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ASSOCIATION ANALYSIS OF SEED YIELD AND ITS COMPONENT TRAITS IN SMALL SEEDED GENOTYPES OF LINSEED (*Linum usitatissimum* L.)

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ABSTRACT

The present study was undertaken to elucidate the relationship among seed yield and its component traits in small-seeded genotypes of linseed (*Linum usitatissimum* L.). Correlation analysis indicated that oil content exhibited a strong and positive association with 1000 seed weight and plant height at both genotypic and phenotypic levels, highlighting their importance as key yield determinants. Additionally, capsule length and number of seeds per capsule showed positive associations, suggesting their contributory role in yield formation, though with relatively lower magnitude. Significant negative associations of oil content with days to maturity and number of primary branches indicated potential trade-offs among traits. To further dissect the nature of these relationships, path coefficient analysis was employed, which revealed that number of secondary branches per plant exerted the highest positive direct effect on oil content, followed by 1000 seed weight, days to 50% flowering, and plant height. These traits were identified as primary contributors with true genetic influence on yield. Conversely, traits such as number of primary branches, days to maturity, and number of capsules per plant exhibited negative direct effects, indicating that their correlations with yield were largely mediated through indirect effects. Understanding the relationships among these traits helps in identifying important characters that directly or indirectly influence yield. These results indicate that selection based on these traits may be effective for improving seed yield in linseed breeding programmes.

***Keywords* :** Linseed, yield, Correlation Coefficient and Path Analysis.

Introduction

Linseed (*Linum usitatissimum* L.) is one of the most ancient and economically important oilseed crops, domesticated over 5000 years ago and widely cultivated for its dual-purpose utility as a source of oil and fiber. It belongs to the family Linaceae and holds a unique position among oilseed crops due to its exceptional nutritional and industrial value. Linseed oil is particularly rich in α-linolenic acid (ALA), an essential omega-3 fatty acid that constitutes about 50–60% of total fatty acids and plays a crucial role in reducing cardiovascular disorders, improving brain function, and exhibiting anti-inflammatory properties (Oomah, 2001; Singh *et al.,* 2021; Verma and Singh, 2023). In addition to its nutritional importance, linseed oil has wide-ranging industrial applications in the manufacture of paints, varnishes, printing inks, linoleum, and polymer-based products (Green and Marshall, 1984; Daun *et al.,* 2003). These attributes make linseed a crop of significant agronomic, nutritional, and economic importance at both national and global levels.

Despite its immense potential, the productivity of linseed remains relatively low, especially under Indian agro-climatic conditions. This is largely due to its narrow genetic base, susceptibility to various biotic and abiotic stresses, and poor adaptation to changing environmental conditions (Kumar *et al.,* 2020; Mehta *et al.,* 2018; Sharma and Dubey, 2022). Moreover, seed yield in linseed is a highly complex quantitative trait governed by multiple genes with small individual effects and is significantly influenced by environmental factors, leading to low heritability and reduced efficiency of direct selection (Falconer and

Mackay, 1996; Allard, 1999). Therefore, improvement in yield requires a comprehensive understanding of the genetic architecture of yield and its component traits.

In plant breeding, yield is not an independent trait but the cumulative result of several interrelated component characters such as days to flowering, plant height, number of branches, number of capsules per plant, seed weight, and oil content. The improvement of such a complex trait necessitates the identification of key contributing characters and the understanding of their interrelationships. Correlation analysis serves as a fundamental statistical tool to measure the degree and direction of association between yield and its component traits (Johnson *et al*., 1955). It provides valuable information for breeders to identify important traits that can be used as indirect selection criteria for yield improvement. However, correlation analysis alone may be misleading, as it does not distinguish between direct and indirect associations among traits (Singh and Chaudhary, 1985).

