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Genetic Variability Studies for Yield and Yield Contributing Traits in Linseed (*Linum usitatissimum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Linseed (*Linum usitatissimum* L.) ranks as one of the most important *Rabi* oilseed crops, following rapeseed and mustard. Linseed is rich in omega-3 fatty acids and ALA, beneficial for heart health, and used for linen and oil production. 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

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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. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) exhibited a range from low to high values, with the lowest GCV and PCV observed for traits such as oil content, days to maturity, 1000-seed weight, number of seeds per capsule, and harvest index. In contrast, the highest GCV and PCV values were recorded for seed yield per plant, number of capsules per plant, number of branches per plant, plant height, and days to 50% flowering. All traits demonstrated high heritability, with the highest values for number of capsules per plant, number of branches per plant, plant height, seed yield per plant, and days to 50% flowering. These findings suggest the predominance of additive genetic effects for these traits. Therefore, these characteristics are promising targets for direct selection in breeding programs. In conclusion, the genotypes under study exhibit considerable genetic variability for yield and related traits, offering substantial potential for improvement in future breeding efforts.

Keywords: Genetic variability; heritability; linseed; randomized block design; oilseeds; genetic advance.

1. INTRODUCTION

Linseed (*Linum ussitassimum* L., 2n=30) is a member of the *Linaceae* family, namely the genus "Linum" and order " Malpighiales". Linseed grown in the *Rabi* season, and it is an annual self – pollinated crop of both tropical and temperate regions of the world. 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). 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 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-IIOR, 2022-23; Tihan-tech OSIS). The global linseed production data reveals significant yield differences, with countries such as Russia, Kazakhstan, and Canada achieving higher productivity than India. To address this gap, it is crucial to enhance cultivation practices, develop high-yielding genotypes, and adopt more efficient agricultural techniques, thereby improving India's competitiveness in the global linseed market. 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 extensively utilized in various industries, including paints, varnishes, linoleum production, and pharmaceuticals. In the paint and varnish industries, linseed oil serves as a fundamental component in the formulation of high-quality coatings and finishes. Additionally, it plays a critical role in the production of linoleum and other industrial products. Despite its economic significance, linseed has not received as much attention as staple food crops, particularly following the Green Revolution (1950s–1960s), which prioritized the enhancement of cereal crop productivity, such as rice, wheat, and maize. Consequently, linseed has not been adequately prioritized in breeding programs, limiting its potential for increased yields.

Improving linseed yield is a complex challenge due to the inheritance patterns of key traits, which are governed by both additive and non-additive gene actions. Understanding genetic parameters such as variability, heritability, and genetic advance is essential for the development of high-yielding linseed varieties. This study aims to assess the genetic variability, heritability, and genetic advance of key traits related to yield and quality in linseed, with the ultimate goal of enhancing productivity and addressing existing yield gaps.

This research investigates 36 genotypes of linseed, selected for their potential to improve seed yield and other critical agronomic traits. The primary traits under investigation include seed yield, oil content, and plant height, all of which are important for improving overall crop productivity. By examining the genetic variability and heritability of these traits, this study seeks to identify superior genotypes that can be utilized in future breeding programs. The results will provide valuable insights into the development of high-yielding linseed varieties, contributing to advancements in breeding techniques and optimizing productivity, particularly in regions such as India, where linseed yield remains suboptimal.

2. MATERIALS 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. The experimental material consisted of 36 genotypes, including two checks, which were analyzed using a Randomized Block Design with two replications. The crop was sown using the line sowing method. 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 m^2.

2.2 Characters Studied

Morphological observations for 10 quantitative traits were recorded by randomly selecting 5 plants from each plot and replication. The traits measured included 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 number of days to 50% flowering was recorded when half the plants in each plot had flowered, while the days to maturity were noted when the plants reached physiological maturity. Plant height was measured from the base to the tip of the tallest stem, and the number of branches per plant, number of capsules per plant, and number of seeds per capsule were counted to evaluate reproductive potential. 1000-seed weight was determined by weighing a random sample of 1000 seeds, and the harvest index was calculated as the ratio of seed yield to total plant biomass, expressed as a percentage. Oil content was determined using the Soxhlet extraction method, and seed yield per plant was measured by weighing the seeds harvested from each plant.

2.3 Statistical 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 advance as a percentage of the mean (GAM). Sivasubramanian and Madhavamenon (1973) categorized (both phenotypic and genotypic) coefficients in the range of 20%: High, 10-20%: Moderate, and <10%: Low. Johnson et al.(1995a) classified heritability (h^2) 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 4.5.1.

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 for 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).

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 for future varietal improvement programs. Similarly, the highest 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%), identifying these genotypes as promising sources for enhancing oil quality in linseed.

Notably, early flowering was recorded in LSL-93 (42.5 days), NL-371 (45.5 days), SLS-145 (E) (45.5 days), and PKVNL-260 (46.5 days). Early flowering genotypes are particularly valuable in regions susceptible to terminal drought stress, as they enable the crop to complete its reproductive phase before the onset of unfavorable environmental conditions, thus contributing to yield stability under moisture-limited situations.

In terms of maturity, genotypes such as 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) exhibited early maturity, making them suitable for early harvesting and facilitating double cropping systems or post-rainy season cultivation, thereby increasing cropping intensity and farm profitability.

Furthermore, dwarf plant height was observed 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). Dwarf genotypes are advantageous as they offer lodging resistance under high input conditions and are better adapted for dense planting, which enhances plant stand stability and may lead to increased yield per unit area.

3.3 Genotypic and Phenotypic coefficient of Variation

Variance serves as a statistical measure that quantifies the degree of variability observed in quantitative traits within a population. 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.

