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Effect of soil NPK levels in conjunction with foliar NPK sprays on productivity and profitability of linseed (*Linum usitatissimum* L.) in Vertisols

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ABSTRACT

A field experiment was carried out during the rabi season of 2025–26 at the Instructional Farm, College of Agriculture, Ummedganj, Kota to assess the effects of soil NPK levels and foliar sprays of NPK on the growth, yield, quality and economics of linseed (cv. Kota Alsi-6) in Vertisols. The experiment comprised of four soil NPK levels (control, 50%, 75% and 100% RDF @ 90-30-30 kg NPK/ha) and three foliar sprays (water spray, NPK 19:19:19 @ 0.5%, and 1.0% at flowering and capsule development) tested in factorial RBD with three replications. Experimental findings revealed that 100% RDF recorded significant improvements in growth parameters viz. plant height, branches per plant, dry matter accumulation and crop growth rate over other soil NPK levels. The application of 100% RDF significantly improved yield attributes viz. capsules per plant, test weight, seed, straw and biological yields over lower soil NPK levels. Foliar spray of NPK @ 1.0% recorded the highest growth, yield attributes, seed yield and nutrient uptake. The interaction of 100% RDF + foliar NPK @ 1.0% recorded the maximum seed yield (1477.8 kg/ha), which was statistically at par with 75% RDF + foliar NPK @ 1.0%. Economic analysis indicated that highest net returns (₹ 84,972/ha) and B:C ratio (2.95) was registered under 100% RDF. Interaction effect of 75% RDF + foliar NPK @ 1.0% fetched the highest net returns (₹ 88,185/ha) and B:C ratio (3.05).

Keywords: Crop growth rate, Dry matter accumulation, Foliar NPK, Linseed, Soil NPK levels

Introduction

Linseed (*Linum usitatissimum* L.) is an important oilseed crop belonging to the family Linaceae and is valued for its oil, fibre and nutritional properties. In India, it ranks as the second most important rabi oilseed crop after rapeseed and mustard in terms of area and seed output (Alam *et al.*, 2024) [1]. India ranks fifth in area and sixth in production, covering about 3.2 lakh hectares with production of 1.74 lakh tonnes and productivity of 637.54 kg/ha (GOI, 2023) [2]. In Rajasthan, linseed is cultivated on 12.8 thousand hectares with production of 13.5 thousand tonnes and productivity of 1050 kg/ha (GoR, 2023) [3]. Linseed contains about 38–40% fat, 26–28% fibre and 20–21% protein and provides nutritional and health benefits (Joana *et al.*, 2019) [4].

Despite its importance, linseed productivity in India remains low compared with many other countries (Dash *et al.*, 2017) [5]. Inadequate and imbalanced fertilization, limited irrigation and poor crop management are major constraints to productivity. Overcoming these yield gaps necessitates improved agronomic management, primarily through timely planting, balanced fertilization, stage-critical irrigation and supplementary foliar nutrition. Balanced use of fertilizer is widely recognized as a key factor in boosting crop production. Among various agronomic practices, the balanced and efficient use of nutrients especially N, P and K is essential for enhancing linseed yield and quality (Singh *et al.*, 2013) [6]. Hence, suitable soil NPK levels need to be evaluated for efficient nutrient use and sustainable production.

Continual reliance on the conventional recommended dose of fertilizers has markedly inflated production costs while steadily exhausting soil health and destabilizing local ecosystems. Transitioning toward sustainable soil stewardship has shifted focus toward rationalizing basal nutrient doses through complementary foliar applications. This integrated regime boosts plant uptake, limits leaching losses and maintains crop productivity.

Foliar nutrition can supplement soil-applied fertilizers by supplying nutrients rapidly during critical growth stages (Reena *et al.*, 2018) [7] and improving their absorption and translocation to developing seeds (Manonmani *et al.*, 2009) [8]. NPK 19:19:19 containing 19% each of N, P and K can improve nutrient uptake and crop performance (Pasala *et al.*, 2022) [9]. Improvement in linseed growth and yield through foliar nutrition has been reported by Gurjar *et al.* (2017) [10], Shelke *et al.* (2024) [11] and Kumari *et al.* (2025) [12].

