Original Research Article

Studies of genetic variability for yield improvement in oilseed flax (Linum usitatisimum L.)

 ABSTRACT

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| After rapeseed and mustard, Linseed (*Linum usitatissimum* L.) is one of the most significant *Rabi* oilseed crops. Genetic variability serves as the foundation of any crop improvement program, and the success of selection largely depends on the extent and type of variation present within the available genetic material. In essence, genetic variability is not only critical for effective selection but also plays a key role in determining the appropriate breeding approach to be adopted. The present investigation was undertaken to assess genetic variability, heritability and genetic advance for yield and its contributing traits in linseed. A total of 36 genotypes were evaluated at the Oilseeds Research Station, College of Agriculture, Latur during Rabi 2024–2025 using a randomized block design with two replications. The trial was sown on November 23, 2024, at a spacing of 30 × 5 cm. Data were recorded on ten traits: days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight, harvest index, oil content, and seed yield per plant. Significant variability was observed among the genotypes for all traits. Genotype RL 18133 exhibited superior performance in plant height, seed weight, and seed yield, indicating its potential as a bold-seeded and high-yielding type. Moderate genotypic and phenotypic coefficients of variation were recorded for seed yield per plant, number of branches, number of capsules, harvest index, and days to 50% flowering. All traits showed high heritability, while high genetic advance as percent of mean was noted for number of capsules, number of branches, plant height, days to 50% flowering, and seed yield per plant. Oil content exhibited low genetic advance. This study highlights linseed improvement potential for yield and traits. |

*Keywords:*  Genetic variability, yield, improvement , oilseed,flax .

1. INTRODUCTION

 Linseed (*Linum usitatissimum* L., 2n = 30) belongs to the Malpighiales order, the genus Linum, and the Linaceae family. Linnaeus gave the botanical name *Linum usitatissimum* in his book "Species Plantarum." Usitatissimum is a Latin word that means "most beneficial." (Linnaeus, 1857). According to the diversity of plant species, linseed originated in two places: the Mediterranean region of Europe and South West Asia, primarily in India (Vavilov, 1935; Richharia, 1962). Linseed is predominantly a self-pollinated crop; however, a small degree of cross-pollination (less than 2%) may occur due to insect activity. The family consists of around 200 species distributed across four genera, with *Linum usitatissimum* L. being the sole species of significant economic and agronomic value. The species name *usitatissimum* is derived from Latin, meaning "most useful," while the genus name *Linum* originates from the word "lin," signifying thread. Linseed is highly valued for its nutritional composition, containing approximately 33–45% oil and about 24% protein, depending on the variety. It is particularly rich in unsaturated fatty acids, including oleic acid (16–24%) and linoleic acid (18–24%). One of its most notable components is alpha-linolenic acid (ALA), which constitutes 52–53% of the total fatty acid content. ALA is a type of omega-3 fatty acid, essential for human health, known to lower cholesterol levels and support cardiovascular health.

Globally, Russia leads in linseed cultivation with 2 million hectares and a production of 1.7 million tonnes, followed by Kazakhstan (1.3 million ha; 800,000 tonnes). Canada, despite a smaller area (300,000 ha), achieves higher productivity with 450,000 tonnes, reflecting efficient cultivation practices. China and India have similar cultivation areas (~200,000 ha), but India lags in production (126,000 tonnes vs. China's 290,000 tonnes), indicating a significant yield gap (ICAR-IIFOR, 2022–23). In India, Madhya Pradesh is the leading producer, followed by Uttar Pradesh and Jharkhand. Rajasthan, though with a smaller area, records the highest productivity (1071 kg/ha), while Maharashtra reports moderate productivity (475 kg/ha) from 7.2 thousand hectares (MH State APY, 2023–24). These trends underline the need for improved genotypes and scientific cultivation practices to enhance productivity.

Linseed oil is widely used in industries for paints, varnishes, patent leather, and some pharmaceutical products. However, linseed has received limited attention compared to food grains, especially since the Green Revolution, which prioritized cereals like rice, wheat, and maize. Improving linseed yield is challenging due to the complex inheritance of related traits, governed by both additive and non-additive gene actions. Understanding genetic parameters such as variability, heritability, and genetic advance is essential for effective selection and the development of high-yielding varieties.

