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Correlation and path coefficient analysis in linseed (*Linum usitatissimum* L.) for yield and yield contributing traits

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Abstract
This study aimed to assess the correlation and path coefficient relationships among 40 linseed genotypes using ten yield-related traits. The experiment was carried out during the *Rabi* season of 2023 at the Experimental Farm, Department of Genetics and Plant Breeding at College of Agriculture, Latur (Maharashtra), following a Randomized Block Design (RBD) with a spacing of 30 cm × 5 cm. Genotypic and phenotypic correlation analyses indicated that seed yield had highly significant positive associations with branches per plant, capsules per plant, seeds per capsule, 1000 seed weight, harvest index and oil content. Path coefficient analysis showed that branches per plant, 1000 seed weight, harvest index and oil content exerted the strongest direct positive influences on seed yield. Additionally the magnitude of genotypic path coefficients both at direct and indirect, was greater than that observed for the corresponding phenotypic path coefficients.

Keywords: Linseed, Correlation analysis, Path coefficient analysis, Genetics

Introduction

Linseed, also known as "Alsi," is a non-edible oilseed crop grown mainly during the *Rabi* season. It belongs to the genus *Linum* and has a chromosome number of 2n=30. Linseed is an annual plant and is valued for both oil and fiber. Today, it is cultivated widely across Asia, Europe, America, and Africa. The seeds are primarily used to extract oil which is mostly utilized in industries. Around 80% of linseed oil goes into making products like paints, varnishes, printing pad inks, soaps, patent leather and oilcloth. The remaining 20% is used for edible purposes. Interestingly every part of the linseed plant has commercial value either directly or after processing. According to scientist Vavilov, linseed has two origins the oil-producing type comes from Southwest Asia, while the fiber-producing type traces back to the Mediterranean region. Studies show that consuming 25 grams of linseed daily may help lower the risk of breast cancer. Linseed grows best in cool climates. The ideal temperature range for its growth is between 10 °C and 38 °C, and the best time to sow the crop is from October to November. It is cultivated in many countries around the world.

According to the latest figures from 2024-25, global linseed production is about 3.068 million tonnes, grown over 3.223 million hectares, with an average yield of 952 kg per hectare. Russia is the top producer, followed by Kazakhstan and Canada. In India, Linseed production is estimated at 100,000 tonnes from 170,000 hectares, with a much lower average yield of 574 kg per hectare-well below the global average. Among Indian states, linseed is mainly grown in Madhya Pradesh, Uttar Pradesh, Chhattisgarh, Bihar, Jharkhand, and Maharashtra. Maharashtra has very low productivity averaging just 267 kg per hectare. This is mainly due to limited progress in improving plant varieties, low farmer awareness and poor farming practices.

The correlation and path coefficient analysis enable us to understand the importance of different yield component traits. So that an appropriate selection strategy is made. The correlation between various characters and yield contributing traits with yield provides insights into growth and yield attributes. Correlation which represents the relationship between variables assists researchers in identifying the most effective methods for genotype selection. A path coefficient is a standardized partial regression coefficient that partitions a correlation coefficient into its direct and indirect effects. The present study was undertaken to determine the correlation and path coefficients among yield and its component traits in Linseed genotypes. The objective was to identify the key traits that can serve as reliable selection indices for enhancing grain yield in future breeding programs.

Materials and Methods

The study was conducted using 40 linseed genotypes arranged in a randomized block design (RBD) with two replications during the *Rabi* season of 2023 at the Experimental Farm, Department of Genetics and Plant Breeding at College of Agriculture, Latur (Maharashtra). Each genotype was sown in a plot measuring 5 × 0.12 m², maintaining a row spacing of 30 cm and a plant spacing of 5 cm. Standard agronomic practices were applied uniformly throughout the growing season and appropriate plant protection measures were implemented as required. Observations were recorded for ten quantitative characters such as days to 50% flowering, days to maturity, plant height, branches per plant, capsules per plant, seeds per capsule, 1000-seed weight (g), harvest index (%), oil content (%) and seed yield per plant. Relationships among these traits were analyzed by computing correlation coefficients following Fisher's method (1918), while direct and indirect effects on seed yield were determined using path coefficient analysis based on Wright's approach (1921).

Result and Discussion

Correlation Analysis

The genotypic and phenotypic correlation coefficients for seed yield and related traits are provided in Table 1 and Table 2. Analysis of these correlations indicated that seed yield per plant in linseed was positively and significantly associated at both genotypic and phenotypic levels, with several key yield-determining characteristics. At the genotypic level, strong and significant positive correlations were observed for seed yield with traits such as branches per plant (0.6394**), capsules per plant (0.6519**), seeds per capsule (0.7418**), thousand-seed weight (0.7444**), harvest index (0.8575**) and oil content (0.7988**).