Materials and Methods

The field experiment was conducted during the *rabi* season of 2025–26 at the Instructional Farm, College of Agriculture, Ummedganj, Kota under Agriculture University, Kota. The soil was clay loam in texture, slightly alkaline in reaction (pH 7.7), medium in organic carbon (0.55%), low in available nitrogen (198.2 kg/ha), medium in available phosphorus (22.7 kg/ha), high in available potassium (365.2 kg/ha) and while the available zinc content was above critical level (0.62 mg/kg). The experiment was laid out in a Factorial Randomized Block Design (FRBD) with twelve treatment combinations and three replications. The treatments comprised four soil NPK levels *viz.*, control (F_1), 50% RDF (45-15-15 kg NPK/ha; F_2), 75% RDF (67.5-22.5-22.5 kg NPK/ha; F_3) and 100% RDF (90-30-30 kg NPK/ha; F_4), combined with three foliar sprays *viz.*, water spray (S_1), NPK 19:19:19 @ 0.5% (S_2) and NPK 19:19:19 @ 1.0% (S_3). Basal doses of phosphorus and potassium were applied through DAP and MOP, while half dose of nitrogen was applied through urea as basal and remaining half was top-dressed at 30 DAS. Foliar sprays of water-soluble NPK 19:19:19 were applied as 0.5% and 1.0% concentration using a spray volume of 500 l/ha at flower initiation (60–65 DAS) and capsule development stages (80–85 DAS).

Linseed variety Kota Alsi-6 (RL 13165) was sown on 13 November 2025, using a seed rate of 30 kg/ha with a row spacing of 30 cm. Standard cultural practices, including two manual hand weedings (30 and 45 DAS) and two irrigations (30 and 60–65 DAS) were followed. Growth parameters, yields and yield attributes were recorded. Economic analysis was conducted to calculate net returns and benefit-cost (B:C) ratios based on prevailing market rates. Statistical analysis was performed using ANOVA at a 5% significance level (Chandel *et al.*, 2012) [13].

Result and Discussion

Growth parameters

A critical analysis of the data (Table 1) shows that plant height and dry matter accumulation (DMA) increased progressively and significantly with each successive increase in soil NPK levels at all growth stages. Across 45 DAS, 90 DAS and at harvest, application of 100% RDF recorded the maximum plant height and DMA, proving significantly superior to 75% RDF, 50% RDF and the control.

At both 90 DAS and harvest, NPK 19:19:19 @ 1.0% recorded the maximum height and DMA, which was significantly superior to the water spray, however, NPK 19:19:19 @ 0.5% was statistically at par with it.

The results presented in Table 1 shows that maximum number of branches per plant at 45 DAS and 90 DAS (3.24 and 6.20, respectively) was recorded under 100% RDF, which remained statistically at par with 75% RDF but significantly superior to 50% RDF and control.

Foliar sprays of NPK exhibit a significant response on branches per plant at 90 DAS, the highest number of branches per plant (5.83) was obtained under spray of NPK 19:19:19 @ 1.0%, which remained statistically at par with NPK 19:19:19 @ 0.5%, whereas both these foliar NPK treatments were significantly superior to the water spray (5.47).

As evident from Table. 1, soil NPK levels significantly influenced crop growth rate (CGR) during both 45–90 DAS and 90 DAS–harvest period. Across both intervals, 100% RDF recorded the highest CGR, remaining statistically at par with 75% RDF and significantly superior to 50% RDF and the control.

Foliar application of NPK 19:19:19 @ 1.0% induced the most pronounced enhancement in CGR across both growth stages. NPK 19:19:19 @ 0.5% and 1.0% significantly enhanced CGR over the water spray during 45–90 DAS, however, NPK 19:19:19 @ 0.5% remained statistically at par with NPK 19:19:19 @ 1.0%. From 90 DAS to harvest, NPK 19:19:19 @ 1.0% maintained significant superiority over the water spray, while NPK 19:19:19 @ 0.5% was statistically comparable to NPK 19:19:19 @ 1.0%.

The significant improvement in growth parameters with higher soil NPK levels might be primarily due to adequate nutrient availability, which stimulated chlorophyll synthesis and meristematic activity. This enhanced photosynthetic rate promotes rapid cell division, internodal elongation and lateral bud emergence. Consequently, the expanded vegetative canopy facilitated greater photosynthate assimilation and translocation into biomass. These results are in conformity with the findings of Singh *et al.* (2013) [6], Kumar and Kumar (2015) [14], Devedee *et al.* (2019) [15], Gaikwad *et al.* (2020) [16].

