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# Trait Interactions and Yield Enhancement in Linseed (*Linum usitatissimum* L.): Insights from Correlation and Path Analysis

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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.) is a self-pollinated (2n = 30) annual Rabi season crop mainly cultivated for flax fiber and oil due to its commercial use. The present investigation was carried out to study an association analysis among the yield and yield attributes using 75 linseed genotypes including 10 checks in a randomized block design with three replications at Oilseeds Research Farm, Kalyanpur, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, (India) during Rabi season of 2019-20. The correlation analysis revealed that the traits number of secondary branches per plant followed the number of primary branches per plant and

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number of capsules per plant at both the genotypic and phenotypic levels. The results of the path coefficient analysis revealed that traits such as the number of secondary branches per plant, number of capsules per plant, number of seeds per capsule, and plant height exhibited a strong and positive direct effect on seed yield per plant at both the genotypic and phenotypic levels. The seed yield can be improved by selecting traits such as number of primary branches per plant, number of secondary branches, number of capsules per plant, and plant height. It is recommended that the breeder focus on these traits in linseed to enhance its commercial value for the farming community.

*Keywords: Linseed; seed yield; correlation; path analysis.*

## 1. INTRODUCTION

Linseed (*Linum usitatissimum* L.) is an annual, self-pollinated oilseed crop (Yadava *et al*., 2012) primarily cultivated during the rabi season. Belonging to the genus "Linum" in the family Linaceae. It originated in Southwest Asia, particularly in India (Richharia, 1952). It is grown both as an oilseed and a fibre crop, with flax fibre derived from a taller plant variant with greater straw length (Pavelek *et al*., 2020). The oil content of linseed is varied from 36 - 48 % (Patel *et al*., 2023). In India, it is mainly cultivated in the states of Chattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, and Odisha. The area, production, and productivity of linseed in India is 2.39 lakh hectares, 1.67 lakh tones and 698 kg/hectares (Indiastat 2023) respectively. The main reason for the low productivity of linseed in input-starved conditions, marginal and sub-marginal lands which are risk-prone and have poor fertility status. Over 63% of the area under linseed cultivation relies on rain-fed conditions, with farmers often using traditional sowing methods, such as relay (utera) cropping (Srivastava, 2009). Limited awareness and dissemination of advanced agricultural techniques, coupled with a persistent lack of essential inputs like improved seed varieties, irrigation, fertilizers, and weed control measures, further constrain productivity in this sector (Chandrawati et al., 2016). The present status of linseed production could be increased 2-3fold through the adoption of improved varieties coupled with recommended production and protection technologies. The idea of the factors which are responsible for higher yield is a complicated problem. Because yield is a very complex character and an interactive effect/ multiplication of different traits and is highly influenced by environmental factors. Therefore, to achieve a high yield level, the breeder requires simplifying this complex situation by handling yield components with a negative association. To achieve this rational approach, it is vital to obtain information on the nature and extent of the correlation between different yield components and to resolve quality/quantity and how they contribute to yield. The current research was carried out to study the association analysis between yield and yield attributes.

## 2. MATERIALS AND METHODS

The experiment was conducted to estimate the association of traits for seed yield per plant using 75 linseed (*Linum usitatissimum* L.) genotypes including 10 checks in Randomized Block Design with three replications at Oilseeds Research Farm, Kalyanpur, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, (India) during Rabi season 2019-20. Sowing was done in a 2-row plot of 5-meter length. The spacing is 30 cm × 7 cm distance was maintained by proper thinning. A healthy and good crop is raised by the proper recommended package of agronomic practices. Equally competitive five plants were tagged for recording the observations on traits viz., days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, plant height, number of capsules per plant, number of seeds per capsule, days to maturity, oil content, thousand seed weight and seed yield per plant. The oil content was estimated by weight of 50 g seeds taken after threshing and drying on a Nuclear Magnetic Resonance (NMR) technique. Both the genotypic correlation coefficient and phenotypic correlation coefficient were estimated from the formula given by Al-Jibouri *et al*. (1958). The path analysis was performed by a process as described by (Dewey and Lu, 1959).