To overcome this limitation, path coefficient analysis, first proposed by Wright (1921), has been widely adopted in plant breeding to partition correlation coefficients into direct and indirect effects, thereby providing a clearer understanding of cause-and-effect relationships among traits (Dewey and Lu, 1959). This method enables breeders to identify traits that have a true genetic influence on yield and to formulate effective selection strategies. Several studies in linseed have successfully utilized correlation and path analysis to identify major yield-contributing traits and improve selection efficiency (Mehta *et al.*, 2018; Patel *et al.*, 2019; Kumar *et al.*, 2020; Singh *et al.*, 2021; Sharma and Dubey, 2022; Verma and Singh, 2023).

Previous research findings have consistently reported that traits such as 1000 seed weight, plant height, number of primary and secondary branches, and number of capsules per plant exhibit strong positive associations with seed yield, indicating their importance as reliable selection indices (Kumar *et al.*, 2020; Sharma and Dubey, 2022; Mehta *et al.*, 2018). Similarly, studies by Tadesse *et al.* (2010) and Khan *et al.* (2013) also emphasized the significance of branching pattern and seed weight in determining yield potential. Conversely, certain traits may show negative or negligible direct effects on yield, suggesting that their improvement through direct selection may not be effective (Patel *et al.*, 2019; Singh and Singh, 2014). Such contrasting relationships highlight the complexity of yield determination in linseed.

Furthermore, the association among traits may arise due to genetic causes such as pleiotropy or linkage disequilibrium, which facilitates the simultaneous improvement of correlated traits through indirect selection (Falconer and Mackay, 1996). Therefore, a combined approach involving both correlation and path coefficient analysis is essential to unravel the intricate relationships among yield components and to identify traits with substantial direct effects on yield.

In view of the above considerations, the present investigation was undertaken to evaluate the magnitude and nature of association among seed yield and its component traits in small-seeded genotypes of linseed. The study also aims to dissect these relationships through path coefficient analysis in order to identify key traits that can be effectively utilized as selection criteria for yield improvement. The findings of this study are expected to provide a strong scientific basis for developing high-yielding linseed genotypes through trait-based breeding strategies and genetic improvement programmes.

Materials and Methods

The experiment was conducted during *Rabi* 2021–22 at the Research cum Instructional Farm, Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh. The experimental material consisted of Forty small seeded linseed genotypes, including three check varieties RLC-143, RLC-148 and RLC-153 obtained from AICRP on Linseed, IGKV Raipur. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Five competitive plants were selected randomly from each genotype in each replication for recording observations. The observations were recorded on the eleven characters viz., Seed coat colour, Days to 50% flowering, Days to maturity, Plant height (cm), Number of primary branches per plant, Number of secondary branches per plant. Number of capsules per plant, Capsule length (cm), Number of seeds per capsule, 1000 seed weight (g), Oil content (%) Correlation coefficients were calculated at both genotypic and phenotypic levels to determine the association among different characters.

Geographical situation

The research was carried out at the IGKV Raipur, Chhattisgarh, Research cum Instruction farm during the *rabi* 2021–22. With a 21°16'N latitude, 81°31'E longitude, and an elevation of 289.56m above mean sea level, Raipur is situated in the state's southern region.

Methodology

In the current study, phenotypic characteristics are observed based on "National guidelines for distinctness, uniformity, and stability in linseed, India" published in accordance with the catalogue on linseed germplasm, DUS descriptor in accordance with UPOV 2011 (International union for the protection of new varieties of plants) & Flax Council of Canada and descriptor of IFDB-International Flax Database (2006), Project Coordinating Unit (Linseed) Kanpur For the experiment. Observations were recorded on five randomly selected plants from each plot for 11 quantitative characters *viz.* seed coat colour, days to 50% flowering, days to maturity, plant height (cm), number of primary branches/plant, number of secondary branches/plant, number of capsules/plant, capsule length (cm), number of seeds/capsules, 1000 seed weight (g) and oil content (%).

Statistical analysis

The analysis was conducted using OPSTAT software.

