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Studies on Genetic Variability Parameters in Linseed under Bihar Climatic Conditions

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Abstract

The present study was carried out during the Rabi season of 2022–2023 at the Research Farm of Dholi Kothi farm, Tirhut College of Agriculture, Dholi, Muzaffarpur, under RPCAU, Pusa, Samastipur, Bihar. Twenty-five linseed genotypes, including two checks i.e. Kota Alsi-6 (local) and T-397 (national)were evaluated in a Randomized Block Design with three replications to assess genetic variability, correlation, path coefficient analysis, heritability and genetic advance for yield and seed quality traits. Significant genetic variability was observed for all traits studied. Seed yield and related attributes exhibited the highest genotypic and phenotypic coefficients of variation, with PCV consistently exceeding GCV, indicating environmental influence. High heritability coupled with high to moderate genetic advance as percentage of mean were recorded for seed yield, seed yield per plant, seedling root length, number of capsules per plant, number of primary branches per plant and plant height, suggesting predominance of additive gene action and effectiveness of direct selection. Traits such as days to maturity showed high heritability but low genetic advance, implying non-additive gene effects and the need for alternative breeding strategies. The findings provide valuable guidance for prioritizing traits in linseed breeding programmes aimed at enhancing productivity and seed quality under irrigated conditions.

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Keywords

Linum usitatissimum, GCV, PCV, Heritability and Genetic Advance.

Introduction

Linseed (*Linum usitatissimum* L., 2n = 30) belongs to the family Linaceae. The genus Linum is among the earliest crops cultivated for its seeds and fibre. Ethiopia ranks as the fifth-largest global producer of linseed and is recognized as a centre of genetic diversity for this crop. In Ethiopia, linseed is primarily grown as an oilseed crop rather than for fibre production and performs best on medium-heavy soils. It is valued for its high-quality oil and serves as a key raw material for various agro-industries. Linseed cultivation exhibits considerable variability in traits such as flower colour, plant height, flowering and maturity periods, capsule size and resistance to wilt disease (Biru and Dareje, 2014).

The susceptibility of linseed to adverse environmental conditions significantly limits its growth and productivity across different regions. In India and other tropical to temperate countries, linseed cultivation is heavily affected by prolonged water deficits, resulting in drought stress, which remains one of the major abiotic factors constraining crop production. Drought stress causes considerable yield reductions by disrupting critical physiological and biochemical processes vital for plant growth and development (Jewell *et al.,* 2010; Wei *et al.,* 2018; Rangwala *et al.,* 2018). According to Wei *et al.,* (2018), the extent of drought damage varies at different growth stages, with the flowering, boll development, and seed-filling phases being particularly vulnerable, as water scarcity during these stages leads to substantial yield losses. To address this challenge, it is essential to explore and implement advanced physiological and biotechnological approaches aimed at enhancing linseed's tolerance to environmental stresses. Notably, modern breeding techniques and physiological interventions offer promising avenues for improving linseed adaptability under diverse abiotic stress conditions. Jewell *et al.,* (2010) emphasize that manipulating genetic and physiological mechanisms could play a crucial role in enhancing drought and chilling tolerance in oilseed crops, which could be effectively applied to linseed improvement programs. India's growing population, expected to reach 1.48 billion by 2043, exerts tremendous pressure on domestic oilseed production to fulfill nutritional demands. The country's dependence on oilseed imports threatens its goal of achieving self-sufficiency by 2047, underscoring the need for high-yielding, stress-resilient linseed varieties.

