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Effect of sulphur and spacing on growth and yield of linseed

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Abstract
A field experiment was conducted during *Rabi* season 2024 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, to determine Effect of Sulphur and Spacing on Growth and Yield of Linseed. The result revealed that treatment 6 (25 cm x 15 cm + 50 kg/ha S) recorded significantly higher plant height (93.07 cm), higher plant dry weight (15.14 g) and at harvest, maximum number of capsules per plant (44.27), maximum number of seeds per capsule (8.73), highest test weight (8.07 g) highest seed yield (1101.61 kg/ha) and highest stover yield (2345.97 kg/ha). Highest gross return (121748.20INR/ha), net return (81088.20 INR/ha) and B:C ratio (1.99) was recorded in treatment 6 (25 cm x 15 cm + 50 kg/ha S) was found to be productive as well as economically feasible.

Keywords: Linseed, spacing, sulphur, yield and economics

Introduction

Linseed (*Linum usitatissimum* L.), commonly known as flaxseed, is one of the oldest cultivated crops, valued for both its oil-rich seeds and strong fibers. It belongs to the family Linaceae and is cultivated in temperate and subtropical regions worldwide. Traditionally grown for its fiber used in linen production, linseed has gained prominence in recent decades due to its nutritional and industrial applications. Grown primarily for its oil-rich seeds, linseed also plays a vital role in sustainable agricultural systems due to its adaptability and agronomic benefits. It is a cool-season crop that thrives in a wide range of agro-climatic conditions, making it suitable for both irrigated and rainfed farming systems. India is the second largest producer of linseed, next to Canada in the world with an area of 5.25 lakh ha, total production of 2.11 lakh tones per annum and productivity of 403 kg ha^{-1}. In India, Madhya Pradesh leads in yield and acreage, followed by Uttar Pradesh. Madhya Pradesh and Uttar Pradesh together contribute to national linseed production to the extent of about 70 per cent. The average productivity of this crop is very low as compared to other oilseed crops which can be attributed to several reasons.

Nutritionally, linseed is rich in alpha-linolenic acid (ALA), an essential omega-3 fatty acid, along with lignans, dietary fiber, and high-quality protein, all of which contribute to cardiovascular health, hormone regulation, and improved digestion. These properties have led to its growing use in functional foods and therapeutic diets. Medicinally, linseed has been traditionally used to treat gastrointestinal and inflammatory conditions, and modern studies support its role in managing cholesterol levels, blood pressure, and menopausal symptoms. Industrially, linseed oil is valued for its drying properties, making it a key ingredient in paints, varnishes, linoleum, and other products, while the residual linseed meal serves as a protein- rich animal feed (Patil *et al.*, 2018) [9]. Moreover, its cultivation promotes environmental sustainability due to reduced chemical input requirements and its contribution to agro-biodiversity.

Linseed cultivation faces several challenges that limit its productivity and widespread adoption. One of the primary issues is low yield potential, often attributed to the use of traditional, low-yielding varieties and inadequate crop management practices. Linseed is highly sensitive to environmental factors, and its growth can be significantly affected by unfavorable weather conditions such as drought, frost, and excessive rainfall. Pest and disease infestations, including rust, wilt, powdery mildew, and cutworms, also pose serious threats to crop health and yield.

Additionally, nutrient deficiencies, particularly of sulphur, nitrogen, and phosphorus, are common in many linseed-growing regions, leading to poor plant growth and reduced oil content. Limited awareness among farmers about improved agronomic practices, lack of access to quality seeds, and minimal research extension support further compound the problem (Gaikwad *et al*., 2019) [3]. In some areas, linseed is often cultivated on marginal lands with low fertility, which restricts its productivity. These combined factors have led to stagnation in linseed production, despite its high potential as a valuable oilseed crop.

One of the common problems in linseed production is poor plant growth and low yield, which can often be attributed to improper plant spacing. In many cases, linseed is either sown too densely or too sparsely, both of which negatively affect crop performance. Overcrowded planting leads to excessive competition among plants for sunlight, water, and nutrients, resulting in weak stem development, increased plant height, and lodging—especially under windy or rainy conditions. It also creates a humid microenvironment that encourages the development and spread of fungal diseases such as rust and powdery mildew (Teshome *et al*., 2020) [14]. On the other hand, sparse sowing results in inefficient use of available land and allows weed growth, which competes with the crop and reduces overall yield. Proper spacing ensures adequate air circulation and sunlight penetration, which are crucial for healthy plant development and disease prevention. It also promotes better root and canopy development, efficient nutrient uptake, and uniform maturity, leading to improved seed quality and higher yields. By adopting scientifically recommended spacing practices, linseed farmers can overcome several agronomic challenges and achieve more productive and profitable cultivation.

