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Effect of nitrogen and phosphorus on growth and yield of linseed (*Linum usitatissimum* L.)

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Abstract

A field experiment was carried out during *Rabi* season of 2024-2025, at Crop Research Farm, Department of Agronomy at Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) on sandy loam soil with neutral soil reaction to investigate the "Effect of Nitrogen and Phosphorus on Growth and Yield of Linseed (*Linum usitatissimum* L.)". The experiment was laid out in randomized block design (RBD) which consisted of nine treatments and replicated twenty-seven. There were two factors taken into consideration i.e. Nitrogen (40, 50, 60) and Phosphorus (20, 30, 40). Application of 60 kg/ha Nitrogen + 40 kg/ha Phosphorus (Treatment 9) recorded significantly higher plant height (93.20 cm), higher plant dry weight (11.56 g/plant), maximum number of capsules/plant (46.00), maximum number of seeds/capsule (8.73), higher seed yield (1.23 t/ha), and higher stover yield (2.61 t/ha), maximum gross return (INR 68076/ha), maximum net return (INR 44895/ha) and benefit-cost ratio (1.96).

Keywords: Linseed, growth parameters, nitrogen, phosphorus, yield attributes and economics.

Introduction

Linseed (*Linum usitassimum* L.), commonly referred to as flax, is a member of the Linaceae family and belongs to the genus Linum. In India, linseed is also known as jawas and is recognized as a significant oilseed crop. This plant has been cultivated since ancient times for its fiber and seeds, which are rich in oil. It is exclusively a Rabi crop, cultivated during the winter season. The ideal climatic conditions for its growth are characterized by a temperate and cool climate. The temperature range for optimal growth is between 10 degrees Celsius and 38 degrees Celsius. Consequently, the primary growth season for linseed occurs from October to November, depending on soil moisture levels. Early planting allows the crop to evade the threats posed by rust, linseed bud fly, and powdery mildew in various regions. Depending on the specific cultivar, the crop typically matures in approximately 120 to 140 days. Drought conditions and elevated temperatures during the early growth and seed-filling stages can adversely affect both production and quality. Flax seeds are composed of 23% omega-3 fatty acids (18:3), predominantly ALA, and 6% omega-6 fatty acids (18:2). One of the key components of flax is lignin, which contains plant estrogen and antioxidants, with flax having up to 800 times more lignans than other plant foods. Linseed, often referred to as flax, is a valuable crop with numerous applications. Its oil is utilized in the production of paints, varnishes, oil cloth, and linoleum. If the oil has a high linolenic acid content but a low oleic acid content, it is classified as an oil with a high oleic acid content. Conversely, its fiber has been highly sought after for thousands of years in the textile and coarse twine industries. In India, linseed is cultivated on 5.25 lakh hectares, yielding a total production of 2.12 lakh tonnes and an average productivity of 403 kg/ha (Singh *et al.*, 2022) [15-16].

India is acknowledged as the second largest country for linseed cultivation globally, covering roughly 21% of the world's linseed area, second only to Canada (Srivastava, 2009) [17]. However, in terms of production volume, India ranks lower approximately 4th in global output with about an 8% share, following Canada (~40%), China (~19%), and the USA (~11%) which underscores the disparity between cultivated area and yield efficiency (Srivastava, 2009) [17].

Nitrogen serves as a fundamental element in both chlorophyll and protein; consequently, a sufficient supply of nitrogen is advantageous for the metabolism of carbohydrates and proteins. An excess or imbalance of this nutrient, particularly in relation to others such as phosphorus, may extend the growing period and hinder crop maturity. An overabundance of nitrogen can also lead to a poorly developed root system and a low root-to-shoot ratio. Conversely, an adequate nitrogen supply is linked to robust vegetative growth and a deep green color. It facilitates cell division and enlargement, resulting in an increased leaf area, thereby ensuring improved growth, development, plant vigor, and yield (Sameer *et al.*, 2021) [11].

