International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(8): 854-858
www.biochemjournal.com
Received: 12-05-2025
Accepted: 16-06-2025

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Effect of phosphorus and sulphur on growth and yield of linseed (*Linum usitatissiumum* L.)

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i8Sm.5264

Abstract
Linseed (*Linum usitatissiumum* L.) is an important oilseed crop of India, locally known as Alesi and Tessi. It has been cultivated since ancient times for its oil-rich seeds and flax (fiber). It is a member of the family *Linaceae*. It is an annual plant with blue flowers that yields tiny linseed that ranges in colour from reddish brown to golden yellow. Madhya Pradesh, Uttar Pradesh, Maharashtra, Chhattisgarh, Bihar, and Jharkhand are the primary Indian states where linseed is grown. An experiment entitled on Effect of Phosphorous and Sulphur on growth and yield of Linseed (*Linum usitatissiumum* L.) was conducted during *Rabi* season of 2024 at Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Science, Prayagraj (U.P.) India. Three levels of phosphorus (25, 35, and 45 kg/ha) and Sulphur (15, 20, and 30 kg/ha) were used in the various treatments, along with RDF. The sandy loamy soil in the experimental plot had a pH of (7.3), was almost neutral in soil reaction, and had a low organic carbon content of (0.45%), potassium (243.8 kg/ha) and available phosphorus (27.4 kg/ha) nitrogen (239.5 kg/ha). The experiment was laid out in a Randomized Block Design with ten treatments which have replicated thrice. The results revealed that significantly higher growth attributes of Linseed at 80 DAS *viz.*, plant height (51.63 cm), dry weight (3.52 g), Capsule /plant (30.88), seed/Capsule (8.11), test weight (9.61), grain yield (945.82 kg/ha) and stover yield (1560.67) were recorded in T_7 (Phosphorus 45 kg/ha + Sulphur 15 kg/ha) compared to other treatments and Maximum gross return (INR 95030.92/ha), net return (INR 64952.92/ha) and B:C ratio (2.16) were also recorded in T_6 (Phosphorus 45 kg/ha + Sulphur 15 kg/ha). It was determined that applying phosphorus and Sulphur improves linseed development and yield, as evidenced by the highest test weight, grain yield, stover yield, gross return, net return, and benefit cost ratio, as well as the fact that it is financially advantageous.

Keywords: Economics, linseed, phosphorus, sulphur and yield

Introduction
Linseed (*Linum usitatissimum* L.) is one of the most important oil seed crops in India. It is self-pollinating flax crop include linen, linum, and tisi. India ranks first in terms of area under linseed cultivation and third in production in world. It is primarily cultivated worldwide for its multifunctional oil and fiber. Flax, also known as Linum Linseed, is a valuable crop with a wide range of uses. It is an annual herbaceous plant that belongs to the *Linaceae* family. According to Chaurasiya *et al.* (2024) [2], flax seeds are known to contain chemical compounds with particular biological activity and functional properties, including soluble dietary fibers, lignins, proteins, carbohydrates, and the omega-3 family of polyunsaturated fatty acids (PUFA). They also have the ability to hold water and fat, as well as to be thermally stable, emulsifying, and to have an electrostatic charge density. 40 percent fat, 20 percent protein, 28 percent total dietary fiber, 7.7 percent moisture, and 3.4% ash—the mineral-rich residue left over when samples are burned—are all present. The protein composition of the seed decreases as its oil concentration increases. With an annual production of 403 kg/ha and a total production of 2.12 lakh tons, linseed is cultivated on 5.25 lakh hectares in India (Singh *et al.* 2022) [14, 15]. Linseed is grown on 5.25 lakh ha in India, with a total production of 2.12 lakh tones and an annual production of 403 kg/ha (Singh *et al.* 2022) [14, 15]. The climate conditions that are ideal for growth are those that are characterized as being moderate and cold throughout the year. The temperature ranges that are the lowest and highest are 10 degrees Celsius and 38 degrees Celsius, respectively. It is therefore the principal growth season for linseed, which occurs during the months of October and

November, depending on the amount of soil moisture. By planting the crop at an earlier stage, it is possible to prevent the spread of diseases such as rust, linseed bud fly, and powdery mildew in various areas. The maturation of the crop might take anywhere from 110 to 120 days, depending on the variety. It is detrimental to both productivity and quality if there is a drought and very high temperatures during the early and seed filling phases Singh *et al.* (2022) [14, 15].

