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Genetic variability, heritability and genetic advance for yield, yield-attributing and quality traits in linseed (*Linum usitatissimum* L.) genotypes

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Abstract

An investigation was carried out to assess genetic variability, heritability and genetic advance for eighteen quantitative and quality traits in linseed (*Linum usitatissimum* L.) genotypes evaluated in a Randomized Block Design with three replications. Genotypes showed wide variation for most traits, including days to 50% flowering, plant height, number of capsules per plant, biological yield per plant, harvest index, and seed yield per plant, indicating sufficient exploitable genetic diversity. Fatty acid composition also varied considerably, with stearic acid showing the widest range. PCV was marginally higher than GCV for all traits, and the narrow gap between them for most characters indicated limited environmental influence on trait expression. High GCV and PCV were recorded for stearic acid, moderate estimates for branches per plant, biological yield, harvest index, oleic acid, linoleic acid, and seed yield per plant, while the remaining traits showed low GCV and PCV. Broad-sense heritability was high (>60%) for most traits, with moderate heritability for capsules per plant and palmitic acid. High heritability coupled with high genetic advance was observed for branches per plant, biological yield, harvest index, stearic acid, oleic acid, and linoleic acid, indicating additive gene action and good scope for direct selection. In contrast, days to maturity, palmitic acid, and protein content showed high heritability but low genetic advance, suggesting non-additive gene effects requiring alternative breeding approaches. Harvest index, biological yield, branch number, and key fatty acids offer strong potential for simultaneous improvement of seed yield and oil quality through simple selection.

Keywords: Linseed, genetic variability, heritability, genetic advance, fatty acids, selection

1. Introduction

Linseed (*Linum usitatissimum* L.), also known as flaxseed, is one of the oldest cultivated oilseed and fibre crops, valued worldwide for its industrial-grade oil rich in polyunsaturated fatty acids, particularly alpha-linolenic acid, as well as for its nutraceutical and pharmaceutical properties. Despite its economic and nutritional importance, productivity of linseed has remained largely stagnant compared to other oilseed crops, primarily due to its cultivation on marginal and resource-poor lands and the limited genetic base exploited by breeders in the development of improved cultivars (Kumar *et al.*, 2019) [13].

Genetic improvement of any crop is fundamentally dependent on the magnitude and nature of variability present in the available germplasm (Burton and De Vane, 1953) [2]. The presence of adequate genetic variability for yield and its component traits is a prerequisite for initiating an effective selection programme, since selection can only be effective when heritable variation exists within the population (Falconer and Mackay, 1996) [4]. However, phenotypic variation observed in a population represents the combined effect of genotype, environment, and genotype-by-environment interaction; merely observing phenotypic variation is therefore not sufficient for planning a selection strategy (Comstock and Robinson, 1952) [3].

The genotypic and phenotypic coefficients of variation (GCV and PCV) provide a standardized measure of the extent of variability present for a given trait, independent of the unit of measurement, allowing meaningful comparison across traits (Burton and De Vane, 1953; Sivasubramanian and Menon, 1973) [2, 12]. However, coefficients of variation alone do not indicate the extent to which a trait is transmissible to the next generation.

Heritability estimates, particularly along with genetic advance, offer a more reliable index for predicting the effectiveness of selection, since heritability associated with high genetic advance indicates that a trait is largely under the control of additive gene action, whereas high heritability coupled with low genetic advance suggests the involvement of non-additive gene effects (Johnson *et al.*, 1955; Robinson *et al.*, 1949) ^[7, 11].

Keeping in view the importance of genetic parameters in crop improvement programmes, the present investigation was undertaken to estimate the extent of genetic variability, heritability, and genetic advance for growth, yield, yield-attributing, and quality traits, including oil content and fatty acid composition, among a set of linseed genotypes.

2. Materials and Methods

2.1 Experimental Site and Plant Material

The present investigation was carried out at the research farm under agro-climatic conditions typical for linseed cultivation. The experimental material comprised of 10 diverse linseed (*Linum usitatissimum* L.) genotypes.

