x HimAlsi-1	-7.62 **	0.39	57.29 **	59.49 **	1.16	2.28
Chambal x EC-541194	-1.90 **	-21.57 **	15.38 **	12.96 **	12.64 **	5.52 *
Kangra Local x Nagarkot	-3.43 **	-5.25 **	14.17 **	13.43 **	4.78 **	-31.17 **
Kangra Local x HimAlsi-1	-7.17 **	-0.94	60.32 **	54.63 **	7.79 **	-14.11 **
Kangra Local x EC-541194	-27.29 **	-30.48 **	9.31 **	4.17	34.08 **	- 47.81 **
HimAlsi -2 x Nagarkot	1.72 **	1.53	34.01 **	25.93 **	-2.15 *	10.49 **
HimAlsi-2 x HimAlsi-1	0.45	9.41 **	38.06 **	20.60 **	7.59 **	13.40 **
HimAlsi-2 x EC-541194	-3.39 **	-5.51 **	26.52 **	18.52 **	38.78 **	13.71 **
SE (m) ±	0.48	0.47	0.28	0.22	0.44	0.27

Table 3: Cont.....

Crosses / Traits	Seeds per capsules	Straw yield per plant (g)	Seed yield per plant (g)	Seed yield per plot (g)	1000 seeds weight(g)	Harvest Index(%)
T-397 x Nagarkot	6.16	19.02 **	34.24 **	2.52 **	11.51 **	15.59 **
T-397 x HimAlsi-1	16.59 **	-14.36 **	8.31 **	10.07 **	19.80 **	17.56 **
T-397 x EC-541194	14.69 **	-28.67 **	-36.10 **	-37.92 **	- 4.92	2.46
Chambal x Nagarkot	3.32	5.69	43.56 **	3.52 **	15.48 **	28.00 **
Chambal x HimAlsi-1	-2.84	-10.68 **	21.53 **	6.54 **	5.53 *	18.82 **
Chambal x EC-541194	-16.59 **	-13.01 **	22.54 **	-3.02 **	7.54 **	16.11 **
Kangra Local x Nagarkot	18.01 **	-18.43 **	-23.39 **	- 4.36 **	- 30.55 **	11.29 **
Kangra Local x HimAlsi-1	18.96 **	-22.49 **	-21.19 **	- 5.70 **	1.81	- 8.04 *
Kangra Local x EC-541194	19.91 **	- 47.64 **	-27.12 **	- 27.85 **	- 46.48 **	39.62 **
HimAlsi -2 x Nagarkot	1.90	6.23 *	1.69	- 0.67	0.00	- 7.98 *
HimAlsi-2 x HimAlsi-1	9.00 **	7.86 *	37.29 **	6.88 **	21.01 **	21.05 **
HimAlsi-2 x EC-541194	12.32 **	- 2.44	40.17 **	- 17.11 **	- 18.49 **	23.25 **
SE (m) ±	0.24	0.19	0.13	1.28	0.16	1.06

*, ** Significant at 5% and 1% levels, respectively

Out of twelve crosses only two crosses *viz.*,Chambal x Nagarkot and HimAlsi-2 x HimAlsi-1 expressed significant positive heterosis over standard check. In linseed, short stature with vigorous structure containing more number of branches provide opportunity for more yields, so positive heterosis is desirable for number of primary and secondary branches. For primary branches heterosis estimates over standard check showed that all the crosses had significant positive effects where values ranged from 9.31 (Kangra Local x EC-541194) to 97.81 per cent (T-397 x EC-541194), whereas, heterosis for secondary branches varied from 4.17 (Kangra Local × EC-541194) to 84.91 (T-397 x EC-541194) per cent over standard check. The presence of significantly positive heterosis for primary and secondary branches per plant in crosses indicates their potential use in developing high yielding genotypes. The presence of high levels of standard heterosis indicates a considerable potential to embark on breeding of hybrid cultivars in *Linum usitatissimum*. The results of this study are similar to earlier findings of Rao and Singh (1983); Wang and Feng (1997); Patil and Chopde (1983); Dakhore *et al.* (1987)

Table 4: List of crosses showing significant positive heterosis over standard check (%) for various traits in linseed