Phosphorus is crucial for the growth and physiological functions of linseed *(Linum usitatissimum* L.). It plays an important role in fostering early and robust root development, which improves the efficiency of nutrient and water absorption (Singh *et al.*, 2021) [13]. As a fundamental element of ATP and ADP, phosphorus governs the energy transfer necessary for metabolic processes, photosynthesis, and seed development (Nadeem *et al.*, 2022) [7]. Additionally, it is involved in photosynthetic phosphorylation and carbohydrate metabolism, thus ensuring effective transport of assimilates for capsule filling and increased seed weight (Rani *et al.*, 2017) [10]. Furthermore, as a component of DNA, RNA, and phospholipids, phosphorus aids in cell division, tissue differentiation, and overall plant growth (Sharma *et al.*, 2016) [12]. Sufficient phosphorus nutrition not only hastens flowering and capsule development but also enhances seed yield, oil content, and quality in linseed (Nadeem *et al.*, 2022) [7].

Materials and Methods

The experiment was conducted during the *Rabi* season 2024, at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.) which is located at 25^0 30' 42''N latitude, 81^0 60' 56" E longitude and 98 m altitude above the mean sea level (MSL). This area is situated on the right side of the *Yamuna* River by the side of Prayagraj-Rewa Road about 12 km from the city. The experiment was conducted in Randomized Block Design with 9 treatments each replicated thrice. The plot size of each treatment was 3m x 3m. The factors are Nitrogen (40 kg/ha, 50 kg/ha, 60 kg/ha) and Phosphorus (20 kg/ha, 30 kg/ha, 40 kg/ha). Linseed variety Neelam was selected for sowing. Seeds were sown in line manually. Seeds were covered with the soil immediately after sowing. The Linseed crop was sown on 7 Nov. 2024. Harvesting was done by taking $1m^2$ area from each plot. And from it, five plants were randomly selected for recording growth and yield parameters. The observations were recorded for Plant height, Dry weight, Crop growth rate, Number of capsules/plants, Number of seeds/capsule, Test weight, Seed yield and Stover yield. The data was subjected to statistical analysis by analysis of variance method.

Result and Discussion

Growth and Yield attributes

1. Plant height (cm)

The findings indicated that Treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha) achieved the highest plant height of 93.20 cm. Additionally, Treatment 8 (60 kg N/ha + 30 kg P_2O_5/ha) was statistically comparable to Treatment 9. This can be attributed to the synergistic interaction of nitrogen, which promotes vegetative growth, and phosphorus, which enhances root development, thus improving nutrient absorption and photosynthetic efficiency. This suggests that applying phosphorus at 30-40 kg/ha in conjunction with 60 kg N/ha is adequate to achieve the optimal height in linseed. Comparable results were documented by Singh *et al.* (2022) [15-16] and Patil *et al.* (2018) [9], who noted significant increases in linseed plant height due to balanced nitrogen and phosphorus fertilization.

2. Number of capsules/plant

The highest number of capsules per plant (46.00) was observed in Treatment 9 (60 kg N/ha + 40 kg P2O5/ha). Nevertheless, Treatment 8 was statistically comparable to Treatment 9. The enhancement in yield characteristics under these treatments can be ascribed to improved assimilate distribution towards reproductive structures, facilitated by sufficient nutrient availability. Comparable findings were documented by Yadav *et al.* (2015) [19] and Patel *et al.* (2018) [8], who noted that balanced applications of N and P promote capsule development in linseed.

3. Number of seeds/capsule

Significantly higher seeds per capsule (8.73) were recorded in Treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha), though Treatment 8 remained at par. This indicates that both phosphorus levels (30 and 40 kg/ha) combined with 60 kg N/ha are effective in optimizing seed setting. The rise in seeds per capsule could be attributed to enhanced physiological efficiency and improved nourishment of the reproductive organs. These results align with the findings of Kushwaha *et al.* (2006) [4] and Choudhary *et al.* (2016) [1], who documented an increase in seeds per capsule in linseed with elevated nitrogen and phosphorus applications.

4. Dry weight of plant (g)

The highest dry matter accumulation per plant (11.56 g) was obtained under Treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha), where Treatment 8 was found to be statistically at par with Treatment 9. This might be due to better vegetative growth and enhanced photosynthetic efficiency under optimum nutrient supply. Nitrogen facilitates cell division and elongation, whereas phosphorus enhances energy transfer and metabolic processes, leading to increased biomass accumulation. These findings align with the research conducted by Meena *et al.* (2011) [5] and Sune *et al.* (2006) [18], who highlighted that the combined application of nitrogen and phosphorus markedly boosts dry matter production in linseed.