In linseed, breeding progress is constrained by limited genetic diversity. Earlier research has mainly focused on morphological traits and yield performance, often overlooking the genetic interactions responsible. A comprehensive understanding of inheritance patterns of both quantitative and qualitative traits, through estimation of genetic parameters such as phenotypic and genotypic coefficients of variability (PCV and GCV), heritability, and genetic advance, is critical for designing effective breeding strategies. Evaluating the genetic variability for yield and its component traits is an essential preliminary step before initiating any breeding program to ensure substantial genetic gains. Yield in crop, being a polygenic and complex trait, is regulated by interconnected physiological processes. Due to its intricate inheritance and association with multiple yield components, direct genetic improvement of yield poses challenges. Therefore, indirect selection by improving correlated traits provides a more practical approach. However, systematic germplasm collections in crop have revealed narrow genetic variability for both biotic and abiotic stress tolerance. It is suggested that natural selection may have reduced the frequency of high-yielding alleles, resulting in a restricted genetic base within modern cultivars (Roopalakshmi *et al.,* 2003; Patial, *et al.,* 2018). Furthermore, the predominantly self-pollinating nature of crop limits the efficacy of hybridization for creating new variability, as it faces issues like flower drop and low cross-pollination rates (Deepalakshmi and Anandakumar, 2004). Additionally, the lack of ideotypes suited to varying agro-climatic zones, low harvest index, and susceptibility to diseases further hinder yield improvement (Souframanien and Gopalakrishnan, 2004). Therefore, genetic variability remains the cornerstone for advancement in crop breeding programs (Appalaswamy, 2004).

In India, crop is mainly cultivated as a *Rabi* oilseed crop, either as a sole crop or in intercropping systems depending on the region. Hence, a single plant type is insufficient to meet all production environments, emphasizing the necessity of developing region-specific ideotypes. Given crop's long cultivation history and economic importance in India, a successful breeding program demands thorough knowledge of the extent and nature of genetic divergence within available germplasm, facilitating the selection of appropriate parents for hybridization (Falconer, 1989). Moreover, understanding the inheritance of key traits by estimating genetic parameters such as PCV, GCV, heritability, and genetic advance is imperative for a strategic breeding approach. Assessing genetic variability for yield and its components before starting a breeding program is crucial to ensure meaningful genetic improvement (Singh *et al.,* 2016).

Materials and Methods

The present study entitled "Genetic parameter assessment for yield and seed quality attributes in linseed under irrigated conditions (*Linum usitatissimum* L.)" aimed to evaluate genetic variability, correlation, path coefficient analysis, heritability, and genetic advance. The experiment was conducted during the Rabi season of 2022-2023 at the Research Farm of Dholi Kothi farm, TCA, Dholi, Muzaffarpur, under RPCAU, Pusa, Samastipur, Bihar-848125. Dholi is situated at an altitude of 55.21 meters above sea level, located at 25° 99' North latitude and 85° 59' East longitude. The experimental field featured flat terrain with good drainage. The soil type was alluvial with significant calcium carbonate content, ranging between 10% and 40%, typical of soils found along the BurhiGandak riverbanks. Climatic conditions during the crop growth period were normal and favourable for standard plant development. Twenty-five linseed genotypes, including two checks i.e. Kota Alsi-6 (local check) and T-397 (national check) were obtained from the All India Coordinated Research Project (AICRP) on Linseed, Department of Genetics & Plant Breeding, TCA, Dholi, Muzaffarpur, RPCAU, Pusa, Samastipur (Bihar). The experiment was laid out in a Randomized Block Design (RBD) with three replications. Plot size was 5 m × 2 m, and spacing was maintained at 30 cm × 10 cm. The soil was characterized as sandy loam. The Burton (1952) method was used to statistically analyse the data to work out ANOVA. The genotypic and phenotypic coefficients of variation among the studied genotypes were calculated following the method of Johanson *et al.,* (1955). Broad-sense heritability was estimated using the formula proposed by Burton and Devane (1953). The expected genetic advance for each trait was computed according to the procedure described by Johnson *et al.,* (1955). The characters studied comprised of days to 50% flowering, days to maturity, plant height (cm), primary branches per plant, number of capsules per plant, number of seeds per capsule, test weight / 1000-seed weight (g), harvest index (%), seed yield per plant (g), seed yield (kg/ha), seed germination percentage (%), speed of germination, seedling root length (cm), seedling shoot length (cm), seedling length (cm), seedling dry weight (g), vigour index I and vigour index II.

Results and Discussion

Analysis of Variance

The experimental materials, comprising 25 linseed genotypes including two checks, were arranged in a randomized block design with three replications. The mean squares values for the studied traits are presented in Table 1. Analysis of variance indicated highly significant differences among the genotypes for all characters evaluated which demonstrating substantial genetic variability within the materials. Similar findings have been reported by Choudhary *et al.,* (2017) and Singh *et al.,* (2015).