2.2 Experimental Design

The experiment was laid out in a Randomized Block Design (RBD) with three replications, a design widely used for genetic variability studies in linseed. Each replication was made up of three rows of each genotype with a gap of 30 cm and 10 cm respectively for row to row and plant to plant. Standard agronomic practices were applied uniformly throughout the growing season and appropriate plant protection measures were implemented as required.

2.3 Observations Recorded

Data were recorded on five randomly selected competitive plants per genotype per replication for days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, capsule size, 1000-seed weight, biological yield per plant, harvest index, seed yield per plant, protein content and Oil content and fatty acid like Palmitic acid, Stearic acid, Oleic acid, Linoleic acid, Linolenic acid.

2.4 Statistical Analysis

Data were subjected to analysis of variance (ANOVA) following the standard procedure for RBD (Panse and Sukhatme, 1978) ^[10]. Genotypic and phenotypic coefficients of variation (GCV and PCV) were computed and categorized as low (<10%), moderate (10–20%) and high (>20%) as per Sivasubramanian and Menon (1973) ^[12]. Broad-sense heritability (h^2_b) was estimated as the ratio of genotypic to phenotypic variance following Lush (1940) ^[9] and Comstock and Robinson (1952) ^[3], and categorized following Robinson *et al.* (1949) ^[11]. Genetic advance (GA) and Genetic advance as percentage of mean were calculated using the formula of Johnson *et al.* (1955) ^[7].

3. Results and Discussion

3.1 Mean Performance and Range of Variability

The traits studied exhibited considerable variability in mean, minimum and maximum values (Table 1), consistent with findings reported for other linseed germplasm collections (Kanwar *et al.*, 2014; Terfa *et al.*, 2020) ^[8, 1]. Days to 50% flowering ranged from 55.67 to 67.67 days (mean 61.47), while days to maturity varied from 127.67 to 138.00 days

(mean 132.30), indicating the presence of both early- and late-maturing genotypes in the population. Plant height ranged widely from 57.16 to 70.47 cm, and the number of branches per plant varied from 5.80 to 8.87, suggesting differential vegetative growth patterns among genotypes.

Yield-contributing traits also displayed wide ranges. Number of capsules per plant ranged from 122.21 to 146.20, biological yield per plant from 24.98 to 34.80 g, and seed yield per plant from 6.62 to 9.27 g. Harvest index showed the widest relative spread among agronomic traits (20.32–36.77%), indicating substantial genotypic differences in partitioning of biomass towards economic yield, and this wide range of variation is consistent with reports of considerable exploitable diversity in linseed germplasm.

Among the quality traits, fatty acid composition showed marked variability. Stearic acid exhibited the widest range (2.38–6.47%), followed by linolenic acid (38.74–51.74%) and oleic acid (22.00–33.55%), while palmitic acid (5.71–6.40%) and protein content (22.09–24.13%) were comparatively stable across genotypes, consistent with the considerable fatty-acid variability reported in Ethiopian and Indian linseed germplasm (Ghiday *et al.*, 2024; Green, 1986) ^[5, 6].

3.2 Genotypic and Phenotypic Coefficients of Variation

The genotypic coefficient of variation (GCV) was lower than the corresponding phenotypic coefficient of variation (PCV) for all traits studied, an expected outcome since phenotypic variance includes both genotypic and environmental components. However, the magnitude of difference between GCV and PCV was narrow for most traits, particularly for days to maturity (2.68 vs. 3.20%), protein content (2.67 vs. 3.06%), palmitic acid (3.44 vs. 4.52%), and stearic acid (26.70 vs. 26.97%), agreeing with earlier reports of low environmental influence on these characters in linseed (Terfa *et al.*, 2020) ^[1].

Based on the classification proposed by Sivasubramanian and Menon (1973) ^[12], high GCV and PCV (>20%) were recorded for stearic acid (26.70%, 26.97%), while moderate values (10–20%) were observed for number of branches per plant, biological yield per plant, harvest index, oleic acid, linoleic acid, and seed yield per plant. This pattern is consistent with result reported by Kanwar *et al.* (2014) ^[8], where harvest index and yield-related traits similarly showed moderate-to-high GCV and PCV. The remaining traits - days to 50% flowering, days to maturity, plant height, number of capsules per plant, number of seeds per capsule, capsule size, 1000-seed weight, oil content, palmitic acid, linolenic acid, and protein content — recorded low GCV and PCV (<10%), indicating limited genetic variability for these traits in the studied material.