At the phenotypic level, seed yield exhibited a strong and highly significant positive correlation with several traits such as branches per plant (0.5627**), capsules per plant (0.5886**), seeds per capsule (0.8598**), thousand-seed weight (0.6713**), harvest index (0.7629**) and oil content (0.6688**). These findings indicate that such traits should receive emphasis when selecting plants for yield enhancement. Similar result has been documented by Sharma *et al.* (2016) [15], Patial *et al.* (2018) [12], Kaur *et al.* (2020) [7], and Patel *et al.* (2023) [11]. Conversely, days to 50% flowering, days to maturity, and plant height showed negative and non-significant correlations with seed yield per plant at both genotypic and phenotypic levels. This observation aligns with the reports of Meena *et al.* (2020) [10], Kaur *et al.* (2020) [7] and Kumar *et al.* (2024) [8]. In summary, traits such as branches number, capsules per plant, seeds per capsule, thousand-seed weight, harvest index and oil content are key determinants of yield and should be prioritized in linseed breeding programs.

Path Analysis

Path coefficient analysis was utilized to assess both the direct and indirect contributions of different yield-associated traits to seed yield per plant at genotypic and phenotypic levels (Table 3 and Table 4). At the genotypic level, the most substantial positive direct effects on seed yield were recorded for branches per plant (0.2800) followed by capsules per plant (0.0881), thousand-seed weight (0.2377), harvest index (0.6182) and oil content (0.2438). At the phenotypic level, the leading positive direct influence was observed for seeds per capsule (0.5568) along with thousand-seed weight (0.1959), harvest index (0.1808), oil content (0.0845) and a smaller effect from branches per plant (0.0076). These traits can be considered key selection parameters in breeding programs aimed at enhancing yield potential.

The path analysis revealed that positive direct effect for the traits such as number of branches per plant, 1000 seed weight, harvest index and oil content while for the characters days to 50 per cent flowering, plant height, days to maturity, number of seeds per capsule and number of capsules per plant indicates negative direct effect on seed yield per plant. Similar results were identified by Chaudhary *et al* (2016) [1], Kasana *et al.* (2018) [6], Patial *et al.* (2018) [12], Meena *et al.* (2020) [10], Kaur *et al.* (2020) [7] and Prajapati *et al.* (2022) [13]. Since genotypic path effects were generally higher than phenotypic effects, the associations among traits appear to be largely genetic and heritable. Thus, direct selection for yield-contributing traits like number of seeds per capsule, capsules per plant, harvest index and 1000 seed weight is recommended for developing high yielding linseed varieties.

Table 1: Estimates of genotypic correlation coefficients for yield and yield contributing traits in Linseed.

Characters	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 (%)	Seed yield per plant (g)
Days to 50% flowering	1.000	0.3449*	0.4643**	-0.0268	0.1156	-0.2072	-0.1150	-0.0023	-0.0551	-0.1081
Days to maturity		1.0000	0.3187*	-0.2413*	-0.4035*	-0.3918	-0.3041	-0.0687	-0.1352	-0.3868
Plant height (cm)			1.000	0.1078	0.0676	0.0834	-0.1474	-0.0527	0.0602	-0.0747
No. of branches per plant				1.0000	0.5848**	0.8176**	0.3915	0.5369*	0.5664	0.6394**
Number of capsules per plants					1.000	0.8362**	0.3291*	0.6486**	0.3931**	0.6519**
Number of seeds per capsules						1.0000	0.7123*	0.6557**	0.8436**	0.7418**
1000 seed weight (g)							1.000	0.6038**	0.5996**	0.7474**
Harvest index (%)								1.0000	0.7184**	0.8575**
Oil content (%)									1.000	0.7988**
Seed yield per plant (g)										1.000

* and ** significant at 5 and 1 per cent respectively

Table 2: Estimates of phenotypic correlation coefficients for yield and yield contributing traits in Linseed.

Characters	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 (%)	Seed yield per plant (g)
Days to 50% flowering	1.000	0.3099**	0.4524**	-0.0325	0.1164	-0.1149	-0.1139	0.0023	-0.0541	-0.1002
Days to maturity		1.000	0.2967*	-0.2201**	-0.3616**	-0.2767	-0.2736*	-0.0642	-0.1021	-0.3333*
Plant height (cm)			1.000	0.0975	0.0686	0.0826	-0.1364	-0.0536	0.0558	-0.0570
No. of branches per plant				1.000	0.5670**	0.5986**	0.3714*	0.5126**	0.5370**	0.5627**
Number of capsules per plant					1.000	0.6207**	0.3165**	0.6244**	0.3713**	0.5886**
Number of seeds per capsule						1.000	0.5239**	0.7193**	0.6232**	0.8598**
1000 seed weight (g)							1.000	0.5820**	0.5524**	0.6713**
Harvest index (%)								1.000	0.6822**	0.7629**
Oil content (%)									1.000	0.6688**
Seed yield per plant (g)										1.000

* and ** significant at 5 and 1 per cent respectively

Table 3: Direct and indirect effects (genotypic) of different characters on seed yield per plant in Linseed.