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

S.No	**Characters**	**Mean sum of squares**		
		Replications (df=1)	**Treatments (df=35)**	**Error (35)**
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*

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 and Fig 1). 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%). indicating less variability exists in these characters. Low variability indicates the need for improvement of the base population. Similar results were reported by Gudmewad et al. (2016), Meena et al. (2020), and Shankar et al. (2024).

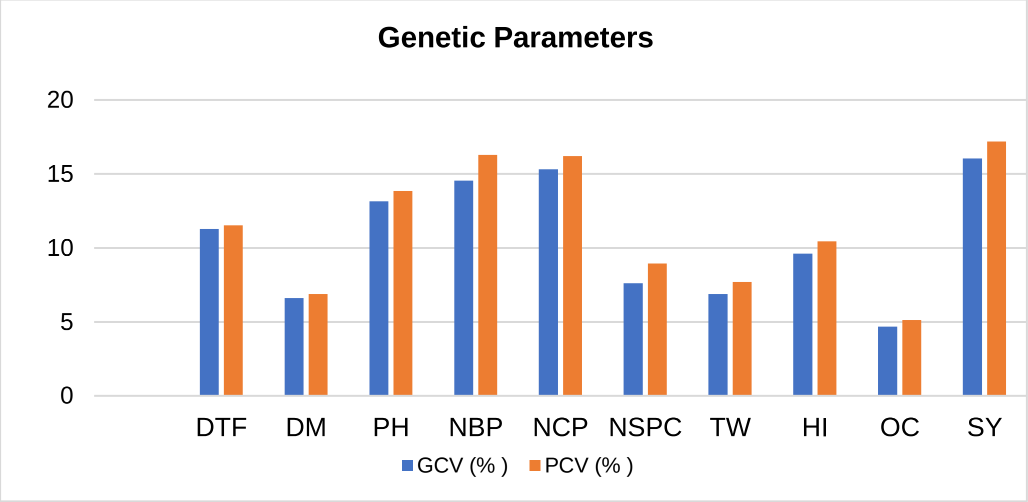

Fig. 1. Genotypic and phenotypic coefficient of variation for yield and yield contributing character

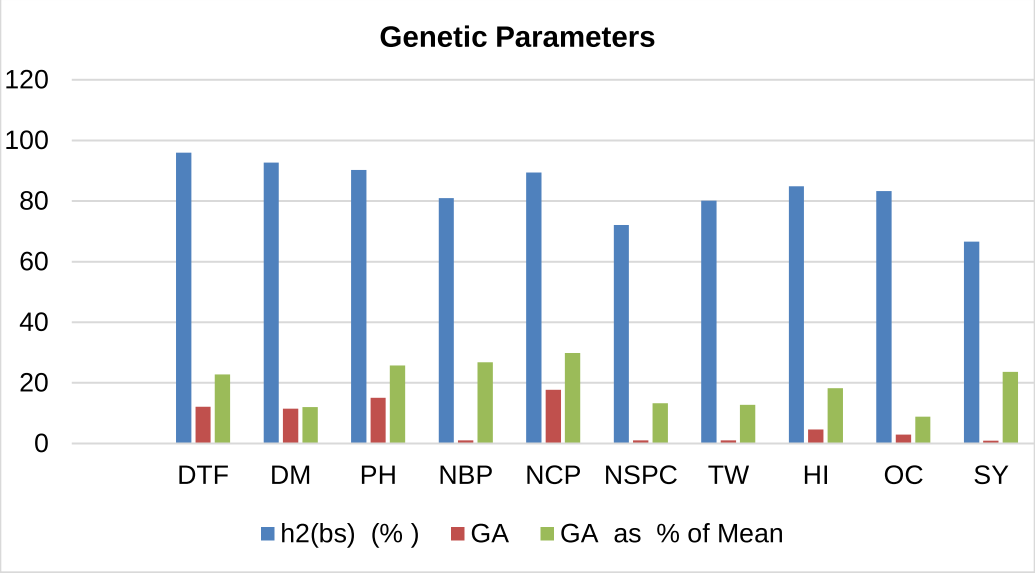

Fig. 2. Heritability and genetic advance for yield and yield contributing character

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

Sr. No.	Name of the Character	Range	Mean	GV (σ^2g)	PV (σ^2p)	GCV	PCV	Heritability (Broad sense) (%)	Genetic advance (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 Seeds 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

3.4 Heritability and Genetic Advance as Percent of Mean

Heritability indicates the proportion of phenotypic variation attributable to genetic factors, while genetic advance 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.

All the traits presented in (Table 2 and Fig. 2.) recorded the highest heritability. 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 action 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 estimates coupled with moderate to low genetic advance as a percent of the mean typically indicate the involvement of non-additive gene action such as dominance and epistasis, or the potential influence of environmental factors that may obscure the expression of genetic potential. This scenario can reduce the efficiency of direct selection for trait improvement in early generations. 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 present study reveals that there is a significant amount of variability among all the genotypes for all the traits studied. The highest GCV and PCV values were recorded for seed yield per plant (g), number of capsules per plant, number of branches per plant, plant height and days to 50 percent flowering. Low GCV and PCV were recorded for Oil content, days to maturity, 1000 seed weight, number of seeds per capsule, and harvest index. The presence of significant genetic variability was found breeding material as it provides a fundamental basis for selection and offers critical information for identifying suitable parental lines to be utilized in hybridization programmes aimed at crop improvement. High heritability combined with 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, and days to 50% flowering. Additionally, moderate heritability along with moderate genetic advance was recorded for 1000-seed weight, number of seeds per capsule, and seed yield per plant. These findings suggest that these traits are primarily controlled by additive gene effects, indicating that selection based on these characters would be effective for genetic improvement.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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