Phosphorus are required in the early phases of cell division, and the first general indication is weak, slowed growth. Some plants have dark to blue-green hue on their older leaves as a result of phosphorus's relative mobility, which allows it to be moved to areas of new growth. Leaf and stem purpling may occur in cases of severe deficiency. By restricting plant growth, phosphorus deficit results in delayed maturity and poor seed and fruit development, which lowers production. Phosphorus availability in Indian soils ranges from poor to medium. Crops can only use around 30% of the phosphorus that is applied; the remainder is transformed to insoluble phosphorus.

An essential factor in assessing the quality of oil extracted from these crops is Sulphur (S). It is necessary for the synthesis of vitamins, proteins, and chlorophyll. One of the primary causes of the Sulphur deficiency in Indian soils is the use of fertilizers devoid of Sulphur. Sulphur encourages vegetative development and is a component of chlorophyll. The synthesis of certain amino acids and oils requires Sulphur. Since Sulphur is a component of amino acids (cysteine, cysteine, and methionine), it is necessary for protein creation. It is linked to both the synthesis of oils and the production of chlorophyll. Depending on improving development and plant part, linseed crop Sulphur uptake and genetic mutation vary. Application of Sulphur improved yield and quality (Patil *et al.* 2018) [9].

According to experimental data, the two most important plant nutrients that are typically deficient in Indian soil are phosphorous and Sulphur. Because phosphorus is comparatively mobile in plants, it can be transported to areas where new development is occurring. As a result, older leaves of certain plants may exhibit signs of dark to blue-green hue. Additionally, Sulphur is linked to oilseed quality and blooming. Among other nutrients, phosphorus and Sulphur are crucial for enhancing the quantity and quality of linseed Jimo *et al.* (2017) [5]. Due to the low phosphorus and Sulphur content of the soil, a significant portion of the planted area linseed needs fertilizer to produce a satisfactory crop. Phosphorus promotes the growth and development of roots in seedlings. It also encourages the growth of seeds and fruit. Sulphur encourages vegetative development and is a component of chlorophyll. The synthesis of certain amino acids and oils requires Sulphur was reported by Singh *et al.* (2022) [14, 15].