## 3. RESULTS AND DISCUSSION

### 3.1 Correlation Analysis

The observed genotypic values of the correlation coefficient were higher than the phenotypic correlation coefficient value of most of the characters, which significantly impacts seed yield (Table 1). Indirect selection is effective under the traits, which is low heritability (Singh *et al*., 2024). This correlation studies guides the breeder to select the traits which is responsible for yield and quality improvement in linseed. Seed yield per plant was high and significantly correlated with the number of secondary branches per plant (G = 0.567), number of primary branches per plant (G = 0.498) and number of capsules per plant (G = 0.438) at the genotypic level. At the phenotypic level, seed yield per plant showed positive and significant association with the number of secondary branches per plant (P = 0.544), number of capsules per plant (P = 0.4356) and number of primary branches per plant (P = 0.426). Similar type results were reported by (Tariq *et al*., 2014; Patel *et al*., 2023), for capsules per plant and primary branches per plant; (Singh *et al*., 2024; Jain *et al*., 2011) for primary branches per plant, secondary branches per plant and capsules per plant. The results revealed that the seed yield per plant was positively correlated with thousand seed weight (G = 0.0934, P = 0.0897), number of seeds per capsule (G = 0.0584, P = 0.0494), days to 50 per cent flowering (G = 0.0318, P = 0.0315) and oil content (G = 0.0282, P = 0.0288). These results agree with those of (Muhammad Akbar *et al*. 2001; Ibrar *et al*. 2016). The interrelationship were positive and significant among yield attributes like days to 50 per cent flowering with days to maturity (G = 0.638, P = 0.616), plant height (G = 0.252, P = 0.247), number of capsules per plant (G = 0.158, P = 0.155) and number of primary branches per plant (G = 0.156, P = 0.141), number of primary branches with number of secondary branches per plant (G = 0.798, P = 0.709), number of capsules per plant (G = 0.457, P = 0.383) and days to maturity ( G = 0.182, P = 0.1567), number of secondary branches per plant with number of capsules per plant (G = 0.550, P = 0.531), plant height with days to maturity (G = 0.264, P = 0.257), oil content (G = 0.178, P = 0.176) and thousand seed weight (G = 0.131, P = 0.129), oil content with test weight (G = 0.511, P = 0.5023) at both the genotypic and phenotypic levels, except for traits viz., number of primary branches with days to 50 per cent flowering and plant height with thousand seed weight which is at genotypic level only. These type results are in agreement with Paul *et al*. (2020), Kumar and Paul (2016), Kasana *et al*. (2018), Chaudhary *et al*. (2016), Sharma *et al*. (2016) and Ankit *et al*. (2019). The interrelationships were negative and significant among the yield-contributing traits like days to 50 per cent flowering with oil content (G = -0.343, P = -0.336) and thousand seed weight (G = -0.202, P = -0.198), plant height with number of capsules per plant (G = -0.296, P = -0.293), number of capsules per plant with oil content (G = -0.278, P = -0.275) at both the genotypic and phenotypic levels (Patial *et al*., 2018). The number of seeds per capsule was negative and significant at genotypic and negative at phenotypic level correlated with days to maturity (G = -0.261, P = -0.192), number of primary branches (G = -0.233, P = -0.129), oil content (G = -0.199, P = -0.1622), number of secondary branches per plant (G = -0.177, P = -0.133) and thousand seed weight (G = -0.1578, P = -0.128). Such results were matched with (Patel *et al*., 2023).