2. material and methods

**2.1 Experimental Site and Experimental Design**

The present investigation was conducted at the Oilseeds Research Station, Latur, during the Rabi season of 2024-25 under normal irrigated conditions. The experimental material consisted of 36 genotypes, including two checks, which were analyzed using a Randomized Block Design with two replications. Line sowing was the method of planting. Recommended fertilizers and cultural practices were followed to ensure the growth of healthy crops. Morphological observations of 10 quantitative characters were recorded by randomly selecting 5 plants from each plot and replication. Each genotype was sown in rows, each 5 meters in length, with a spacing of 30 cm between rows and 5 cm between plants. Border rows were planted on all sides of the experimental plots to prevent border effects. All recommended practices were adhered to for optimal crop growth, and the plot size was 5 x 11.6 m².

**2.2 Characters Studied**

 The morphological observation of 10 quantitative characters were recorded by selecting randomly 5 plants in each plot and in each replication viz. days to 50% flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight (g), harvest index (%), oil content (%) and seed yield per plant (g).

**2.3 Stastical Analysis**

 The overall mean values for various traits were analyzed statistically. The analysis of variance was carried out using the randomized block design (RBD) method, as outlined by Panse and Sukhatme (1985). The parameters, genotypic coefficient (GCV) and phenotypic coefficient of variation (PCV) were calculated by the formula given by Burton and Devane (1953). Heritability, and genetic advane as a percentage of the mean (GAM). Sivasubramanian and Madhavamenon categorized (both phenotypic and genotypic) coefficients in the range of 20%: High, 10-20%: Moderate, and <10%: Low. Johnson et al. classified heritability (h²) estimates as Low: 0- 30%, Medium: 30-60%, and High: Above 60%. The categorization of genetic advance as percentage of mean estimates as <10%: Low, 10-20%: Moderate and >20%: High by Johanson *et al.* All statistical analyses were performed by using R-software.

3. results and discussion

**3.1 Analysis of Variance**

 The analysis of variance and mean performance of the linseed genotypes for the various traits under investigation are summarized in Table 1. The findings indicate that the mean sum of squares for genotypes showed significant differences across all the traits examined.

Analysis of variance revealed significant differences among the genotypes for all characters, namely days to 50% flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight (g), harvest index (%), oil content (%) and seed yield per plant (g). The extent of variability observed among genotypes for yield and its related traits suggests ample opportunity for genetic enhancement, where selection for one character may simultaneously influence improvement in others. Similar results were recorded by Choudhary et al. (2017), Kumar et al. (2017), Meena *et al*. (2020), Paul and Kumari (2018), Patil *et al*. (2023) and Paliwal *et al*. (2024)

**Table 1 : Analysis of variance for ten yield-contributing characters in linseed.**

|  |  |  |
| --- | --- | --- |
| S.No |  CHARACTERS | Mean sum of squares |
| **Replications (df=1)** | **Treatments (df=49)** | Error (49) |
| 1 | Days to 50% flowering | 6.125 |  **73.15 \*\*** | 1.49 |
| 2 | Days to maturity | 2 | **86.35 \*\*** | 3.54 |
| 3 | Plant height (cm) | 2.761 | **125.75\*\*** | 6.46 |
| 4 | Number of branches per plant | 0.293 | **0.695 \*\*** | 0.077 |
| 5 | Number of capsules per plant | 32.16 | **174.49\*\*** | 9.799 |
| 6 | Number of seeds per capsule | 0.390 | **0.874\*\*** | 0.14 |
| 7 | 1000-seed weight (g) | 0.190 | **0.664\*\*** | 0.073 |
| 8 | Harvest index (%) | 1.048 | **20.227\*\*** | 1.083 |
| 9 | Oil content (%) | 0.864 | **5.583\*\*** | 0.525 |
| 10 | Seed yield per plant (g) | 0.586 | 0.745\*\* | 0..149 |