Materials and Methods

An experiment entitled on Effect of Phosphorous and Sulphur on growth and yield of Linseed (*Linum usitatissiumum* L.) was conducted during *Rabi* season of 2024. A field experiment was conducted in alluvial soil at the Department of Agronomy at Crop Research Farm, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Science, Prayagraj (U.P.) India. the different levels of phosphorus and Sulphur. treatments consisted of 3 levels of Phosphorus 25, 35 and 45 kg/ha and Sulphur 15, 20 and 30 kg/ha along with RDF. The soil of experimental plot was sandy loamy in texture, nearly neutral in soil reaction (PH 7.8), low in organic carbon (0.35%). The experiment was laid out in a Randomized Block Design with ten treatments which have replicated thrice. the treatment combination consists T_1-Phosphorus 25 kg/ha + Sulphur 15 kg/ha, T_2-Phosphorus 25 kg/ha + Sulphur 20 kg/ha, T_3-Phosphorus 25 kg/ha + Sulphur 25 kg/ha, T_4-Phosphorus 35 kg/ha + Sulphur 15 kg/ha, T_5-Phosphorus 35 kg/ha + Sulphur 20 kg/ha T_6-Phosphorus 35 kg/ha + Sulphur 25 kg/ha, T_7-Phosphorus 45 kg/ha + Sulphur 15 kg/ha T_8-Phosphorus 45 kg/ha + Sulphur 20 kg/ha, T_9-Phosphorus 45 kg/ha + Sulphur 25 kg/ha, T_{10}-Control (RDF:-50:30:20 kg NPK/ha). Linseed (SHUATS Alsi-2) were planted on December 12, 2024, with a 30 cm × 10 cm spacing. Using a hand hoe, furrows 4-5 cm deep were dug along the seed rows in order to apply organic manure as a spreading method. Once germination occurred, the gaps were closed by transplanting ten days following sowing. Seedlings were removed where needed to keep the space between plants at 30 cm by 10 cm. Intercultural operations were conducted at intervals of 25 to 45 days in order to decrease crop density and weed competition. The crop was harvested on March 29th, 2025. Plant growth characteristics, including plant height (cm) and dry weight (g/plant), were measured at regular intervals from germination until harvest. At harvest, yield attributes such as Capsules/plant, seeds/ Capsules, test weight (g), seed yield (kg/ha), stover yield (kg/ha), and harvest index (%) were measured at 20, 40, 60 and 80 DAS. Analysis of variance (ANOVA), as it relates to randomized block design, was used to statistically examine the observed data of ten treatments Gomez and Gomez, 1984 [3] and Mohan *et al.* (2024) [8] and Prayagraj has subtropical and semiarid climatic conditions, with both extremes of temperature, i.e. summer and winter. It would be hot which commences in the month of February and with draws by the end of October. The meteorological data including the weekly average of the maximum and minimum temperature, relative humidity, and rainfall recorded at the Agro-meteorological Observatory unit, School of Forestry and Environmental Sciences, SHUATS, during the cropping period.

Results and Discussions

Growth parameter

The data of growth parameter are presented in Table 1. show Effect of Phosphorus and Sulphur on growth and Yield of Linseed. the application of (Phosphorus 45 kg/ha along with 15 kg/ha Sulphur) in T_7 resulted the higher plant height (51.63 cm) was observed at 80 DAS. On the other hand, T_9 (Phosphorus 45 kg/ha along with 25 kg/ha Sulphur) had the lowest plant height (45.83 cm). The early growth of seedlings may be caused by the application of Phosphorus which boosts growth and development capacity and produces growth-promoting hormones like IAA, trace elements, vitamins, amino acids, antibiotics, and micronutrients it's essential for the synthesis and function of several key plant hormones and plays a vital role in plant growth and development. Phosphorus, primarily in the form of phosphate (Pi), is a crucial component in energy transfer (ATP), DNA/RNA, and cell membranes. It also influences the production of hormones like abscisic acid (ABA) and

indoleacetic acid (IAA), and impacts stomatal behaviour and root development, ultimately affecting a plant's response to stress reported by Patil *et al.* (2018) [9]. The application of (Phosphorus 45 kg/ha along with 15 kg/ha Sulphur) in T_7 resulted the highest plant dry weight (3.52 g) was observed at 80 DAS and T_1 (Phosphorus 25 kg/ha along with 15 kg/ha Sulphur) had the lowest plant dry weight (3.12 g). Plant dry weight increased significantly due to excess growth and development of plant which may be the result of growth-promoting hormones of hormones like abscisic acid (ABA) and indoleacetic acid (IAA), and impacts stomatal behaviour and root development in phosphorus that increase the activation of cell division and cell elongation in the axillary buds. Sulphur help in chlorophyll formation and encourages vegetative plant growth. It also increases root growth. It is necessary for the synthesis of vitamins, proteins, and chlorophyll. One of the primary causes of the Sulphur deficiency in Indian soils is the use of fertilizers devoid of Sulphur reported by Singh *et al.* (2022) [14, 15] and Kushwaha *et al.* (2019) [7].