### 3.2 Path Analysis

The direct effect of phenotypic path coefficient value is higher for most of the characters compared to genotypic path coefficient value, it indicates that there is a significant genotype × environment interaction for traits expressed. The findings of path analysis (presented in Table 2 and Figs. 1 &2) revealed that the number of secondary branches per plant (G = 0.3344, P = 3556), number of capsules per plant (G = 0.2014, P = 0.2535), number of primary branches (G = 0.1928, P = 0.1004) and number of seeds per capsule (G = 0.1772, P = 0.1075) and plant height (G = 0.0998, P = 0.1045) exhibited positive and direct effect on seed yield per plant at both genotypic and phenotypic levels. Plant height (P = 0.1045) showed positive direct effect on seed yield per plant at phenotypic level. These results are matched with Ronika *et al*. (2020), Ibrar *et al*. (2016), Naik and Setapathy (2002) and Rahimi *et al*. (2011), Gaurah and Rao (2011) and Yadav (2001) for the number of primary branches per plant, capsules per plant and seeds per capsule. The number of secondary branches per plant showed a positive indirect effect on seed yield per plant through the number of primary branches per plant (G = 0.2669, P = 0.2552) and number of capsules per plant (G = 0.1840, P = 0.1887) at both genotypic and phenotypic levels. Similar results were reported by Gudmewad *et al*. (2016). On the other hand, the number of primary branches per plant (G = 0.1539, P = 0.0712) and number of capsules per plant (G = 0.1108, P = 0.1345) exhibited indirect effect on seed yield per plant via number of secondary branches per plant at both the genotypic and phenotypic levels (Gudmewad *et al*.,2016; Ghiday *et al*. (2023). The remaining characters exerted negligible direct and indirect contributions towards the seed yield per plant (Goyalet al., 2014).

**Table 1. Estimates of genotypic (G) and phenotypic (P) correlation among different traits in Linseed**

| Sr No. | Characters | | D50F | NPBPP | NSBPP | PH (cm) | NCPP | NSPC | DM | OC (%) | SW (g) | SYPP (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.** | **D50F** | $r_g$ | **1.000** | 0.156* | 0.034 | 0.252** | 0.158* | 0.091 | 0.638** | -0.343** | -0.202** | 0.0318 |
| | | $r_p$ | **1.000** | 0.141 | 0.038 | 0.247** | 0.155* | 0.071 | 0.616** | -0.336** | -0.198** | 0.0315 |
| **2.** | **NPBPP** | $r_g$ | | **1.000** | 0.798** | -0.031 | 0.457** | -0.233** | 0.182** | 0.022 | -0.034 | 0.498** |
| | | $r_p$ | | **1.000** | 0.709** | -0.031 | 0.383** | -0.129 | 0.1567* | 0.0178 | -0.0281 | 0.426** |
| **3.** | **NSBPP** | $r_g$ | | | **1.000** | -0.045 | 0.550** | -0.177** | 0.053 | -0.001 | 0.079 | 0.567** |
| | | $r_p$ | | | **1.000** | -0.045 | 0.531** | -0.133 | 0.047 | -0.001 | 0.070 | 0.544** |
| **4.** | **PH (cm)** | $r_g$ | | | | **1.000** | -0.296** | -0.085 | 0.264** | 0.178** | 0.131* | 0.008 |
| | | $r_p$ | | | | **1.000** | -0.293** | -0.062 | 0.257** | 0.176** | 0.129 | 0.011 |
| **5.** | **NCPP** | $r_g$ | | | | | **1.000** | 0.1167 | 0.0268 | -0.278** | -0.068 | 0.438** |
| | | $r_p$ | | | | | **1.000** | 0.096 | 0.0267 | -0.275** | -0.066 | 0.4356** |
| **6.** | **NSPC** | $r_g$ | | | | | | **1.000** | -0.261** | -0.199** | -0.1578* | 0.0584 |
| | | $r_p$ | | | | | | **1.000** | -0.192 | -0.1622 | -0.128 | 0.0494 |
| **7.** | **DM** | $r_g$ | | | | | | | **1.000** | -0.1156 | -0.028 | 0.0068 |
| | | $r_p$ | | | | | | | **1.000** | -0.1106 | -0.0252 | 0.0057 |
| **8.** | **OC (%)** | $r_g$ | | | | | | | | **1.000** | 0.511** | 0.0282 |
| | | $r_p$ | | | | | | | | **1.000** | 0.5023** | 0.0288 |
| **9.** | **SW (g)** | $r_g$ | | | | | | | | | **1.000** | 0.0934 |
| | | $r_p$ | | | | | | | | | **1.000** | 0.0897 |
| **10.** | **SYP (g)** | $r_g$ | | | | | | | | | | **1.0000** |
| | | $r_p$ | | | | | | | | | | **1.0000** |

***Indicates significant at 5% level, ** indicates significance at 1% level**

*D50F: Days to 50 % flowering; NPBPP: Number of primary branches per plant; NSBPP: Number of secondary branches per plant; PH: Plant height; NCPP: Number of capsules per plant; NSPC: Number of seeds per capsule; DM: Days to maturity; OC: Oil content; SW: Thousand seed weight; SYP: Seed yield per plant*