\* and \*\* Significance at 5 and 1 per cent level, respectively

**3.2** **Mean Performance**

 Based on mean performance, the highest seed yield per plant was recorded in OL-2022-23-1 (5.00 g) and Kota Barni Alsi-4 (ZC) (5.00 g), followed by JLS-95 (ZC) (4.55 g), RLC-148 (ZC) (4.45 g), and T-397 (NC) (4.45 g), indicating their potential as high-yielding genotypes. Similarly, high oil content was observed in DLV-8 (36.73%), followed by RLC-197 (36.39%), OL-2022-23-1 (35.68%), and T-397 (NC) (35.63%), suggesting these entries are promising for oil quality improvement. Early flowering was noted in LSL-93 (42.5 days), NL-371 (45.5 days), SLS-145 (E) (45.5 days), NL-508 (45.5 days), and PKVNL-260 (46.5 days), making them suitable for short-duration growing environments. Genotypes with early maturity included LSL-93 (88.5 days), NL-422 (90.0 days), NL-371 (90.0 days), BLS-2022-R-23 (90.5 days), and RLC-205 (90.5 days), which are ideal for early harvesting or double cropping. Dwarf plant height was recorded in NL-260 (42.5 cm), NL-427 (44.0 cm), LSL-93 (44.9 cm), LCK-2313 (47.4 cm), and NL-356 (47.85 cm), indicating these genotypes may be advantageous in terms of lodging resistance and dense planting adaptability. Consequently, the significant variability observed in ten traits across thirty-six linseed genotypes suggests that there is ample variability for plant breeders to select superior and preferred genotypes for further enhancement. Overall, all the traits examined exhibited a broad spectrum of variation.

**3.3 Genotypic and Phenotypic coefficient of Variation**

The amount of differences in quantitative characteristics is measured and expressed as a variance. The total quantity of observed variation or phenotypic variation in character does not accurately represent variation that can be fixed in subsequent generations, whereas genotypic variation is the number of fixable differences from one generation to the next. The environmental variance changes from one location to another and so cannot be fixed.

Among the traits studied, seed yield per plant exhibited moderate genotypic and phenotypic coefficients of variation followed by number of capsules per plant and number of branches per plant, plant height, number of seeds per capsule, days to 50 per cent flowering as presented in Table 2. The comparatively high values of both GCV and PCV for these characters reflect substantial genetic variability, indicating that these traits offer promising scope for improvement through selective breeding. Similar result recorded by Gudmewad *et al.* (2016), Kumar *et al.* (2015), Thakur *et al.* (2020), Toor *et al.* (2023), Kumar *et al*. (2024). The lowest PCV and GCV values were observed for the traits: 1000-seed weight (7.70% and 6.89%, respectively), oil content (4.68% and 5.13%, respectively), number of seeds per capsule (7.59% and 8.95%, respectively), and days to maturity (6.61% and 6.89%). Similar results were reported by Gudmewad *et al.* (2016), Meena *et al*. (2020), and Shankar *et al.* (2024).

**3.4 Heritability and Genetic Advance as percent of mean**

 Heritability indicates the proportion of phenotypic variation attributable to genetic factors, while geneticadvance shows how much improvement we can expect through selection. Knowing both helps plant breeders plan better ways to develop improved crop varieties. Broad-sense heritability provides an idea about the portion of observed variability attributable to genetic differences. Genetic advance, which predicts improvement in the succeeding generations through selection, is a highly effective method for managing breeding material and enhancing genetic gain. Genetic advance, which predicts improvement in the succeeding generations through selection, is a highly effective method for managing breeding material and enhancing genetic gain.

High heritability estimates coupled with high genetic advance as a percentage of the mean were observed for several traits, indicating the predominance of additive gene effects and the scope for effective selection. Significantly, days to 50 per cent flowering exhibited heritability of 95.99 % and genetic advance of 22.27 %, number of capsules per plant exhibited heritability of 89.37% and genetic advance of 29.81%, while plant height recorded heritability of 90.22% and genetic advance of 25.72%. Similarly, the number of branches per plant and seed yield per plant exhibited high heritability values of 80.92% and 66.63%, respectively, with corresponding genetic advances of 26.80% and 23.61%, respectively, as presented in Table 2. These results suggest that simple phenotypic selection would be effective for improving these traits. Comparable findings were reported by Tadese *et al.* (2010), Singh *et al.* (2014), Kanwar *et al.* (2014), Tyagi *et al.* (2014), Kumar *et al.* (2017), Terfa and Gurmu (2020), who also observed high heritability coupled with high genetic advance for similar traits in linseed, supporting the conclusion that these characters are largely controlled by additive gene action and can be reliably improved through selection.