Genotypic and Phenotypic coefficient of variation

The genotypic coefficient of variation (GCV) values was slightly lower than the corresponding phenotypic coefficient of variation (PCV) values for all the traits studied (table- 2), indicating that environmental factors contributed to the observed variability. The highest GCV was recorded for seed yield (kg/ha) (41.94%), followed by seed yield per plant (30.97%), number of capsules per plant (25.54%), and number of primary branches per plant (20.87%), whereas the lowest GCV was observed for days to maturity (4.29%). Overall, GCV values ranged from 4.29% to 41.94%. Similarly, PCV values were consistently higher than GCV values, further confirming the role of environmental influences in the expression of these traits. The maximum PCV was observed for seed yield (kg/ha) (43.84%), followed by seed yield per plant (33.11%), number of capsules per plant (27.79%), and number of primary branches per plant (25.43%). The lowest PCV was recorded for days to maturity (5.50%), with the overall range being 5.50% to 43.84%.

These results suggest that traits such as seed yield, seed yield per plant, number of capsules per plant, and number of primary branches per plant exhibit a high magnitude of both PCV and GCV, indicating substantial genetic variability and suggesting that selection for these traits could be highly effective. In contrast, traits like days to maturity showed low GCV and PCV values, implying a narrower genetic base and less scope for improvement through simple selection. The consistent observation of PCV values being greater than GCV values across traits is in agreement with earlier reports (Tadesse *et al.,* 2010; Tahira *et al.,* 2013; Paul *et al.,* 2020).

This difference between PCV and GCV can be attributed to the modifying effect of environmental conditions on the phenotypic expression of traits, as also reported by Reddy *et al.,* (2013); Paul and Kumari (2018) and Upadhyay *et al.,* (2019). The high variability observed for seed yield and its related traits aligns with the findings of Tyagi *et al.,* (2014) who also reported similar magnitudes in linseed and other crops. Such high variability is desirable for breeding programs, as it provides a broader scope for selecting superior genotypes that can contribute to genetic improvement.

Genetic parameters

Heritability and Genetic Advance

Heritability estimates (table 2), when interpreted alongside genetic advance, provide a more accurate prediction of the potential gain from selection than heritability alone. In this study, heritability was assessed in the broad sense, which, as described by Hanson *et al.,* (1956), includes both additive and non-additive gene effects. In contrast, narrow-sense heritability (Lush, 1949; Johnson *et al.,* 1955) accounts only for additive effects. Following Johnson *et al.,* (1955a), traits were categorized based on broad-sense heritability as low (< 30%), moderate (30–60%), and high (> 60%).

The highest heritability values were observed in seedling root length (92.4%), seed yield (kg/ha) (91.5%), seed yield per plant (87.5%), vigour index-I (86.2%), number of capsules per plant (84.4%), seedling length (83.4%), seedling shoot length (82.8%), seedling dry weight (81.4%), vigour index-II (79.0%), speed of germination (78.6%), seed germination percentage (73.7%), number of primary branches per plant (67.3%), test weight (65.8%), days to 50% flowering (64.9%), plant height (61.1%), and days to maturity (60.8%). Moderate heritability values were found for harvest index (53.5%) and number of seeds per capsule (52.8%).

Genetic Advance and Genetic Advance as Percent of Mean

Genetic advance (GA) was calculated as the product of the genotypic variance to phenotypic standard deviation ratio and the selection differential (K′), expressed both in absolute units and as a percentage of the mean. High GA values (table 2 and figure 1) indicate the presence of additive gene action, suggesting that selection can bring substantial improvement in these traits. The highest GA in absolute terms was recorded for seed yield (kg/ha) (535.49), while the lowest was for vigour index-II (0.26). When expressed as a percentage of the mean, the highest values were for seed yield (kg/ha) (82.67%), seed yield per plant (59.70%), number of capsules per plant (48.35%), number of primary branches per plant (35.27%), seedling root length (33.62%), and plant height (21.26%). The lowest GA% values were for days to maturity (6.89%), seed germination percentage (8.93%), and harvest index (9.34%).