The high GCV and PCV recorded for stearic acid indicate considerable scope for improvement of this trait through direct selection, whereas the low GCV values for traits such as days to maturity and protein content suggest that these traits are less amenable to improvement through simple phenotypic selection and may require more refined breeding approaches (Panse and Sukhatme, 1978) ^[10].

3.3 Heritability and Genetic Advance

Heritability (broad sense) estimates ranged from moderate to very high across the traits studied. According to the classification of Robinson *et al.*, (1949) ^[11], heritability was high (>60%) for the majority of traits, including days to

50% flowering (78.31%), days to maturity (70.36%), plant height (74.44%), number of branches per plant (91.40%), number of seeds per capsule (65.39%), capsule size (64.68%), 1000-seed weight (82.34%), biological yield per plant (86.90%), harvest index (95.57%), oil content (88.41%), stearic acid (97.98%), oleic acid (92.84%), linoleic acid (95.68%), linolenic acid (89.80%), protein content (76.07%), and seed yield per plant (87.41%), consistent with high heritability reported for plant height, capsules per plant, 1000-seed weight and seed yield per plant in linseed (Ghiday *et al.*, 2024) [5]. Moderate heritability (30–60%) was recorded only for number of capsules per plant (54.73%) and palmitic acid (58.05%). High heritability alone does not always indicate the effectiveness of selection, since it includes both additive and non-additive gene effects. Genetic advance as percentage of mean (GA% mean), which reflects the additive gene action, was therefore examined together with heritability, following Johnson *et al.* (1955) [7]. Traits exhibiting a combination of high heritability coupled with high genetic advance (>20%) — namely number of branches per plant (91.40%, 27.52%), harvest index (95.57%, 35.63%), stearic acid (97.98%, 54.44%), oleic acid (92.84%, 23.40%), linoleic acid (95.68%, 36.49%), and biological yield per plant (86.90%, 20.84%) — indicate that these traits are governed predominantly by additive gene action, similar pattern also

reported for capsules per plant, harvest index, and seed yield per plant in linseed (Terfa *et al.*, 2020; Kanwar *et al.*, 2014) [1, 8]. Such traits offer the greatest promise for improvement through simple selection methods, as the heritable component of variation is largely fixable across generations. In contrast, traits with high heritability but low-to-moderate genetic advance, such as days to maturity (70.36%, 4.63%), palmitic acid (58.05%, 5.40%), and protein content (76.07%, 4.80%), suggest that the high heritability observed for these traits may be attributable largely to non-additive gene effects (dominance and epistasis) or to a favourable environmental influence on genotype expression rather than heritable genetic variance alone, similar result was reported for days to maturity in linseed by Terfa *et al.*, (2020) [1]. Improvement of such traits would therefore require heterosis breeding or recurrent selection procedures rather than straightforward mass selection.

The present investigation reveals that considerable exploitable genetic variability exists among the genotypes for several yield-attributing and quality traits. The consistently narrow gap between GCV and PCV across most traits indicates a limited role of environmental factors in the phenotypic expression of these characters, lending greater reliability to phenotypic selection based on these traits (Burton and De Vane, 1953) [2].

Table 1: Estimates of mean, range, genotypic and phenotypic variance, heritability, genetic advance and coefficients of variation for yield, yield-attributing and quality traits in linseed