The significant enhancement in growth parameters with foliar application of NPK 19:19:19 might be attributed to the rapid leaf absorption and ready availability of balanced nutrients at active metabolic sites. This balanced supply of N, P and K stimulated cell division, energy transfer and stomatal regulation, thereby boosting photosynthetic efficiency and dry matter accumulation. These results corroborate the findings reported by Gurjar *et al.* (2017) [10], Kikon *et al.* (2026) [17] in linseed and by Solanki *et al.* (2022) [18] in mustard.

Yield attributes

A perusal of data presented in Table 2 revealed that maximum number of capsules per plant was obtained under application of 100% RDF, however, 75% RDF remained statistically at par with it. Both these treatments were significantly superior over 50% RDF and control. The highest 1000-seed weight was attained under 100% RDF, which remained statistically at par with 75% RDF and 50% RDF.

Foliar application of NPK 19:19:19 @ 1.0% significantly enhanced number of capsules per plant over water spray and was statistically comparable with NPK 19:19:19 @ 0.5%.

Table 2 revealed that harvest index was significantly influenced by soil NPK levels. Highest harvest index was obtained with application of 75% RDF (34.84%) which was statistically comparable to 50% RDF (34.33%) and 100% RDF (33.88%).

Foliar application of NPK also significantly influenced the harvest index. Foliar application of NPK 19:19:19 at both 1.0% and 0.5% significantly improved the harvest index over the water spray, with the two concentrations exhibiting statistical parity.

The increment in yield attributes under higher soil NPK levels could be ascribed to adequate basal N, P and K availability, which sustained photosynthesis, minimized capsule shedding and ensured effective seed filling, thereby improving yield attributes. Similar findings have also been reported in linseed by Devedee *et al.* (2018) [19], Gaikwad *et al.* (2020) [16].

Foliar application of NPK 19:19:19 provided readily available nutrients directly to active foliage, reducing flower and capsule drop to significantly enhance the number of capsules per plant and harvest index over water spray. Comparable results have been documented earlier by Gurjar *et al.* (2017) [10], Kumar *et al.* (2023) [20].

Yield

The results presented in Table 2 reveal that a marked improvement in seed, straw and biological yields were brought about with successive increments in soil NPK level. The highest seed yield (1423.1 kg/ha) was obtained under 100% RDF, which was significantly superior over 75% RDF (1344.4 kg/ha), 50% RDF (1094.4 kg/ha) and the control (812 kg/ha). Likewise, 75% RDF recorded significantly higher seed yield than 50% RDF and control, while 50% RDF also outperformed the control significantly. The magnitude of increase in seed yield over the control was 34.78, 65.57 and 75.26 per cent under 50%, 75% and 100% RDF, respectively.

The crop exhibited a significant response to foliar application of NPK with respect to seed, straw and biological yields. Foliar spray of NPK 19:19:19 @ 1.0% resulted in significant enhancements in seed yield (1277.8 kg/ha), which was found significantly superior over NPK 19:19:19 @ 0.5% (1190.3 kg/ha) and water spray (1037.5 kg/ha). Foliar NPK 19:19:19 @ 0.5% recorded a significant increase in seed yield over control. Relative to the water spray, seed yield was improved to the extent of 14.72 and 23.16 per cent under NPK 19:19:19 @ 0.5% and 1.0%, respectively.

The maximum straw (2781.5 kg/ha) and biological yields (4204.6 kg/ha) were attained under 100% RDF, which proved significantly superior to 75% RDF (2511.6 and 3856.0 kg/ha), 50% RDF (2082.4 and 3176.8 kg/ha) and the control (1705.5 and 2517.6 kg/ha), with each soil NPK level differing significantly from one another. Similarly, foliar application of NPK 19:19:19 @ 1.0% conferred a significant advantage in straw yield (2419.4 kg/ha) and biological yield (3697.2 kg/ha), which was significantly superior to NPK @ 0.5% (2283.3 and 3473.6 kg/ha) and water spray (2108.0 and 3145.5 kg/ha). Foliar spray of NPK @ 0.5% also recorded significantly higher straw and biological yields than water spray.