Low seed yield and poor oil content is one of the major challenges in linseed production, often resulting from nutrient deficiencies, particularly sulphur. Sulphur is a critical macronutrient that plays a fundamental role in the growth, development, and productivity of linseed, particularly in enhancing both seed yield and oil quality. It is essential for the synthesis of key amino acids such as cysteine and methionine, which are building blocks of proteins and are vital for metabolic functions. In linseed, where both protein and oil are economically valuable components, sulphur ensures proper development of seeds and supports high oil accumulation. It also contributes to chlorophyll formation, which enhances photosynthesis, resulting in better biomass production and overall plant vigor. One of the key agronomic benefits of sulphur is its ability to improve the efficiency of other nutrients, especially nitrogen (Kushwaha *et al*., 2019) [8]. By balancing nitrogen uptake and utilization, sulphur promotes optimal vegetative and reproductive growth.

In sulphur-deficient soils—a growing concern due to intensive farming practices and reduced use of organic manures—linseed often shows symptoms such as stunted growth, pale yellowing of young leaves, delayed flowering, and reduced seed filling. The application of sulphur, therefore, not only corrects these deficiencies but also contributes to improved flowering, pod development, and seed set (Singh and Singh, 2007) [12]. Field studies have shown that sulphur application can significantly enhance the quantity and quality of linseed oil, particularly by increasing the concentration of alpha-linolenic acid (ALA), a valuable omega- 3 fatty acid.

Furthermore, sulphur helps in increasing disease resistance and stress tolerance in linseed plants, making them more resilient against adverse climatic conditions such as drought and low temperatures. By strengthening the plant's cellular structure and enzymatic activity, sulphur boosts the crop's immunity and supports better adaptation to environmental stressors. In addition to its physiological benefits, sulphur also improves the overall economic return from linseed cultivation by increasing the harvestable yield and improving market quality. For sustainable and profitable linseed farming, especially in sulphur-depleted regions, the balanced application of sulphur is therefore indispensable.

Materials and Methods

The experiment was conducted during *Rabi* season of 2024 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P.). The soil of the experimental field was sandy loamin texture, with soil pH 7.7, low level of organic carbon (0.48%), available N (226 Kg/ha), P (23.4 kg/ha), K (237.3 kg/ha). The treatment consists of three different spacing and three levels of sulphur. The experiment was laid out in RBD with 9 treatments each replicated thrice. The treatment combinations are T1 – 20 cm x 15 cm + 30kg/ha S, T2 - 20 cm x 15 cm + 40kg/ha S, T3 - 20 cm x 15 cm + 50kg/ha S, T4 - 25 cm x 15 cm + 30kg/ha S, T5 - 25 cm x 15 cm + 40kg/ha S, T6 - 25 cm x 15 cm + 50kg/ha S, T7 - 30 cm x 15 cm + 30kg/ha S, T8 - 30 cm x 15 cm + 40kg/ha S, T9 - 30 cm x 15 cm + 50kg/ha S. Data recorded on different aspects of crop, *viz*., growth, yield attributes and yield were subjected to statistically analysed by analysis of variance method as described by Gomez and Gomez (1976) [6].

Results and Discussion

Plant height (cm): At 120 DAS, significant and higher plant height (93.07 cm) was shown in the treatment 6 (25 cm x 15 cm + 50 kg/ha S). However, treatment 3 (20 cm x 15 cm + 50 kg/ha S) was found to be statistically at par with treatment 6 (25 cm x 15 cm + 50 kg/ha S). The significant and higher plant height was with the spacing of 20 cm x 15 cm might be due to well-spaced plants grow sturdier and healthier with better light penetration and air circulation. Adequate spacing also supports strong root development, leading to more uniform and vigorous growth. Similar result was also reported by Gohil *et al.* (2016) [5]. Further, application of 50 kg/ha S gave more plant height might be attributed to the sulphur which plays a key role in the formation of amino acids, enzymes, and vitamins, which support cell division and elongation. It also enhances chlorophyll production, boosting photosynthesis and overall plant vigor. Similar finding was also reported by Pandey and Ali (2014) [10].