Yield attributes

The data presented in Table 2 Sowed the result related to yield-attributing characters. The application of (Phosphorus 45 kg/ha along with 15 kg/ha Sulphur) in T_7 produced the highest number of Capsules/plant (30.88), which was statistically comparable to treatments 4, 6, 8, and 9. T_7 (Phosphorus 45 kg/ha along with 15 kg/ha Sulphur) was found to have a significantly higher number of seeds/ Capsules (8.11), while treatment 8 and 9 was found to be statistically equivalent to treatment 7 (Phosphorus 45 kg/ha along with 15 kg/ha Sulphur). However, the application of Phosphorus 45 kg/ha and Sulphur 15 kg/ha resulted in a considerably greater test weight (9.61 g) that was statistically equivalent to other treatments. It might be due to the fact that P and S found to be increased the photosynthates, which accumulated into seeds consequently increasing test weight. Sulphur is closely associated with seed containing constituents such as greater accumulation of sulphur containing amino acids, higher synthesis of proteins and glucosides, related to the higher test weight of seeds (Singh *et al.* 2007 and Singh *et al.* 2022) [14, 15]. Sulphur applied topically had a major impact on Linseed. It is necessary for the synthesis of vitamins, proteins, and chlorophyll and increases in growth, development and yield, including test weight, number of seeds per Capsules, and number of capsules per plant. It increases in flowering reproduction stage for formation of capsules in plant which increase the seed quality and quantity Kumar *et al.* (2018) [6]

Grain yield

According to the statistical data in Table 2, The application of (Phosphorus 45 kg/ha along with 15 kg/ha Sulphur) had the significantly highest grain yield (945.82 kg/ha), which was statistically comparable to treatments (3, 5, 8 and 9) with highest T_7 (Phosphorus 45 kg/ha along with 15 kg/ha Sulphur) respectively. The activation of cell division and cell elongation in the axillary buds, which promotes an increased number of Capsules, seeds, and grain yield, may be the result of growth-promoting hormones present in Phosphorus. It might be due to the fact that P and S found to be increased the photosynthates, which accumulated into seeds consequently increasing test weight. Sulphur is closely associated with seed containing constituents such as greater accumulation of sulphur containing amino acids, higher synthesis of proteins and glucosides, related to the higher test weight of seeds. The application can lead to significant improvements in plant growth, yield components, and overall grain production. It's important to assess soil nutrient levels and consult with agricultural experts to determine the appropriate fertilization strategies for specific crops and growing conditions. (Kumar *et al.* 2018 and Parmar *et al.* 2020) [6, 10].

Stover yield

According to the results in Table 2, the application of (Phosphorus 45 kg/ha along with 15 kg/ha Sulphur) in T_7 resulted in a substantially higher stover yield (1560.67 kg/ha), while all other treatments were found to be statistically equivalent to the highest. The stover output increased significantly after Phosphorus along with Sulphur were applied this could be because of better growth in terms of plant height, seedling emergence, and dry matter buildup, all of which increase photosynthetic efficiency. Superior vegetative development results from increased photosynthetic accumulation in vegetative components, which raises stover production. Phosphorus boosts growth and development capacity and produces growth-promoting hormones like IAA, trace elements, vitamins, amino acids, antibiotics, and micronutrients it's essential for the synthesis and function of several key plant hormones Kumar *et al.* (2018) [6] and Rahil *et al.* (2021) [11]

Harvest index

Data presented in table 2 showed that the highest harvest index (45.87%) was recorded with the application of (Phosphorus 45 kg/ha along with 15 kg/ha Sulphur) in T_7 which was statistically at par to all treatments.

Economics

With the application of Phosphorus 45 kg/ha along with Sulphur 15 kg/ha, T_7 demonstrated the highest Maximum gross return (INR 95030.92/ha), net return (INR 64952.92/ha) and B:C ratio (2.16) were also recorded in T_7 (Phosphorus 45 kg/ha + Sulphur 15 kg/ha). These findings may be the consequence of increased grain and stover yields in the same treatment as a result of improved nutrient availability by Phosphorus and improved micronutrient use by Sulphur, which produced noticeably higher results (Anonymous 2010) [1].

Table 1: Influence of Phosphorus and Sulphur on growth attributes of Linseed.

