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*Short Communication*

# Crossability relationship and influencing factor among linseed genotypes over the agro-climatic conditions in mid hill of North West Himalayas

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**Abstract**

**To determine the response of different genotypes, environment on crossability and seed formation efficiency, four genotypes *viz*., (T-397, Chamble, Kangra Local and HimAlsi-2 as female and HimAlsi-1 and Nagarkot as male were used to make eight crosses in linseed. Maximum crossability 92.06% and seed formation efficiency 63.48% was recorded at Palampur, 91.04% crossability and seed 63.17% formation efficiency was observed at Kangra, indicated Palampur as the best location for both the parameters. Significant genotypic and environmental variations were observed for crossability and seed formation efficiency at two agro-climatic conditions. Among parental genotypes, T-397 (female) and HumAlsi-1(male) responded significantly better for both the parameters due to significant positive GCA effects at both locations.**

**Keywords:** Linseed, **c**rossability, seed formation efficiency, locations

## Introduction

Linseed (*Linum usitatissimum* L.) is a multipurpose crop, cultivated for oil and fibre, belongs to the genus *Linum*. Comprising of over 200 species (Gill 1987). The crop is highly self pollinated but insect activity leads to out-crossing (<2%) Dillman (1938). Linseed having about 36 to 48% oil content which has been a rich source of two essential fatty acids, alpha-linolenic acid (Foulk et al. 2002) and linoleic acid (Bloedon and Szapary, 2004). The linseed fibre is known for its good quality having high durability and strength, therefore, used in the manufacturing of water resistant pipes, cloth, paper and strawboard. The by-product, oil cake is a valuable dairy feed containing 36 % protein, of which 85% is digestible. So, every part of linseed is utilized commercially either directly or after processing with numerous medicinal uses. Despite huge benefits of linseed, the productivity of linseed in India is very low, because of various factors like non-adoption of plant protection measures, evolving new races of biotic stresses and improved agro-techniques etc (Kumar et al. et al. 2016). Hybridization with the different sources having desirable genes can play a significant role in addressing these issues. However, in hybridization, limited crossability is a major constraint which is influenced by the environmental conditions and genotypic differences thereby significantly affecting the outcome of gene transfer.

Keeping all above issues in consideration, the present investigation was carried out to determine the crossability and seed formation efficiency and the influence of genotypic and environmental factors on such parameters.

The present investigation was carried out at two different agroclimatic locations of northwest Himalayas *viz*., CSK Himachal Pradesh Agricultural University, Palampur ($32^0$6' N latitude, $76^o$3' E longitude at an elevation of 1290.8m a.m.s.l) and Shiwalik Agricultural Research & Extension Centre Kangra Agricultural Research and Extension Centre ($32^0$5' N latitude, $75^o$18' E longitude at an elevation of 950 m a.m.s.l), respectively. The weather parameters were recorded at both the locations. The material used for hybridization included four genotypes as female (T-397, Chamble, Kangra Local and HimAlsi-2) and two genotypes as male (HimAlsi-1 and Nagarkot). The parental material was staggered sown with an interval of 10 days to ensure regular availability of linseed pollen. Three rows of each genotype were sown with 1

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m row length and 30 cm row × row distance following recommended package of practices. The intervarietal hybridization programme was started from second week of February first at Palampur and Kangra and continued for fourth week of March.

Manual emasculation was done in the evening (4 to 6 pm) and pollination of the emasculated flower bud was carried out next day in morning (6:30 am to 8:00 am) with fresh pollen of linseed cultivars.

The analysis of variance was used to find out differential effect of the two environments on crossability and seed formation efficiency. To assess the significant differences in the crossability and seed formation efficiency among linseed cultivars at both locations, simple t-test was used. The line × tester (Kempthorne 1957) method detected promising genotypes with good combining abilities. Observations pertaining to crossability and seed formation efficiency were recorded with respect to total number of linseed flowers pollinated, number of seed carrying capsules, number of seeds produced.

(i) The crossability (%) was calculated by using the formula

$$\text{Crossability (\%)} = \frac{\text{No. of seeds carrying capsules}}{\text{No. of flowers pollinated}} \times 100$$

(ii) The seed formation efficiency (%) was calculated by using the formula

$$\text{Seed formation effiicienty (\%)} = \frac{\text{Total no. of seeds formed}}{\text{No. of flowers pollinated x 10}} \times 100$$

Significant differences ($p < .05$) for crossability and seed formation efficiency at both the agroclimatic locations in the crosses were observed. Higher $F_1$ mean values for crossability and seed formation efficiency of 92.06% and 63.48%, respectively was recorded at Palampur (Table 1), with a weekly average rainfall (5.66 mm), higher relative humidity (62.58 %) and narrow range of variation in temperature from 7.21° C to17.86° C whereas, lower crossability (91.04%) and seed formation efficiency (63.17%) was observed at Kangra (Table 1) representing low rainfall (4.51mm), low RH (45.79%) and more temperature variation (9.69° C to 21.18°C) during the six-week hybridization period. Besides agro-climatic conditions, genotypic differences in crossability and seed formation efficiency among crosses were also observed. The crosses among released cultivars showed crossability and seed formation efficiency ranging from 48.45 to 90.38% at Palampur whereas at Kangra it ranged from 48.16 to 88.57% (Table 1). The crosses T-397 × HimAlsi-1 and HimAlsi-2 × HimAlsi-1 performed significantly better at both the locations, whereas, Chambal × Nagarkot at Palampur for crossability. For seed formation efficiency T-397 × HimAlsi-1 performed significantly better at both the locations. On an average, T-397 × HimAlsi-1 cross combination revealed higher crossability and seed formation efficiency than others at both the locations.