Genotypes/Traits	Mean	Range		Var (g)	Var (p)	Heritability (%)	GA	GA % mean	GCV (%)	PCV (%)
Days to 50% Flowering	61.47	55.67	67.67	15.29	19.52	78.31	7.13	11.6	6.36	7.19
Days to maturity	132.3	127.67	138	12.59	17.89	70.36	6.13	4.63	2.68	3.2
Plant height (cm)	63.38	57.16	70.47	18.76	25.2	74.44	7.7	12.15	6.83	7.92
Number of branches/plant	7.08	5.8	8.87	0.98	1.07	91.4	1.95	27.52	13.98	14.62
Number of capsules/plant	133.85	122.21	146.2	32.36	59.14	54.73	8.67	6.48	4.25	5.75
Number of seeds/capsule	7.68	6.8	8.53	0.22	0.33	65.39	0.78	10.15	6.09	7.53
Capsule Size	6.52	5.92	7.14	0.15	0.22	64.68	0.63	9.69	5.85	7.28
1000 Seed weight (g)	7.93	6.92	8.85	0.47	0.57	82.34	1.28	16.2	8.67	9.55
Biological Yield/Plant	28.4	24.98	34.8	9.5	10.93	86.9	5.92	20.84	10.85	11.64
Harvest index (%)	29.32	20.32	36.77	26.92	28.17	95.57	10.45	35.63	17.69	18.1
Oil content (%)	35.4	32	39.16	4.06	4.59	88.41	3.9	11.02	5.69	6.05
Palmitic acid	6.15	5.71	6.4	0.04	0.08	58.05	0.33	5.4	3.44	4.52
Stearic acid	4.98	2.38	6.47	1.77	1.8	97.98	2.71	54.44	26.7	26.97
Oleic acid	29.13	22	33.55	11.79	12.7	92.84	6.82	23.4	11.79	12.23
Linoleic acid	11.78	8.23	14.87	4.55	4.76	95.68	4.3	36.49	18.11	18.51
Linolenic acid	47.67	38.74	51.74	14.81	16.49	89.8	7.51	15.76	8.07	8.52
Protein Content (%)	23.29	22.09	24.13	0.39	0.51	76.07	1.12	4.8	2.67	3.06
Seed yield per plant (g)	7.97	6.62	9.27	0.64	0.73	87.41	1.54	19.3	10.02	10.72

Traits such as harvest index, biological yield per plant, and number of branches per plant, which showed high heritability accompanied by high genetic advance, are particularly important from a breeding standpoint. These findings are consistent with the general understanding that yield and its component traits, when governed by additive gene action, respond favourably to direct phenotypic selection (Johnson *et al.*, 1955) [7], a conclusion also drawn in linseed improvement studies emphasizing capsules per plant, harvest index, and plant height as effective selection criteria. Selection based on harvest index and biological yield could therefore be an effective indirect strategy for improving seed yield per plant, which itself exhibited high

heritability (87.41%) and moderately high genetic advance (19.30%).

Among the quality traits, the fatty acid profile demonstrated an especially favourable genetic architecture for improvement. Stearic acid recorded the highest GCV, PCV, heritability, and genetic advance among all traits studied, indicating that this trait is under strong genetic control with minimal environmental interference (Ghiday *et al.*, 2024; Green, 1986) [5, 6].

Conversely, traits such as days to maturity, number of capsules per plant, palmitic acid, and protein content, which exhibited comparatively low genetic advance despite moderate-to-high heritability, appear to be more complex in

their genetic control, likely involving non-additive gene action. Improvement in such traits may necessitate alternative breeding strategies such as biparental mating, diallel selective mating, or heterosis breeding to exploit non-additive genetic variance effectively.

4. Conclusion

The present study demonstrates that substantial genetic variability exists among the genotypes evaluated for growth, yield, and quality traits. Low differences between GCV and PCV for most traits confirmed a predominant genetic basis for phenotypic expression with minimal environmental interference. Traits including number of branches per plant, biological yield per plant, harvest index, stearic acid, oleic acid, and linoleic acid exhibited high heritability coupled with high genetic advance, indicating that these traits are controlled by additive gene action and are highly responsive to direct phenotypic selection. These traits should therefore be prioritized in selection programmes aimed at simultaneous improvement of seed yield and oil quality. Traits such as days to maturity, number of capsules per plant, palmitic acid, and protein content, despite showing moderate-to-high heritability, recorded low genetic advance, suggesting the influence of non-additive gene effects. Improvement of these traits would require more sophisticated breeding methodologies beyond simple selection. The study provide valuable insight for breeders in designing efficient selection strategies for the genetic improvement of yield and quality traits in linseed.

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