5. Crop growth rate (g/m^2/day)

The results showed that during 80-100 DAS (Days After Sowing) Significant higher crop growth rate (3.33 g/m^2/day) was recorded in treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha). The data were found to be Significant among the treatments. The increased Crop Growth Rate (CGR) can be attributed to improved canopy development, enhanced photosynthetic efficiency, and a higher accumulation of assimilates when optimal nitrogen and phosphorus nutrition is provided. This aligns with the research conducted by Meena *et al.* (2017) [6] and Jat *et al.* (2020) [2], which indicated that sufficient nutrient availability promotes dry matter accumulation, consequently enhancing CGR in linseed.

6. Relative growth rate (g/g/day)

The results showed 80-100 DAS (Days After Sowing) Non significant higher relative growth rate (0.0097 g/g/day) was recorded in treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha) however, the difference was non-significant. This indicates that although the application of nutrients improved overall growth, the relative increase per unit of biomass remained consistent across the various treatments. Kumar *et al.* (2016) [3] and Singh and Verma (2019) [14] have documented comparable patterns, wherein the differences in relative growth rate were minimal despite notable variations in total growth.

9. Test weight (g)

The application of Non-Significant higher Test weight (8.73 g) was recorded in treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha) and though there was non-significance difference among the treatments.

10. Seed yield (t/ha)

Treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha) recorded the highest seed yield (1.23 t/ha), significantly surpassing all other treatments. The enhanced seed yield observed in treatment 9 can be linked to increased plant height, crop growth rate (CGR), dry matter accumulation, the number of capsules per plant, and the number of seeds per capsule. These results align with the findings of Meena *et al.* (2017) [6] and Patel *et al.* (2018) [8], who noted a significant improvement in seed yield of linseed due to the application of balanced nitrogen and phosphorus fertilization.

11. Stover yield (t/ha)

Stover yield was also significantly higher (2.61 t/ha) under treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha), reflecting the combined effect of improved vegetative growth and biomass accumulation. An increased yield of stover under optimal nutrient availability signifies effective vegetative development that enhances reproductive success. Comparable patterns were noted by Jat *et al.* (2020) [2] and Yadav *et al.* (2015) [19].

Harvest index (%)

The harvest index was higher in treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha), though the difference was non-significant. This suggests that the ratio of economic yield (seed) to total biomass experienced a slight enhancement with optimal nitrogen and phosphorus application; however, the proportional allocation remained fairly consistent across the various treatments. Kumar *et al.* (2016) [3] and Singh and Verma (2019) [14] noted comparable non-significant increases in harvest index under improved fertilization.

Cost of cultivation (INR/ha)

The maximum cost of cultivation (23181.00 INR/ha) was recorded in treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha).

Gross returns (INR/ha)

The maximum gross return (68076.00 INR/ha) was recorded in treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha).

Net returns (INR/ha)

The maximum net return (44895.00 INR/ha) was recorded in treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha).

Benefit Cost Ratio (B:C)

The highest B:C ratio was recorded in Treatment 9 (60 kg N/ha + 40 kg P_2O_5/ha), indicating superior economic returns compared to other treatments. This indicates that the joint application of 60 kg N/ha and 40 kg P_2O_5/ha not only improves growth and yield metrics but also optimizes profitability for linseed farming. Comparable findings were documented by Patel *et al.* (2018) [8] and Meena *et al.* (2017) [6].