Table 1: Experimental materials used in the present study

S.No.	Genotypes	S.No.	Genotypes	S.No.	Genotypes	S.No.	Genotypes
1	GP-630	11	GP-2415	21	GP-2750	31	GP-1936
2	GP-761	12	GP-2566	22	GP-2751	32	GP-262
3	GP-1663	13	GP-2638	23	GP-2755	33	GP-1678
4	GP-1716	14	GP-2646	24	GP-2806	34	GP-2232
5	GP-1809	15	GP-2667	25	GP-2808	35	GP-2240
6	GP-2009	16	GP-2741	26	GP-2915	36	GP-2486
7	GP-2053	17	GP-2743	27	GP-2918	37	GP-2608
8	GP-2148	18	GP-2745	28	GP-2936	38	**RLC-143** ©
9	GP-2306	19	GP-2748	29	GP-2937	39	**RLC-148** ©
10	GP-2308	20	GP-2749	30	GP-2938	40	**RLC-153** ©

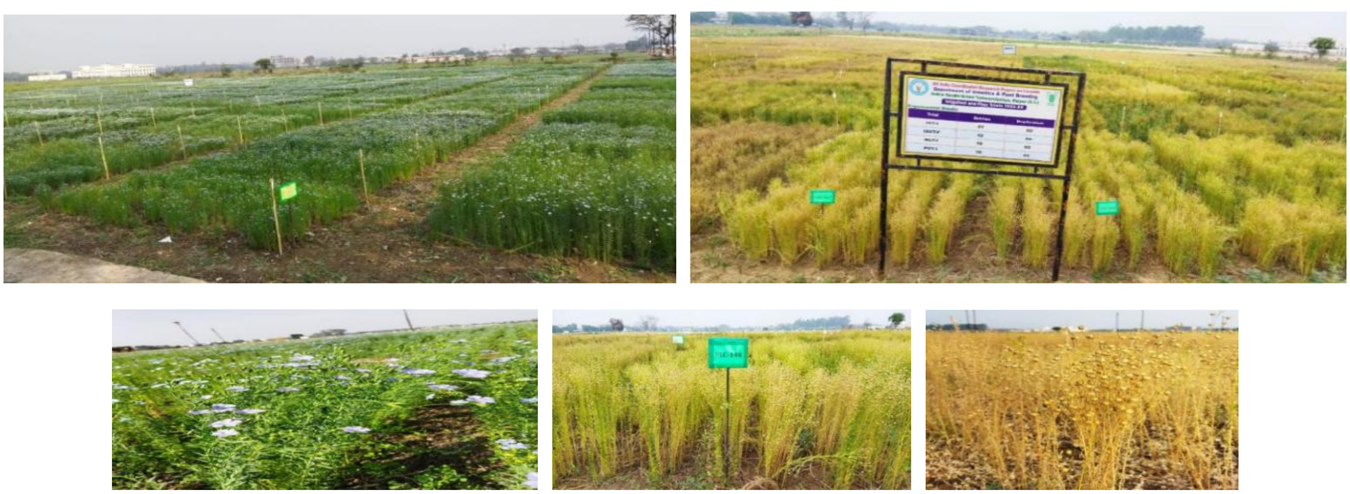

Fig. 1 : View of experimental field

Results and Discussion

The association analysis among seed yield and its contributing traits revealed that yield is a complex quantitative character governed by the cumulative effects of several interrelated components. The correlation coefficients at both genotypic and phenotypic levels provided a clear understanding of the direction and magnitude of relationships among traits. In the present investigation, oil content exhibited a significant and positive association with plant height (rg = 0.226; rp = 0.204) and 1000 seed weight (rg = 0.285; rp = 0.266), indicating that genotypes with taller plants and heavier seeds tend to produce higher oil yield. These findings are in close agreement with recent studies by Kumar *et al.* (2020), Patel *et al.* (2019), and Singh *et al.* (2021), who also reported strong positive correlations of seed yield with seed weight and plant height in linseed. The positive association suggests that these traits can be effectively utilized as selection criteria in breeding programmes aimed at yield enhancement.