Table.1 Estimates of Analysis of variance for eighteen quantitative characters in linseed.

S.No.	Characters	Mean Sum Square		
		Replication	Treatments	Error
1.	Days to 50% flowering	30.04	64.02**	8.33
2.	Days to maturity	6.77	108.19**	19.16
3.	Plant height (cm)	19.78	186.88**	32.75
4.	No. of Primary Branches per Plant	0.14	0.64**	0.03
5.	No. of Capsules per plant	4.89	125.85**	7.28
6.	No. of Seeds per Capsules	0.48	1.46**	0.24
7.	Harvest Index	1.018	12.43*	2.79
8.	Test Weight (gm)	0.18	1.29**	0.19
9.	Seed Germination %	8.49	58.72**	6.23
10.	Speed of germination	0.07	5.27**	0.44
11.	Seedling Root Length (cm)	0.02	0.504*	0.014
12.	Seedling Shoot Length (cm)	0.02	0.67**	0.044
13.	Seedling Length (cm)	0.0097	0.92**	0.057
14.	Seedling Dry Weight (gm)	0.093	10.77**	0.76
15.	Vigour Index I	351.26	9529.25*	483.16
16.	Vigour Index II	0.0098	0.065**	0.0053
17.	Seed Yield per Plant (gm)	0.0049	0.111*	0.0050
18.	Seed Yield (kg/ha.)	16727.26	228294.81**	6828.025

***,** at 5% and 1% Level of Significance**

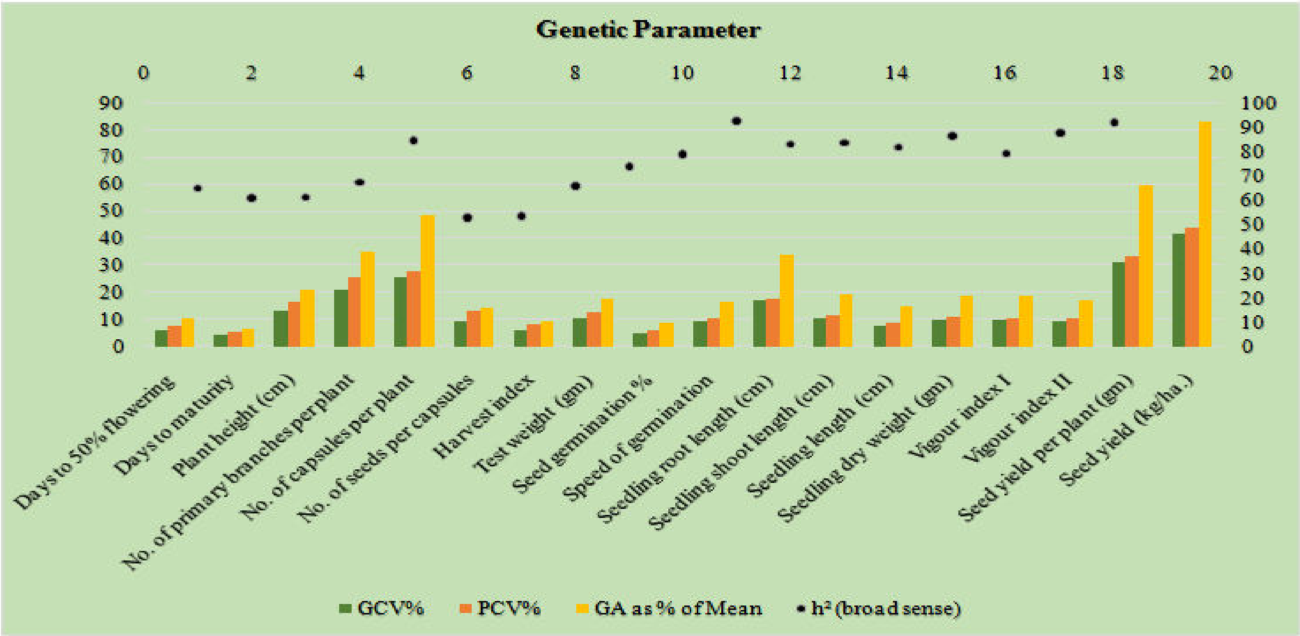
Table.2 Estimates of genetic variability parameters for 18 quantitative traits in Linseed