Characters	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 (%)	Seed yield per plant (g)
Days to 50% flowering	-0.2355	-0.0812	-0.1094	0.0063	-0.0272	0.0488	0.0271	0.0005	0.0130	-0.1081
Days to maturity	-0.1591	-0.4613	-0.1470	0.1113	0.1861	0.1807	0.1403	0.0317	0.0624	-0.3868
Plant height (cm)	0.1417	0.0973	0.3052	0.0329	0.0206	0.0254	-0.0450	-0.0161	0.0184	-0.0747
No. of branches per plant	-0.0075	-0.0676	0.0302	0.2800	0.1638	0.2290	0.1096	0.1504	0.1586	0.6394
Number of capsules per plant	0.0102	-0.0355	0.0060	0.0515	0.0881	0.0736	0.0290	0.0571	0.0346	0.6519
Number of seeds per capsule	0.1856	0.3510	-0.0747	-0.7325	-0.7491	-0.8959	-0.6381	-0.9114	-0.7557	0.7418
1000 seed weight (g)	-0.0273	-0.0723	-0.0350	0.0930	0.0782	0.1693	0.2377	0.1435	0.1425	0.7474
Harvest index (%)	-0.0028	-0.0842	-0.0646	0.6586	0.7956	0.1446	0.7407	0.6182	0.8813	0.8575
Oil content (%)	-0.0134	-0.0330	0.0147	0.1381	0.0959	0.2057	0.1462	0.1752	0.2438	0.7988
Seed yield per plant (g)	-0.1081	-0.3868	-0.0747	0.6394	0.6519	0.7418	0.7474	0.8575	0.7988	1.000

Table 4: Direct and indirect effects (phenotypic) of different characters on seed yield per plant in Linseed.

Characters	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 (%)	Seed yield per plant (g)
Days to 50% flowering	0.0525	0.0163	0.0237	-0.0017	0.0061	-0.0060	-0.0060	0.0001	-0.0028	-0.1002
Days to maturity	-0.0320	-0.1032	-0.0306	0.0227	0.0373	0.0286	0.0282	0.0066	0.0105	-0.3333
Plant height (cm)	-0.0293	-0.0192	-0.0647	-0.0063	-0.0044	-0.0053	0.0088	0.0035	-0.0036	-0.0570
No. of branches per plant	-0.0002	-0.0017	0.0007	0.0076	0.0043	0.0045	0.0028	0.0039	0.0041	0.5627
Number of capsules per plants	-0.0008	0.0024	-0.0004	-0.0037	-0.0066	-0.0041	-0.0021	-0.0041	-0.0024	0.5886
Number of seeds per capsule	-0.0640	-0.1541	0.0460	0.3334	0.3457	0.5568	0.2918	0.4005	0.3470	0.8598
1000 seed weight (g)	-0.0223	-0.0536	-0.0267	0.0728	0.0620	0.1026	0.1959	0.1140	0.1082	0.6713
Harvest index (%)	0.0004	-0.0116	-0.0097	0.0927	0.1129	0.1300	0.1052	0.1808	0.1233	0.7629
Oil content (%)	-0.0046	-0.0086	0.0047	0.0454	0.0314	0.0526	0.0467	0.0576	0.0845	0.6688
Seed yield per plant (g)	-0.1002	-0.3333	-0.0570	0.5627	0.5886	0.8598	0.6713	0.7629	0.6688	1.000

Conclusion

For enhancing yield potential in linseed, emphasis should be placed on traits such as branches per plant, capsules per plant, seeds per capsule, 1000 seed weight and harvest index as these have a strong association with increased seed yield and serve as valuable selection markers in breeding efforts.

Path coefficient analysis revealed that seeds per capsule, capsules per plant, branches per plant, harvest index and 1000 seed weight exerted significant and positive direct influences on seed yield at both genotypic and phenotypic levels. Hence, these characteristics merit priority in selection programs aimed at yield improvement. Integrating correlation studies with path coefficient analysis offers a comprehensive perspective on trait interrelationships, enabling breeders to formulate more precise and effective strategies for identifying superior high-yielding genotypes.

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