Furthermore, capsule length and number of seeds per capsule showed positive correlations with oil content, although the magnitude of association was relatively low. Similar trends have been reported by Sharma and Dubey (2022) and Verma and Singh (2023), indicating that these traits contribute indirectly to yield improvement and should be considered in combination with major traits during selection. The observed positive association among yield-contributing traits may be attributed to pleiotropic gene effects or linkage relationships, as also suggested in recent genetic studies on linseed and other oilseed crops (Mehta *et al.*, 2018; Singh *et al.*, 2021). This implies that simultaneous improvement of correlated traits is feasible through appropriate selection strategies.

To further elucidate the cause-and-effect relationship, path coefficient analysis was performed by partitioning the correlation coefficients into direct and indirect effects. The results revealed that number of secondary branches per plant exerted the highest positive direct effect on oil content, followed by days to 50% flowering, 1000 seed weight, and plant height. These findings are in conformity with recent reports by Kumar *et al.* (2020) and Sharma and Dubey (2022), which emphasized the importance of branching pattern and seed weight as major determinants of yield in linseed.

The high direct effect of number of secondary branches per plant suggests that increased branching enhances sink capacity and reproductive efficiency, thereby improving oil accumulation. Similarly, the substantial direct contribution of 1000 seed weight confirms that heavier seeds directly influence oil yield rather than acting through indirect pathways. Plant height also showed a positive direct effect, indicating its role in biomass production and photosynthetic efficiency, ultimately contributing to higher yield.

On the contrary, number of primary branches per plant, days to maturity, and number of capsules per plant exhibited negative direct effects on oil content. This indicates that their apparent association with yield is primarily due to indirect influences via other traits rather than their inherent contribution. Similar observations have been reported by Patel *et al.* (2019) and Verma and Singh (2023), suggesting that direct selection for these traits may not be effective and should be approached cautiously. The indirect effects further revealed that several traits contributed to oil content through complex interrelationships. For instance, days to maturity influenced oil content indirectly via plant height and seed weight, while capsule length and number of seeds per capsule exerted small but positive indirect effects. These findings highlight the intricate genetic architecture of yield, where multiple traits interact to determine the final expression.

Overall, the results suggest that selection based on number of secondary branches per plant, 1000 seed weight, and plant height would be most effective for improving oil yield in linseed. The findings are in strong agreement with contemporary research trends emphasizing trait-based selection for genetic improvement in oilseed crops.

Table 2: Genotypic & Phenotypic correlation coefficient among dependent and independent character in linseed genotypes.

Genotypic and phenotypic correlation coefficient for seed yield and its components											
Characters		**DTF**	**DTM**	**PH**	**NPB/PL**	**NSB/PL**	**NC/PL**	**CL**	**NS/C**	**TSW**	**OIL (%)**
DTF	G	1.000									
	P	1.000									
DTM	G	**0.424****	1.000								
	P	**0.375****	1.000								
PH	G	**-0.238****	**0.091**	1.000							
	P	**-0.201***	**0.087**	1.000							
NPB/PL	G	**0.455****	**0.092**	**0.041**	1.000						
	P	**0.403****	**0.062**	**0.012**	1.000						
NSB/PL	G	**0.232***	**0.070**	**0.237****	**0.761****	1.000					
	P	**0.204***	**0.047**	**0.176**	**0.744****	1.000					
NC/PL	G	**0.242****	**0.101**	**0.229***	**0.603****	**0.872****	1.000				
	P	**0.243****	**0.061**	**0.216***	**0.563****	**0.762****	1.000				
CL	G	**-0.402****	**-0.016**	**0.326****	**0.125**	**0.066**	**0.065**	1.000			
	P	**-0.361****	**-0.006**	**0.279****	**0.110**	**0.058**	**0.058**	1.000			
NS/C	G	**0.346****	**-0.108**	**0.078**	**0.259****	**0.122**	**0.111**	**-0.099**	1.000		
	P	**0.292****	**-0.078**	**0.106**	**0.202***	**0.098**	**0.100**	**-0.087**	1.000		