Analysis of variance indicated significant variation for crossability and seed formation efficiency at both the agro-climatic locations as the two environment responded differentially for the genotypes and crosses. This also showed that different

**Table 1.** Performance of various linseed genotypes for response to their crossibility and Seed formation efficiency

| | Palampur | | | | | | Kangra | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crosses | FP | SCC | TNS | SS | Cr | SFE | FP | SCC | TNS | SS | Cr | SFE |
| T-397 × HimAlsi-1 | 108 | 102 | 803 | 7.87 | 94.44* | 74.35* | 103 | 97 | 771 | 7.95 | 94.17* | 74.85* |
| T-397× Nagarkot | 104 | 94 | 688 | 7.32 | 90.38 | 66.15 | 104 | 93 | 687 | 7.39 | 89.42 | 66.06 |
| Chambal× HimAlsi-1 | 110 | 100 | 533 | 5.33 | 90.91 | 48.45 | 103 | 93 | 496 | 5.33 | 90.29 | 48.16 |
| Chambal× Nagarkot | 103 | 96 | 567 | 5.91 | 93.20* | 55.05 | 103 | 94 | 558 | 5.94 | 91.26 | 54.17 |
| Kangra Local× HimAlsi-1 | 105 | 97 | 709 | 7.31 | 92.38 | 67.52 | 102 | 94 | 689 | 7.33 | 92.16 | 67.55 |
| Kangra Local× Nagarkot | 107 | 97 | 708 | 7.30 | 90.65 | 66.17 | 105 | 93 | 679 | 7.30 | 88.57 | 64.67 |
| HimAlsi-2× HimAlsi-1 | 106 | 99 | 697 | 7.04 | 93.40* | 65.75 | 104 | 96 | 685 | 7.14 | 92.31* | 65.87 |
| HimAlsi-2× Nagarkot | 101 | 92 | 650 | 7.07 | 91.09 | 64.36 | 101 | 91 | 647 | 7.11 | 90.10 | 64.06 |
| Mean | | | | | 92.06 | 63.48 | | | | | 91.04 | 63.17 |
| SE | | | | | 0.53 | 3.06 | | | | | 0.64 | 2.93 |

*FP* No. of flowers pollinated, *SSC* Number of seed(s) carrying capsules obtained, *TNS* Total number of seeds set, *SS* Average seed set/ capsule, *Cr* Crossability (%) *SFE* Seed formation efficiency (%)

genotypes behaved differently for crossability and seed formation efficiency at different locations. These findings are in agreement with earlier reports by Badiyal et al. (2014). Based on the line × tester analysis, mean squares due to crosses, female, male and male x female interaction were significant for crossability as well as seed formation efficiency at both short day (Palampur) and long day (Kangra) locations (Table 2). Similar results of crossability have been reported earlier

**Table 2.** Line × tester analysis for per cent crossability and seed formation efficiency at both locations

| Source | Df | MS Crossability | | Seed formation efficiency | |
|---|---|---|---|---|---|
| | | Palampur | Kangra | Palampur | Kangra |
| Crosses | 7 | 6.84* | 9.80* | 193.60* | 206.01* |
| Female | 3 | 1.88* | 2.24* | 394.46* | 418.21* |
| Male | 1 | 12.78* | 34.39* | 7.06* | 20.96* |
| M x F | 3 | 10.82* | 9.16* | 54.92* | 55.50* |
| Error | 14 | 0.99 | 0.18 | 0.03 | 0.15 |

(Badiyal et al. 2014; Jamwal et al. 2016). The weekly average temperature ranged between 7.21-17.86°C at Palampur and 9.69-21.18°C at Kangra. The average rainfall measured at Palampur and Kangra was 5.66 mm and 4.51 mm respectively, during the crossing period. Among the female parents, the highest positive and significant GCA effect was observed in T-397 for both the parameters, *viz*., crossability (0.35 and 0.76) and seed formation efficiency (6.78 and 7.28) at Palampur and Kangra respectively. Similarly, among pollinator parents, highest significant GCA effect for crossability and seed formation efficiency was found in HimAlsi-1 at both locations (Table 3). Based on significant estimates of positive GCA effects, T-397among the female parents was identified as outstanding genotype influencing frequency of all the two parameters. In case of male parent, HimAlsi-1 was identified to be outstanding genotypes influencing the frequency of respective parameter. Estimates of