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Table 1: Effect of Nitrogen and Phosphorus on Growth on Linseed (*Linum usitatissimum*)

Sr. No	Treatments	100 DAS, 80-100 DAS			
		Plant height (cm)	Plant dry Weight(g)	CGR (g/m/day)	RGR (g/g/day)
1	Nitrogen 40 kh/ha + Phosphorus 20 kg/ha	81.90	8.82	1.83	0.0067
2	Nitrogen 40 kg/ha + Phosphorus 30 kg/ha	82.04	9.02	1.94	0.0070
3	Nitrogen 40 kg/ha + Phosphorus 40 kg/ha	86.94	10.29	2.20	0.0067
4	Nitrogen 50 kg/ha + Phosphorus 20 kg/ha	82.76	9.30	2.20	0.0077
5	Nitrogen 50 kg/ha + Phosphorus 30 kg/ha	84.11	9.22	2.16	0.0077
6	Nitrogen 50 kg/ha + Phosphorus 40 kg/ha	88.65	10.54	2.17	0.0067
7	Nitrogen 60 kg/ha + Phosphorus 20 kg/ha	84.24	9.85	1.99	0.0067
8	Nitrogen 60 kg/ha + Phosphorus 30 kg/ha	91.89	11.08	2.55	0.0073
9	Nitrogen 60 kg/ha + Phosphorus 40 kg/ha	93.20	11.56	3.33	0.0097
	F-Test	S	S	S	NS
	S.Em (±)	3.077	0.301	0.279	0.001
	CD (P=0.05)	6.350	0.621	0.575	0.002

Table 2: Effect of Nitrogen and Phosphorus on yield attributes of Linseed (*Linum usitatissimum*)

Sr. No.	Treatments	Capsules per plant	Seeds per capsules	Test Weight (gm)	Seed yield t/ha	Stover yield t/ha	Harvest index (%)
1.	Nitrogen 40 kh/ha + Phosphorus 20 kg/ha	35.00	5.60	7.04	0.77	1.98	28.04
2.	Nitrogen 40 kg/ha + Phosphorus 30 kg/ha	38.33	6.67	7.56	0.82	2.28	26.45
3.	Nitrogen 40 kg/ha + Phosphorus 40 kg/ha	39.67	6.80	7.38	0.84	2.27	26.94
4.	Nitrogen 50 kg/ha + Phosphorus 20 kg/ha	40.00	6.87	7.36	0.86	2.24	27.63

5.	Nitrogen 50 kg/ha + Phosphorus 30 kg/ha	40.33	7.13	7.63	0.86	2.25	27.48
6.	Nitrogen 50 kg/ha + Phosphorus 40 kg/ha	41.67	7.00	7.48	0.75	2.15	25.79
7.	Nitrogen 60 kg/ha + Phosphorus 20 kg/ha	42.33	7.20	7.53	0.92	2.31	28.63
8.	Nitrogen 60 kg/ha + Phosphorus 30 kg/ha	43.00	8.07	7.79	0.98	2.39	29.06
9.	Nitrogen 60 kg/ha + Phosphorus 40 kg/ha	46.00	8.73	8.07	1.23	2.61	32.00
	F-test	S	S	S	S	S	NS
	S. Em. (±)	2.059	0.368	0.235	0.119	0.130	3.223
	C. D. (P=0.05)	4.249	0.760	0.486	0.246	0.268	6.652

Table 3: Effect of nitrogen and phosphorus on economics of linseed (*Linum usitatissimum*).

Treatment combinations	Cost of Cultivation	Gross return (ha-1)	Net Return (ha-1)	B:C ratio
1. Nitrogen 40 kg/ha + Phosphorus 20 kg /ha	22,581	43032	20,451	0.91
2. Nitrogen 40 kg/ha + Phosphorus 30 kg/ha	22,581	46032	23451	1.04
3. Nitrogen 40 kg/ha + Phosphorus 40 kg/ha	22,781	47076	24295	1.07
4. Nitrogen 50 kg/ha + Phosphorus 20 kg/ha	22,381	48096	25715	1.15
5. Nitrogen 50 kg /ha + Phosphorus 30 kg/ha	22,781	48108	25327	1.11
6. Nitrogen 50 kg/ha + Phosphorus 40 kg/ha	22,981	42180	19199	0.84
7. Nitrogen 60 kg/ha + Phosphorus 20 kg/ha	22,581	51348	28767	1.27
8. Nitrogen 60 kg/ha + Phosphorus 30 kg/ha	22,981	54612	31631	1.38
9. Nitrogen 60 kg/ha + Phosphorus 40 kg/ha	23,181	68076	44895	1.94

Conclusion
It is concluded that in linseed with the application of Nitrogen (60 kg/ha) along with Phosphorus (40 kg/ha) in Treatment 9 was observed higher yield and benefit cost ratio.

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