TSW	G	**-0.484****	**-0.320****	**0.352****	**-0.070**	**-0.071**	**-0.097**	**0.671****	**-0.266****	1.000	
	P	**-0.430****	**-0.332****	**0.270****	**-0.057**	**-0.064**	**-0.094**	**0.612****	**-0.235****	1.00ZZ0	
OIL(%)	G	**-0.307****	**-0.353****	**0.226***	**-0.459****	**-0.222***	**-0.152**	**0.053**	**0.035**	**0.285****	1.000
	P	**-0.295****	**-0.332****	**0.204***	**-0.410****	**-0.196***	**-0.144**	**0.048**	**0.032**	**0.266****	1.000

DTF: Days to 50 (%) flowering, DTM: Days to maturity, PH: Plant height (cm), NPB/PL: No. of primary branches/plant, NSB/PL: Number of secondary branches/plant, NC/PL: Number of capsules/plant, CL: Capsule length (cm), NS/C: Number of seeds/capsule, TSW: 1000 seed weight (g), Oil(%): Oil content (%).

■ **Significant positive correlation** ■ **Significant negative correlation**
■ **Positive correlation** ■ **Negative correlation**

Table 3: Path Analysis using genotypic correlations [Direct (Bold) and indirect effects] of different characters

	DTF	DTM	PH	NPB/P	NSB/P	NC/P	CL	NS/C	TSW	Oil (%)
DTF	**0.254**	**0.107**	**-0.061**	**0.115**	0.058	0.062	**-0.102**	**0.087**	**-0.123**	**-0.307****
DTM	**-0.146**	**-0.345**	**-0.032**	**-0.032**	-0.024	-0.034	0.005	0.037	0.110	**-0.353****
PH	-0.043	0.016	**0.180**	**0.007**	**0.042**	0.041	**0.058**	0.014	**0.063**	0.226*
NPB/PL	**-0.372**	-0.075	-0.034	**-0.818**	**-0.622**	**-0.493**	-0.102	-0.211	0.057	-0.459**
NSB/PL	**0.075**	0.023	**0.077**	**0.248**	**0.326**	**0.284**	0.021	0.039	-0.023	-0.222*
NC/PL	-0.003	-0.001	-0.002	-0.005	-0.007	**-0.009**	-0.0005	-0.001	0.0009	-0.152
CL	**-0.021**	-0.001	0.017	0.006	0.003	0.003	**0.051**	-0.005	**0.034**	0.053
NS/C	**0.044**	**-0.014**	0.009	**0.033**	0.015	0.014	-0.012	**0.127**	**-0.033**	0.035
TSW	-0.096	-0.064	**0.069**	-0.014	-0.014	-0.019	**0.132**	-0.053	**0.198**	0.285**

The diagonal values in bold figures represent the direct effect The Residual are 0.54728

DTF: Days to 50 (%) flowering, DTM: Days to maturity, PH: Plant height (cm), NPB/PL: No. of primary branches/plant, NSB/PL: Number of secondary branches/plant, NC/P: Number of capsules/plant, CL: Capsule length(cm), NS/C: Number of seeds/capsule, TSW: 1000 seed weight (g), Oil(%): Oil content (%).

■ **Positive Direct effect** ■ **Negative Direct effect**
■ **Positive effect** ■ **Negative effect**

Conclusion

The study demonstrated the presence of significant variability among genotypes, indicating ample scope for selection and genetic improvement. Correlation analysis indicated that plant height and 1000 seed weight exhibited positive and significant association with oil content at both genotypic and phenotypic levels, suggesting that improvement in these traits would lead to enhanced oil yield. Capsule length and number of seeds per capsule also showed positive association, though with relatively lower magnitude. Path coefficient analysis results revealed that number of secondary branches per plant exerted the highest positive direct effect on oil content, followed by days to 50% flowering, 1000 seed weight, and plant height. These traits were identified as key contributors to oil yield and can be effectively utilized as selection criteria. Traits such as capsule length and number of seeds per capsule also contributed positively, though to a lesser extent, while some traits showed negative direct effects, suggesting their limited role in direct selection. Overall, the combined analysis indicates that selection based on number of secondary branches per plant, 1000 seed weight, and plant height would be most effective for enhancing oil yield. These findings provide a reliable basis for developing high-yielding linseed genotypes through targeted breeding strategies.

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