Plant dry weight (g): At 120 DAS, significant and higher plant dry weight (15.14 g) was observed in the treatment 6 (25 cm x 15 cm + 50 kg/ha S). However, treatment 3 (20 cm x 15 cm + 50 kg/ha S) was found to be statistically at par with treatment 6 (25 cm x 15 cm + 50 kg/ha S). The significant and higher plant dry weight was with the spacing of 20 cm x 15 cm might be due to spacing might have increased the dry weight of linseed by reducing competition among plants for essential resources like sunlight, water, and nutrients. With more space, each plant can access sufficient light for photosynthesis, leading to better energy production and biomass accumulation. Further, application of 50 kg/ha S gave more plant dry weight as sulphur application might have increased the dry weight of linseed by enhancing the plant's metabolic activities and improving nutrient uptake, particularly nitrogen. Sulphur is essential for the synthesis of amino acids, proteins, and enzymes, all of which are vital for plant growth and development. It also boosts chlorophyll formation, leading to better photosynthesis and energy production. Similar results were obtained by the Choudhary *et al.* (2016) [2].

Number of capsules/plant

Significant and maximum number of capsules/plant (44.27) was observed in the treatment 6 (25 cm x 15 cm + 50 kg/ha S). However, treatment 3 (20 cm x 15 cm + 50 kg/ha S) was found to be statistically at par with treatment 6 (25 cm x 15 cm + 50 kg/ha S). Significant and maximum number of capsules/plant was with the spacing of 25 cm x 15 cm which might be due to reduced competition for light, nutrients, and water. This improved resource availability encourages better vegetative growth, including more branching, which in turn supports more capsule formation. Enhanced light penetration and air circulation also contribute to healthier plants and more efficient photosynthesis, further boosting capsule development. Similar result was also reported by Singh *et al.* (2013) [11]. Further, significant and higher number of capsules/plant was with application of 50 kg/ha S might be attributed to the synthesis of amino acids, proteins, and enzymes due to sulphur, which are critical for cell division and plant metabolism. Sulphur also enhances chlorophyll formation, leading to improved photosynthesis and energy production. This promotes vigorous vegetative growth and better branching, providing more sites for capsule formation. Similar result was also reported by Choudhary *et al.* (2016) [2].

Number of seeds/capsules

Significant and maximum number of seeds/capsules (8.73) was observed in the treatment 6 (25 cm x 15 cm + 50 kg/ha S). However, treatment 3 (20 cm x 15 cm + 50 kg/ha S) was found to be statistically at par with treatment 6 (25 cm x 15 cm + 50 kg/ha S). Significant and maximum number of seeds/capsules was with the spacing of 25 cm x 15 cm which might be due to increased spacing may have improved seed development within capsules by creating a more favourable microenvironment around each plant. With less crowding, plants experience lower stress levels, which can lead to better hormonal balance and efficient allocation of assimilates to developing seeds. Similar result was also reported by Gaikwad *et al.* (2019) [3]. Further, significant and higher number of seeds/capsules was with application of 50 kg/ha S in linseed might be likely due to adequate sulphur supply supports balanced growth and ensures that developing flowers receive sufficient nutrients for successful fertilization and seed set. It also plays a role in the formation of vitamins and coenzymes that are crucial during the reproductive phase. Similar results were also reported by Bhavana *et al*. (2022) [1].

Seed yield (kg/ha)

Significant and higher seed yield (1101.61 kg/ha) was recorded in the treatment 6 (25 cm x 15 cm + 50 kg/ha S). However, treatment 3 (20 cm x 15 cm + 50 kg/ha S) was found to be statistically at par with treatment 6 (25 cm x 15 cm + 50 kg/ha S). Significant and higher seed yield was with spacing of 25 cm x 15 cm might be due to spacing might have improved seed yield by creating optimal conditions for both individual plant growth and population productivity, ensuring efficient utilization of soil nutrients and water while maintaining adequate space for robust capsules development and seed filling. Similar result was reported by Giri *et al.* (2024) [4]. Further, significantly higher seed yield of linseed was increased due to 50 kg/ha S as sulphur promotes better plant growth, improved reproductive development, and efficient nutrient utilization. It plays a key role in the synthesis of essential amino acids, enzymes, and chlorophyll, all of which support higher photosynthetic activity and energy production. This leads to more vigorous plants with better flowering, increased seed set, and improved seed filling. Sulphur also enhances oil synthesis and overall seed quality, contributing to greater seed weight and yield.