A significant interaction was observed between soil NPK levels and foliar spray of NPK with respect to seed yield (Table 3). The findings indicated that the highest seed yield was obtained under application of 100% RDF + NPK 19:19:19 @ 1% (1477.8 kg/ha) which was statistically at par with 75% RDF + NPK 19:19:19 @ 1% (1463.9 kg/ha), 100% RDF + NPK 19:19:19 @ 0.5% (1413.9 kg/ha), 75% RDF + NPK 19:19:19 @ 0.5% (1397.2 kg/ha) and 100% RDF + water spray (1377.8 kg/ha). These treatment combinations recorded significantly higher seed yield than all other treatment combinations.

Maximum seed yield obtained under higher soil NPK levels may be attributed to the cumulative improvement in yield attributes, particularly capsules per plant and 1000-seed weight, together with enhanced crop growth under balanced nutrient supply. These findings are in close agreement with the observations of Devedee *et al.* (2018) [19], Shaik *et al.* (2021) [21], Badkul *et al.* (2022) [22], Durgeshwari *et al.* (2024) [23].

Direct nutrient assimilation through foliar spray of NPK sustained canopy photosynthesis at critical growth stages, speeding assimilate transport to maximize capsule set and seed development. These findings are supported by the earlier observations of Gurjar *et al.* (2017) [10], Das *et al.* (2023) [24], Kumari *et al.* (2025) [12], Borah *et al.* (2026) [25] in linseed.

Table 1. Interaction effect of soil NPK levels and foliar spray of NPK on seed yield of linseed

Treatments Soil NPK levels	Foliar spray of NPK		
	Water spray	NPK 0.5%	NPK 1.0%
Control	688.9	825.0	922.2
50% RDF	911.1	1125.0	1247.2
75% RDF	1172.2	1397.2	1463.9
100% RDF	1377.8	1413.9	1477.8
SEm±	34.39		
CD ($p = 0.05$)	100.87		

Economics

The economic returns of linseed showed a significant response to different soil NPK levels. The highest net return (₹ 84,972/ha) was fetched under 100% RDF, which was significantly superior to 75% RDF, 50% RDF and the control, with each soil NPK level differing

significantly from one another. Application of 100% RDF also achieved the maximum B:C ratio (2.95), which remained statistically at par with 75% RDF (2.87) but proved significantly superior to 50% RDF (2.27) and the control (1.65).

A significant influence of foliar application of NPK was observed on the net returns obtained from linseed cultivation. Foliar application of NPK 19:19:19 @ 1.0% fetched the maximum net return (₹ 74,137/ha) and the highest B:C ratio (2.61), which proved significantly superior to NPK 19:19:19 @ 0.5% and the water spray.

Interaction between soil NPK levels and foliar spray of NPK was found significant (Table 4). Highest net returns were fetched under application of 75% RDF + NPK 19:19:19 @ 1% spray (₹ 88,185/ha) which was statistically at par with 100% RDF + NPK 19:19:19 @ 1% spray (₹ 88,176/ha), 100% RDF + NPK 19:19:19 @ 0.5% spray (₹ 83,565/ha), 75% RDF + NPK 19:19:19 @ 0.5% spray (₹ 83,351/ha) and 100% RDF + water spray (₹ 83,176/ha). However, all these most remunerative treatment combinations proved significantly superior to the rest of the combinations.

Economic feasibility in terms of B:C ratio was governed by a significant positive interaction between soil NPK levels and foliar NPK (Table 5). Highest B:C ratio was fetched under application of 100% RDF + water spray (3.08) which remained statistically at par with 75% RDF + NPK 19:19:19 @ 1% spray (3.05), 75% RDF + NPK 19:19:19 @ 0.5% spray (2.93), 100% RDF + NPK 19:19:19 @ 1% spray (2.93), 100% RDF + NPK 19:19:19 @ 0.5% spray (2.83).