High heritability associated with moderate to low genetic advance as a percent of the mean suggests the presence of non-additive gene action, which may limit the effectiveness of direct selection. This was observed for harvest index (84.86, 18.26), days to maturity (92.68%, 12.00%), number of seeds per capsule (72.08%, 13.29%), 1000-seed weight (80.08, 12.70) and oil content (83.27%, 8.81%), indicating that direct selection may not result in substantial improvement for these traits. The findings were reported by Tadesse *et al*. (2010), Patil *et al*. (2023), Nagaraja *et al.* (2009), Vardhan and Rao (2012).

4. Conclusion

 The comparatively high values of both GCV and PCV for these characters reflect substantial genetic variability, indicating that these traits offer promising scope for improvement through selective breeding. High heritability combined with a high genetic advance as a percentage of the mean was observed for traits such as number of branches per plant, number of capsules per plant, plant height, days to 50% flowering and seed yield per plant. This suggests that the observed heritability is primarily due to additive gene action, and that direct selection based on phenotype could be highly effective for improving these traits.

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##  Table 2. Parameters of genetic variability for yield and yield contributing character in Linseed

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sr.No. | Name of the Character | Range | Mean | GV(σ2g) | PV(σ2p) | GCV | PCV | Heritability (Broad sense) (%) | Geneticadvance (1%) | Genetic advance as% mean |
| 1 | Days to 50% flowering | 42.5-63.5 | 53.04 | 35.82 | 37.32 | 11.2849 | 11.5182 | 95.99 | 12.0808 | 22.7761 |
| 2 | Days to maturity | 88.5-110 | 97.22 | 33.68 | 36.34 | 6.61 | 6.8960 | 92.68 | 11.5092 | 12.0009 |
| 3 | Plant height(cm) | 40.2-71 | 58.74 | 59.64 | 66.11 | 13.1460 | 13.8400 | 90.22 | 15.1117 | 25.7227 |
| 4 | No. of Branches per plant | 2.3-4.9 | 3.81 | 0.3090 | 0.3866 | 14.5528 | 16.2782 | 80.92 | 1.0237 | 26.8011 |
| 5 | No. of capsules per plant | 40.4-74.3 | 59.27 | 82.34 | 92.14 | 15.3096 | 16.1949 | 89.37 | 17.6718 | 29.8138 |
| 6 | No. of Seed per capsule | 6.1-8.9 | 7.96 | 0.3661 | 0.50 | 7.5992 | 8.9510 | 72.08 | 1.0582 | 13.2900 |
| 7 | 1000 seed wt. (g) | 6.5-8.9 | 7.88 | 0.2957 | 0.36 | 6.8942 | 7.7042 | 80.08 | 1.0024 | 12.7089 |
| 8 | Harvest index (%) | 20.57-31.23 | 25.60 | 6.0723 | 7.15 | 9.6231 | 10.4461 | 84.86 | 4.6763 | 18.2617 |
| 9 | Oil content (%) | 30.24-36.88 | 33.74 | 2.4971 | 2.99 | 4.6866 | 5.1359 | 83.27 | 2.9705 | 8.8098 |
| 10 | Seed yield per plant (g) | 2.1-5.2 | 3.89 | 0.2983 | 0.4477 | 16.0390 | 17.1987 | 66.63 | 0.9184 | 23.6072 |

 GV = Genotypic variance, PV = Phenotypic variance, GCV = Genotypic coefficient of variation, PCV = Phenotypic coefficient variation

 **Fig. 1. Genotypic and phenotypic coefficient of variation for yield and yield contributing character.**

 **Fig. 2. Heritability and genetic advance for yield and yield contributing character.**