Traits	Heterotic Crosses over standard check (%)
Plant Height (cm)	Chambal x Nagarkot and HimAlsi -2 x Nagarkot
Technical Height (cm)	Chambal x Nagarkot and HimAlsi-2 x HimAlsi-1
Primary branches	T-397 x Nagarkot, T-397 x HimAlsi-1, T-397 x EC-541194, Chambal x Nagarkot,Chambal x HimAlsi-1 Chambal x EC-541194, Kangra Local x Nagarkot, Kangra Local x HimAlsi-1, Kangra Local x EC-541194, HimAlsi -2 x Nagarkot, HimAlsi-2 x HimAlsi-1 and HimAlsi-2 x EC-541194
Secondary branches	T-397 x Nagarkot, T-397 x HimAlsi-1, T-397 x EC-541194, Chambal x Nagarkot, Chambal x HimAlsi-1, Chambal x EC-541194, Kangra Local x Nagarkot, Kangra Local x HimAlsi-1, HimAlsi -2 x Nagarkot,Him Alsi-2 x HimAlsi-1 and HimAlsi-2 x EC-541194
Capsules per plant	Chambal x EC-541194, Kangra Local x Nagarkot, Kangra Local x HimAlsi-1, Kangra Local x EC-541194, HimAlsi-2 x HimAlsi-1 and HimAlsi-2 x EC-541194
Biological Yield per plant (g)	T-397 x Nagarkot, Chambal x Nagarkot, Chambal x EC-541194, HimAlsi -2 x Nagarkot, HimAlsi-2 x HimAlsi-1and HimAlsi-2 x EC-541194
Seeds per Capsule	T-397 x HimAlsi-1, T-397 x EC-541194, Kangra Local x Nagarkot, Kangra Local x HimAlsi-1, Kangra Local x EC-541194, HimAlsi-2 x HimAlsi-1 and HimAlsi-2 x EC-541194
Straw yield per plant (g)	T-397 x Nagarkot, HimAlsi -2 x Nagarkot and HimAlsi-2 x HimAlsi-1
Seed yield per Plant (g)	T-397 x Nagarkot, T-397 x HimAlsi-1, Chambal x Nagarkot, Chambal x HimAlsi-1, Chambal x EC-541194, HimAlsi-2 x HimAlsi-1 and HimAlsi-2 x EC-541194
Seed yield per plot (g)	T-397 x Nagarkot, T-397 x HimAlsi-1, Chambal x Nagarkot, Chambal x HimAlsi-1 and HimAlsi-2 x HimAlsi-1
1000 Seed Weight (g)	T-397 x Nagarkot, T-397 x HimAlsi-1, Chambal x Nagarkot, Chambal x HimAlsi-1, Chambal x EC-541194 and HimAlsi-2 x HimAlsi-1
Harvest Index (%)	T-397 x Nagarkot, T-397 x HimAlsi-1, Chambal x HimAlsi-1, Chambal x Nagarkot, Chambal x EC-541194, Kangra Local x Nagarkot, Kangra Local x EC-541194, HimAlsi-2 x HimAlsi-1 and HimAlsi-2 x EC-541194

and Naushad *et al*. (2006) reported significant positive heterosis for number of branches per plant in linum genotypes. Number of capsules per plant is directly associated with seed yield and for this trait, six crosses *viz*., Chambal x EC-541194, HimAlsi-2 × HimAlsi-1, Kangra Local × Nagarkot, Kangra Local × HimAlsi-1, Kangra Local × EC-541194 and Him Alsi-2 × EC-541194 exhibited significant positive heterosis over standard check as earlier reported by Singh *et al*. (1983); Mishra and Rai (1993); Sakhare (1990); Saraswat *et al*. (1993) and Patil and Chopde (1983). Biological yield per plant is an important economic trait associated with seed yield in linseed. For biological yield per plant six crosses exhibited significant positive heterosis and five crosses expressed negatively significant which varied from -47.81 to 16.24 per cent over best check. For Number of seeds per capsule out of 12 crosses, 7 crosses exhibited significant positive heterosis and only one cross expressed significant negative heterosis over standard check, which varied from -16.59 to 19.91. Manifestation of considerable heterosis for such yield components have been reported earlier (Srivastava *et al*., 2007 and Swarnkar *et al*., 2005). Negative heterosis is important for straw yield per plant and heterosis estimates over standard check showed that out of 12crosses, 7 crosses had negative effects where values ranged from -47.64 (Kangra Local x EC-541194) to 19.02 (T-397 x Nagarkot). The magnitude of heterosis for seed yield per plant varied from -36.10 per cent (T-397 x EC-541194) to 43.56 per cent (Chambal x Nagarkot) over standard check. Heterosis for yield was reflected through heterosis in yield related traits especially number of capsules per plant confirmed by many workers which have reported high degree of heterosis for seed yield in linseed *viz*. Kansal and Gupta (1981); Dakhore *et al*. (1987); Rao *et al*. (1987); Saraswat *et al*. (1993); Foster *et al*. (1998); Kurt and Evans (1998); Rede (1999) and Reddy *et al*. (2013). For seed yield per plot heterosis out of 12 crosses, 5 crosses expressed significant positive heterosis which varied from -37.92 (T-397 x EC-541194) to 10.07 (T-397 x HimAlsi-1) per cent over standard check. In linseed, 1000-seed weight serves as an indicator to the end product *i.e*., seed yield. The low seed yield in linseed hybrids is attributed mainly to the 1000-seed weight. For 1000- seed weight, hybrid HimAlsi-2 x HimAlsi-1 (21.01) recorded highly significant standard heterosis. These observations corroborant the findings of Swarnkar *et al*., 2005 and Srivastava *et al*., 2007. Harvest index is also important character for linseed, for harvest index most of the crosses exhibited significant positive heterosis which varied from 2.46 per cent to 39.62 per cent over standard check.

From the present investigation it is perceived that all the studied characters except technical height were controlled by a preponderance of non-additive gene effects. Low heritability was observed for all the traits under study. Hybrid Chambal × Nagarkot recorded significantly highest standard heterosis for seed yield per plant. Hybrids exhibiting significant standard heterosis for different traits are presented in the table 4. Hence, the hybrids having high heterosis can be effectively used for isolating transgressive segregants, which will increase the frequency of desirable genes for yield component traits along with economic traits in linseed.

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