		Plant height (cm)	Dry weight (g)	CGR (g/g/day)	RGR (g/g/day)
S. No.	**Treatments**	**80 DAS**	**80 DAS**	**60-80 DAS**	**60-80 DAS**
1	Phosphorus 25 kg/ha + Sulphur 15 kg/ha	49.17	3.12	0.279	0.038
2	Phosphorus 25 kg/ha + Sulphur 20 kg/ha	47.37	3.17	0.280	0.038
3	Phosphorus 25 kg/ha + Sulphur 25 kg/ha	47.13	3.26	0.298	0.040
4	Phosphorus 35 kg/ha + Sulphur 15 kg/ha	48.30	3.24	0.302	0.041
5	Phosphorus 35 kg/ha + Sulphur 20 kg/ha	48.70	3.15	0.257	0.034
6	Phosphorus 35 kg/ha + Sulphur 25 kg/ha	48.60	3.32	0.324	0.044
7	Phosphorus 45 kg/ha + Sulphur 15 kg/ha	51.63	3.52	0.331	0.041
8	Phosphorus 45 kg/ha + Sulphur 20 kg/ha	47.77	3.42	0.312	0.040
9.	Phosphorus 45 kg/ha + Sulphur 25 kg/ha	45.83	3.27	0.294	0.039
10	Control (RDF:-50:30:20 kg NPK/ha)	45.97	3.33	0.289	0.037
	SEm(±)	1.94	0.13	0.29	0.0039
	CD (P = 0.05)	-	-	-	-

Table 2: Influence of Phosphorus and Sulphur on economics of Linseed.

S. No.	Treatments	No. of Capsule/plant	No. of Seeds/ capsule	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Gross return (₹/ha)	Net returns (₹/ha)	Benefit-cost ratio (B:C)
1	Phosphorus 25 kg/ha + Sulphur 15 kg/ha	27.46	6.30	7.86	606.30	1209.78	40.09	61231.70	31381.70	1.05
2	Phosphorus 25 kg/ha + Sulphur 20 kg/ha	28.09	6.96	7.84	638.89	1353.85	37.60	64641.89	34715.89	1.16
3	Phosphorus 25 kg/ha + Sulphur 25 kg/ha	27.96	7.06	8.50	763.06	1351.11	38.52	76806.11	46804.11	1.56
4	Phosphorus 35 kg/ha + Sulphur 15 kg/ha	28.31	5.79	8.37	674.07	1189.69	40.80	67843.79	37765.79	1.26
5	Phosphorus 35 kg/ha + Sulphur 20 kg/ha	27.82	5.93	7.93	794.07	1449.36	40.45	79993.30	50067.30	1.67
6	Phosphorus 35 kg/ha + Sulphur 25 kg/ha	29.85	6.02	9.34	648.80	1357.67	35.19	65618.91	35616.91	1.19
7	Phosphorus 45 kg/ha + Sulphur 15 kg/ha	30.88	8.11	9.61	945.82	1560.67	45.87	95030.92	64952.92	2.16
8	Phosphorus 45 kg/ha + Sulphur 20 kg/ha	29.30	7.56	9.47	829.73	1406.70	37.17	83423.55	53497.55	1.79
9	Phosphorus 45 kg/ha + Sulphur 25 kg/ha	30.34	7.91	8.93	855.19	1549.56	35.45	86132.48	56130.48	1.87
10	Control (RDF:-50:30:20 kg NPK/ha)	27.67	5.55	7.90	576.30	1060.21	35.19	59197.24	30997.24	1.10
	SEm (±)	S 0.69	0.51	0.43	66.86	87.49	3.63			
	CD (P = 0.05)	2.07	1.52	1.28	198.68	259.95	10.79			

Conclusion

On the basis of one year experimentation, it concludes that with the application of Phosphorus 45 kg/ha along with Sulphur 15 kg/ha performed better in growth and yield of Greengram has recorded highest test weight, grain yield, stover yield, net return and benefit cost ratio and as well as economically profitable.

Acknowledgement

I am grateful to my advisor and chairman as well as all of the faculty members of Department of Agronomy, NAI for their unwavering support and advice throughout the entire experimental research study.

Competing Interests

Authors have declared that no competing interests exits.

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