Table 2. Interaction effect of soil NPK levels and foliar spray of NPK on net returns (₹/ha) of linseed

Treatments Soil NPK levels	Foliar NPK		
	Water spray	NPK 0.5%	NPK 1.0%
Control	32546	40935	48212
50% RDF	48085	62696	71973
75% RDF	67851	83351	88185
100% RDF	83176	83565	88176
SEm±		2752	
CD ($p = 0.05$)		8070	

Table 3. Interaction effect of soil NPK levels and foliar spray of NPK on B:C ratio

Treatments Soil NPK levels	Foliar NPK		
	Water spray	NPK 0.5%	NPK 1.0%
Control	1.44	1.63	1.89
50% RDF	1.94	2.30	2.59
75% RDF	2.62	2.93	3.05
100% RDF	3.08	2.83	2.93
SEm±	0.101		
CD ($p = 0.05$)	0.295		

Table 4. Effect of soil NPK levels and foliar NPK on plant height (cm), branches per plant, DMA and CGR

Treatments	Plant height (cm)			Number of branches/plant		DMA (g/plant)			CGR (g/m ² /day)	
	45 DAS	90 DAS	At harvest	45 DAS	At harvest	45 DAS	90 DAS	At harvest	45- 90 DAS	90 DAS-harvest
Soil NPK levels										
Control	25.5	62.1	63.1	2.76	4.91	1.32	6.11	1.32	3.23	2.34
50% RDF	28.0	65.8	67.0	2.98	5.56	1.45	7.18	1.45	3.73	3.39
75% RDF	30.6	69.8	71.4	3.18	6.02	1.66	7.95	1.66	4.15	3.62
100% RDF	32.1	71.3	73.1	3.24	6.20	1.75	8.23	1.75	4.18	3.68
SEm±	0.29	0.45	0.50	0.047	0.08	0.021	0.076	0.021	0.094	0.083
CD ($p = 0.05$)	0.87	1.33	1.47	0.138	0.234	0.061	0.222	0.061	0.275	0.245

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Treatments	Plant height (cm)			Number of branches/plant		DMA (g/plant)			CGR (g/m ² /day)	
Foliar spray of NPK										
Control	28.9	65.9	67.2	3.02	5.47	1.54	7.15	1.54	3.60	3.10
NPK 19:19:19 @ 0.5%	29.1	67.7	68.9	3.07	5.72	1.54	7.44	1.54	3.83	3.25
NPK 19:19:19 @ 1.0%	29.1	68.2	69.8	3.03	5.83	1.56	7.52	1.56	4.04	3.43
SEm±	0.25	0.39	0.43	0.041	0.069	0.018	0.066	0.018	0.081	0.072
CD (<i>p</i> = 0.05)	NS	1.15	1.27	NS	0.203	NS	0.193	NS	0.24	0.21

Table 5. Effect of soil NPK levels and foliar spray of NPK on yield attributes, yield, harvest index and economic returns in linseed

Treatment	Capsules/ plant	Seeds/ capsule	1000 seed weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Net return (₹/ha)	B: C ratio
Soil NPK levels								
Control	84.9	7.98	7.58	812.0	1705.5	32.20	40564	1.65
50% RDF	93.8	8.03	7.80	1094.4	2082.4	34.33	60918	2.27
75% RDF	99.7	8.09	7.87	1344.4	2511.6	34.84	79796	2.87
100% RDF	103.2	8.12	7.90	1423.1	2781.5	33.88	84972	2.95
SEm±	1.199	0.063	0.058	19.9	46.496	0.494	1589	0.06
CD (<i>p</i> = 0.05)	3.52	NS	0.17	58.2	136.4	1.45	4659	0.17
Foliar spray of NPK								
Control	91.2	7.98	7.70	1037.5	2108.0	32.83	57914	2.27
NPK 19:19:19 @ 0.5%	96.4	8.03	7.82	1190.3	2283.3	34.12	67637	2.42
NPK 19:19:19 @ 1.0%	98.6	8.15	7.85	1277.8	2419.4	34.49	74137	2.61
SEm±	1.038	0.054	0.050	17.2	40.26	0.428	1376	0.050
CD (<i>p</i> = 0.05)	3.04	NS	NS	50.4	118.1	1.255	4035	0.15

Conclusion

Based on the present study, it may be concluded that the application of 75% RDF (67.5-22.5-22.5 kg NPK/ha) supplemented with foliar spray NPK 19:19:19 @ 1.0% at flower initiation (60–65 DAS) and capsule development (80–85 DAS) is advisable for optimizing the yield and profitability of linseed. Further, application of 75% RDF + foliar NPK 19:19:19 @ 1.0% was found equivalent to 100% RDF (with water spray and NPK 19:19:19 @ 1.0%) in terms of seed yield, while fetching the highest net returns (₹ 88,185) and B:C ratio (3.05).

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