**Table 2. Estimates of direct and indirect effects for various traits studied towards seed yield per plant at genotypic (G) and phenotypic (P) levels in linseed**

| Sr No. | Characters | | D50F | NPBPP | NSBPP | PH (cm) | NCPP | NSPC | DM | OC (%) | SW (g) | SYPP (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | D50F | G | **-0.0665** | -0.0106 | -0.0022 | -0.0168 | -0.0105 | -0.0060 | -0.0425 | 0.0228 | 0.0134 | 0.0318 |
| | | P | **-0.0319** | -0.0045 | -0.0012 | -0.0079 | -0.0049 | -0.0023 | -0.0197 | 0.0107 | 0.0063 | 0.0315 |
| 2. | NPBPP | G | 0.0308 | **0.1928** | 0.1539 | -0.0060 | 0.0882 | -0.0449 | 0.0351 | 0.0042 | -0.0066 | 0.4987** |
| | | P | 0.0141 | **0.1004** | 0.0712 | -0.0031 | 0.0385 | -0.0130 | 0.0157 | 0.0018 | -0.0028 | 0.4259** |
| 3. | NSBPP | G | 0.0113 | 0.2669 | **0.3344** | -0.0150 | 0.1840 | -0.0591 | 0.0175 | -0.0003 | 0.0266 | 0.5673** |
| | | P | 0.0137 | 0.2522 | **0.3556** | -0.0161 | 0.1887 | -0.0473 | 0.0167 | -0.0001 | 0.0249 | 0.5439** |
| 4. | PH (cm) | G | 0.0252 | -0.0031 | -0.0045 | **0.0998** | -0.0295 | -0.0084 | 0.0263 | 0.0178 | 0.0131 | 0.0086 |
| | | P | 0.0259 | -0.0032 | -0.0047 | **0.1045** | -0.0306 | -0.0065 | 0.0269 | 0.0185 | 0.0136 | 0.0102 |
| 5. | NCPP | G | 0.0318 | 0.0921 | 0.1108 | -0.0596 | **0.2014** | 0.0235 | 0.0054 | -0.0560 | -0.0138 | 0.4382** |
| | | P | 0.0392 | 0.0972 | 0.1345 | -0.0742 | **0.2535** | 0.0244 | 0.0068 | -0.0697 | -0.0168 | 0.4356** |
| 6. | NSPC | G | 0.0160 | -0.0412 | -0.0313 | -0.0150 | 0.02207 | **0.1772** | -0.0462 | -0.0354 | -0.0280 | 0.0584 |
| | | P | 0.0077 | -0.0139 | -0.0143 | -0.0067 | 0.0103 | **0.1075** | -0.0206 | -0.0174 | -0.0138 | 0.0494 |
| 7. | DM | G | 0.0115 | 0.0033 | 0.0009 | 0.0047 | 0.0005 | -0.0047 | **0.0179** | -0.0021 | -0.0005 | 0.0068 |
| | | P | -0.0076 | -0.0019 | -0.0006 | -0.0032 | -0.0003 | 0.0024 | **-0.0124** | 0.0014 | 0.0003 | 0.0057 |
| 8. | OC (%) | G | -0.0146 | 0.0009 | 0.0000 | 0.0076 | -0.0119 | -0.0085 | -0.0049 | **0.0427** | 0.018 | 0.0282 |
| | | P | -0.0200 | 0.0011 | 0.0000 | 0.0105 | -0.0164 | -0.0097 | -0.0066 | **0.0595** | 0.0299 | 0.0288 |
| 9. | SW (g) | G | -0.0136 | -0.0023 | 0.0054 | 0.0088 | -0.0046 | -0.0106 | -0.0019 | 0.0344 | **0.0674** | 0.0934 |
| | | P | -0.0095 | -0.0014 | 0.0034 | 0.0062 | -0.0032 | -0.0062 | -0.0012 | 0.0299 | **0.0482** | 0.0897 |