Stover yield (kg/ha)

Significant and higher stover yield (2345.97 kg/ha) was recorded in the treatment 6 (25 cm x 15 cm + 50 kg/ha S). However, treatment 3 (20 cm x 15 cm + 50 kg/ha S) was found to be statistically at par with treatment 6 (25 cm x 15 cm + 50 kg/ha S). Significant and higher stover yield was with spacing of 25 cm x 15 cm which might be due to optimized plant density, which balances vegetative growth and reduces competition for resources such as light, nutrients, and moisture. This spacing facilitated the development of healthier plants with greater biomass production, contributing to a higher stover yield. Similar result was reported by Swathi *et al*. (2020) [13]. Further, significant and higher stover yield of linseed was increased due to 50 kg/ha S as sulphur is a vital nutrient for protein synthesis and chlorophyll formation, sulphur improves photosynthesis, leading to increased biomass accumulation. It also supports better root development and nutrient uptake, which contribute to stronger stems, more leaves, and overall plant structure. With improved vegetative vigor and prolonged green leaf duration, plants produce more above-ground biomass, resulting in a higher stover yield. Similar results were observed by Khan *et al*. (2021) [7].

Harvest Index (%)

At harvest, no significant difference was found among all the treatments. Statistically highest harvest index (31.96%) was observed with the treatment 6 (25 cm x 15 cm + 50 kg/ha S) and treatment 2 (20 cm x 15 cm + 40 kg/ha S) recorded lowest value (25.16%)

Table 1: Influence of sulpur and spacing on growth attributes of Linseed

S. No.	Treatments	Plant height (cm) 120 DAS	Dry Weight (g) 120 DAS
1.	20 cm x 15 cm + 30kg/ha S	86.28	13.11
2.	20 cm x 15 cm + 40 kg/ha S	87.58	12.67
3.	20 cm x 15 cm + 50 kg/ha S	90.03	14.67
4.	25 cm x 15 cm + 30 kg/ha S	86.73	12.79
5.	25 cm x 15 cm + 40 kg/ha S	85.15	13.17
6.	25 cm x 15 cm + 50 kg/ha S	93.07	15.14
7.	30 cm x 15 cm + 30 kg/ha S	78.80	11.40
8.	30 cm x 15 cm + 40 kg/ha S	85.16	13.27
9.	30 cm x 15 cm + 50 kg/ha S	83.79	12.85
F – test		S	S
S.Em (±)		1.15	0.17
CD (p=0.05)		3.46	0.51

Table 2: Influence of sulphur and spacing on yield attributes and yield of Linseed

S. No.	Treatments	Capsules per plant	Seeds per capsules	Test Weight (g)	Seed Yield (t/ha)	Stover Yield (kg/ha)	Harvest Index (%)
1.	20 cm x 15 cm + 30kg/ha S	39.27	7.20	7.63	756.63	2048.38	26.91
2.	20 cm x 15 cm + 40 kg/ha S	38.80	6.67	7.56	699.60	2075.53	25.16
3.	20 cm x 15 cm + 50 kg/ha S	42.40	8.07	7.79	880.82	2151.31	29.10
4.	25 cm x 15 cm + 30 kg/ha S	38.53	6.80	7.48	776.39	2017.22	27.68
5.	25 cm x 15 cm + 40 kg/ha S	38.73	6.87	7.37	778.55	2022.37	27.55
6.	25 cm x 15 cm + 50 kg/ha S	44.27	8.73	7.95	1101.61	2345.97	31.96
7.	30 cm x 15 cm + 30 kg/ha S	35.33	5.60	7.04	674.48	1777.38	27.46
8.	30 cm x 15 cm + 40 kg/ha S	39.47	7.13	7.36	756.26	2044.88	26.93
10.	30 cm x 15 cm + 50 kg/ha S	38.93	7.00	7.52	827.53	1934.12	29.88
	F – test	S	S	NS	S	S	NS
	S.Em (±)	0.75	0.26	0.36	76.54	82.54	2.13
	D (p=0.05)	2.27	0.78	--	229.48	247.47	---

Conclusion
It is concluded that in Linseed (Treatment 6) with the combination 25 cm x 15 cm + 50 kg/ha S was observed highest grain yield.

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