**Table 3.** General combining ability effects of per cent crossability and seed formation efficiency at both locations

| Parent | Crossability | | Seed formation efficiency | |
|---|---|---|---|---|
| | gca (Palampur) | gca (Kangra) | gca (Palampur) | gca (Kangra) |
| **Female** | | | | |
| T-397 | 0.35 ** | 0.76 ** | 6.78 ** | 7.28 ** |
| Chambal | -0.20 ns | -0.26 ns | -11.72 ** | -12.01 ** |
| Kangra local | -0.53 ns | -0.67 ** | 3.37 ** | 2.94 ** |
| HimAlsi-2 | 0.19 ns | 0.17 ns | 1.58 ** | 1.79 ** |
| SE | 0.4065 | 0.1747 | 0.0701 | 0.1567 |
| **Male** | | | | |
| HimAlsi-1 | 0.73 * | 1.20 ** | 0.54 ** | 0.93 ** |
| Nagarkot | -0.74 * | - 1.18 ** | -0.55 ** | -0.90 ** |
| SE | 0.29 | 0.12 | 0.05 | 0.11 |

$\sigma^2$GCA and $\sigma^2$SCA revealed that the magnitude of SCA variance was higher than GCA variance for crossability and seed formation efficiency at both the locations, indicating greater role of non-additive gene action in the control of these parameters. This was also confirmed by ratio of $\sigma^2$GCA:$\sigma^2$SCA which is less than unity for both the parameters (Table 4). The results of analysis of variance were also confirmed from the study of additive ($\sigma^2$A) and dominance ($\sigma^2$D) components of variances. The major role of non- additive gene effects in the manifestation of almost both the parameters at both the location except seed formation efficiency at

**Table 4.** Estimation of genetic components for crossability and seed formation efficiency

| S.No. | Parameters | | $\sigma^2_{GCA}$ | $\sigma^2_{SCA}$ | $\sigma^2$GCA/ $\sigma^2$SCA | $\sigma^2$ A | $\sigma^2$ D | $[\sigma^2 D/\sigma^2 A]^{1/2}$ | $h^2$ns | (%) Contribution Lines | Testers | Interaction |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Crossability | P | 0.23 | 3.28 | 0.07 | 0.46 | 2.98 | 2.53 | 15.79 | 5.51 | 26.69 | 67.8 |
| | | K | 0.04 | 2.99 | 0.01 | 0.07 | 2.99 | 6.34 | 2.20 | 9.80 | 50.13 | 40.06 |
| 2 | Seed formation efficiency | P | 8.09 | 18.30 | 0.44 | 16.18 | 2.14 | 0.36 | 25.06 | 87.32 | 0.52 | 12.16 |
| | | K | 8.78 | 18.45 | 0.48 | 17.56 | 18.45 | 1.03 | 25.53 | 87.00 | 1.45 | 11.55 |

*P* = Palampur, *K* = Kangra, $\sigma^2_{GCA}$ = GCA variance, $\sigma^2_{SCA}$ = SCA variance, $\sigma^2$ A = additive genetic variance, $\sigma^2$ D = dominance genetic variance, $[\sigma^2 D/\sigma^2 A]^{1/2}$ = mean degree of dominance and $h^2$ns = narrow sense heritability

Palampur was indicated by the higher magnitude of dominance variance ($\sigma^2$D) than additive variance ($\sigma^2$A). The active involvement of non-additive gene action in the control of these parameters was further confirmed from the ratio of additive to dominant components of variance. This clearly indicated presence of both additive and non-additive gene action with the preponderance of non-additive genetic control of these parameters. Dhiman et al. (2013) also reported that four parameters *viz*., pod formation, healthy hybrid seed formation, seed germination and regeneration were controlled by additive and non-additive gene action. On the basis of present study, both the parameters revealed low narrow-sense heritability, thus indicating that these parameters are governed by non-fixable component of variation. The contribution of lines was found to be higher than individual contribution of testers for seed formation efficiency at both the locations. The contribution of line × tester interaction was found to be higher than the individual contribution of lines for crossability at both the locations. On the other hand, contribution of line × tester interaction was found to be higher than the individual contribution of testers for both the parameters at both the locations except crossability at Palampur, indicating the higher estimates of variances due to specific combining ability which further confirmed the active involvement of non-additive gene action in the parameters studied. The results obtained in the present investigation suggested that both additive and dominance gene effects were important for the traits but dominance was predominant as compared to additive effects. However, we believe that our study is a preliminary report on effect of different factors on crossability in linseed.

Conclusively, for successful gene transfer in linseed through hybridization, proper attention towards parental genotypes as well as location must be stressed. The present study indicated that genotypes T-397 of female parent and HimAlsi-1 of male parent were more responsive at palampur for crossability and seed formation efficiency.

## Authors' contribution

Conceptualization of research (NK, SP, HKC); Designing of the experiments (NK, SP, HKC); Contribution of experimental materials (NK, HKC); Execution of field/lab experiments and data collection (NK); Analysis of data and interpretation (NK, SP, HKC); Preparation of manuscript (NK, SP, HKC).

## Declaration

The authors declare no conflict of interest.

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