*Residual (G): 0.7805, Residual (P): 0.8013*
*Dark figure denotes direct effect*

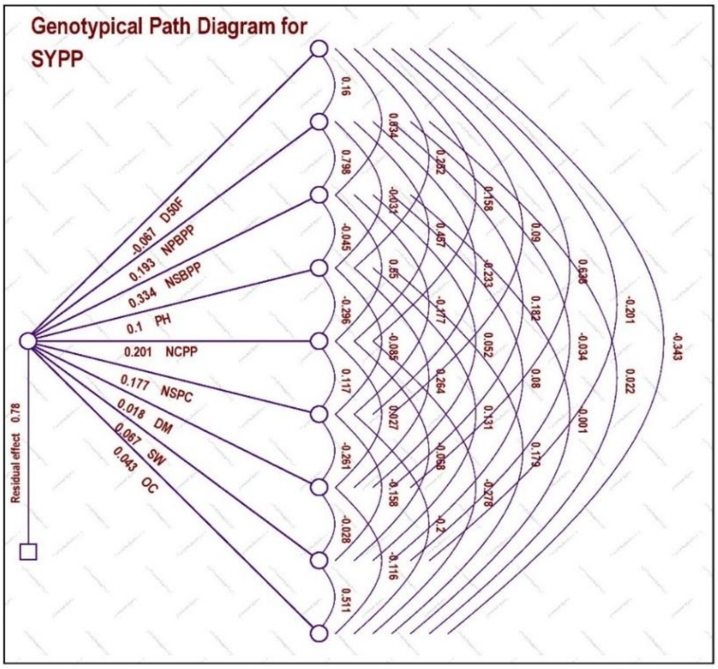


**Fig. 1. Direct and indirect effects of yield components on seed yield per plant at the genotypic level**

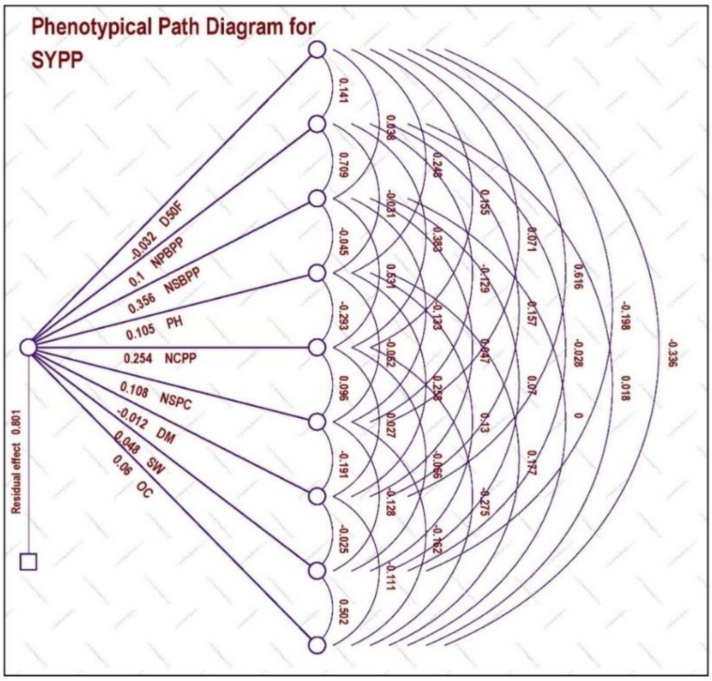


**Fig. 2. Direct and indirect effects of yield components on seed yield per plant at the phenotypic level**

## 4. CONCLUSION

The current research concluded that the number of secondary branches, number of primary branches per plant, and number of capsules per plant demonstrated positive and significant associations with seed yield per plant at both genotypic and phenotypic levels. The results of the path coefficient analysis revealed that traits such as the number of secondary branches per plant, number of capsules per plant, number of seeds per capsule, and plant height exhibited a strong and positive direct effect on seed yield per plant at both the genotypic and phenotypic levels. The secondary branches per plant showed positive and indirect effect on seed yield per plant via number of primary branches per plant and number of capsules per plant. Accordingly, the seed yield can be improved by selecting the traits viz., number of primary branches per plant, number of secondary branches, number of capsules per plant, and plant height. Prioritizing these attributes can enhance yield potential, making linseed cultivation more profitable and suitable for widespread adoption within the farming community.

## 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 the writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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