S.No	Characters	Range	Mean	GCV%	PCV%	h^2 (%)	GAM (%)
1.	Days to 50% flowering	57.67- 72.33	66.44	6.19	7.69	64.9	10.28
2.	Days to maturity	113.33-134.33	126.97	4.29	5.50	60.8	6.89
3.	Plant height (cm)	35.06-64.33	54.27	13.20	16.89	61.1	21.26
4.	No. of primary branches per plant	2.00- 3.00	2.30	20.87	25.43	67.3	35.27
5.	No. of capsules per plant	14.00-37.33	24.61	25.54	27.79	84.4	48.35
6.	No. of seeds per capsules	6.00-8.67	7.44	9.61	13.23	52.8	14.40
7	Harvest index	25.83-33.68	28.91	6.202	8.477	53.5	9.34
8.	Test weight (gm)	4.42-6.82	5.71	10.57	13.03	65.8	17.68
9.	Seed germination %	73.33-87.66	82.81	5.05	5.88	73.7	8.93
10.	Speed of germination	11.52-15.87	13.78	9.20	10.38	78.6	16.80
11.	Seedling root length (cm)	1.73- 3.40	2.38	16.98	17.67	92.4	33.62
12.	Seedling shoot length (cm)	3.60-5.26	4.39	10.42	11.46	82.8	19.54
13.	Seedling length (cm)	5.86-8.43	6.74	7.94	8.70	83.4	14.94
14.	Seedling dry weight (gm)	15.00-21.33	18.10	10.08	11.17	81.4	18.75
15.	Vigour index I	453.00-651.26	557.75	9.84	10.60	86.2	18.82
16.	Vigour index II	1.22-1.81	1.49	9.43	10.61	79.0	17.26
17.	Seed yield per plant (gm)	0.25-0.92	0.60	30.97	33.11	87.5	59.70
18.	Seed yield (kg/ha.)	247.76-1268.90	647.71	41.94	43.84	91.5	82.67

GCV: Genotypic Coefficient of Variation **PCV: Phenotypic Coefficient of Variation**

h^2: Heritability (broad sense) **GAM: Genetic advance as percent of Mean**

Figure.1 Histogram of genetic parameters studied for 18 quantitative characters of linseed



The combination of high heritability with high to moderate GA% was particularly evident for seedling root length, seed yield (kg/ha), seed yield per plant, number of capsules per plant, number of primary branches per plant, and plant height. This combination is a strong indication that these traits are primarily governed by additive gene effects, and hence, direct selection would be effective. Similar patterns have been reported by Dandigadasar *et al.,* (2011); Reddy *et al.,* (2013); Singh *et al.,* (2015) and Terfa and Gurmu (2020).

In contrast, days to maturity exhibited high heritability but low GA%, suggesting that this trait is largely influenced by non-additive gene effects or is under strong environmental control. In such cases, selection may be less effective, and breeding strategies like hybridization or exploitation of heterosis may be more appropriate. Overall, genetic advance and heritability estimates are complementary measures. While heritability indicates the proportion of phenotypic variance attributable to genetic factors, GA% reflects the actual expected improvement through selection. Together, they serve as valuable tools for identifying priority traits in linseed breeding programs.

Conclusion

The study revealed significant genetic variability among 25 linseed genotypes for all traits studied, with seed yield and its related characters showing the highest genotypic and phenotypic coefficients of variation. Consistently higher PCV than GCV values indicated environmental influence on trait expression. High heritability estimates coupled with high to moderate genetic advance as a percentage of mean were observed for seed yield, seed yield per plant, seedling root length, number of capsules per plant, number of primary branches, and plant height, suggesting predominance of additive gene action and the potential for effective improvement through direct selection. Conversely, traits like days to maturity exhibited high heritability but low genetic advance, indicating non-additive genetic control or environmental influence, requiring alternative breeding strategies. Overall, the results provide valuable insights for prioritizing traits in linseed breeding programs aimed at enhancing yield and associated attributes.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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