The Pharma Innovation Journal 2022; 11(10): 214-216

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(10): 214-216

www.thepharmajournal.com
Received: 21-08-2022
Accepted: 29-09-2022

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Effect of phosphorus and sulphur application on yield attributes and yield of linseed (*Linum usitatissimum* L.) grown in middle gangetic plain

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Abstract
A field experiment was conducted to determine the effect of different levels of phosphorus (P) and sulphur (S) on yield attributes and yield of linseed. The experiment was laid out in randomized block design (RBD), with nine treatments with three replications, in the *Rabi* season of 2022 with three different levels of P (40, 50 and 60 kg P_2O_5/ha) and S (30, 40 and 50 kg S /ha) at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). Application of P and S significantly influenced the yield attribute and yield of linseed. Addition of recommended dose of fertilizer (RDF) + 50 kg P ha^{-1} + 50 kg S ha^{-1} recorded the highest capsules/plant (51.68), number of seed/plant (7.64), test weight (8.28 g), seed yield (946.52 kg ha^{-1}), straw yield (2417.19 kg ha^{-1}), biological yield (3660.85 kg ha^{-1}) and harvest index (36.44%). However, the same treatment noted the maximum gross return (Rs. 130584.30), net return (Rs. 79444.30) and B:C ratio (1.55).

Keywords: Benefit: cost ratio, linseed, phosphorus, relative growth rate, yield

Introduction
Linseed (*Linum usitassimum* L.), generally known as flax, is a plant in the Linaceae family that belongs to the genus Linum. Linseed, also known as jawas in India, an important oil seed crop. It has been cultivated since ancient times for flax (fibre) and seed, which is high in oil. It is solely a *Rabi* crop grown during the winter season. The optimal climatic conditions for growth are those that are temperate and cool climate. The lowest and maximum temperature ranges are 10 ºC and 38 ºC, respectively. Thus, depending on the amount of soil moisture, October to November is the primary growth season for linseed. Early seeding enables the crop to avoid the invasion of rust, linseed bud fly, and powdery mildew in different locations. Depending on the cultivar, the crop matures about 120-140 days. Drought and high temperatures during the early and seed filling phases are harmful to production and quality. Flax seed contains 23% omega-3 fatty acids (18:3) (mainly ALA) and 6% omega-6 fatty acids (18:2). One of the primary components of flax lignin, which includes plant oestrogen and anti-oxidants (flax contains up to 800 times more lignans than other plant foods contain). Linseed, often known as flax, is a valuable crop with several applications. Its oil is used to make paints, varnish, oil cloth, and linoleum. If it has a high linolenic acid content but a low oleic acid content, it is an oil with a high oleic acid content. Its fibre, on the other hand, has been coveted for millennia in the manufacturing of textiles and coarse twine. Linseed is grown on 5.25 lakh ha in India, with a total production of 2.12 lakh tonnes and an average productivity of 403 kg/ha.

Phosphorus (P) and sulphur (S) are two important nutrients that have been needed to improve the quality and quantity of linseed (Yawalkar *et al.*, 2002) [11]. Because soil P and S concentration is poor, the majority of farmed area linseed needs fertilizer for high production. In the seedling stage, P encourages root development and growth. It also promotes fruit development and seed production (Yawalkar *et al.*, 2002) [11]. Sulphur is involved in the synthesis of chlorophyll and promotes vegetative development. Sulphur is essential for the synthesis of certain amino acids and oils (Das, 1996) [3]. Sulphur is essential for protein synthesis as a constituent of amino-acid (cystine, cysteine and methionine). It is required for chlorophyll formation and also for the synthesis of oils (Aulakh *et al*., 1989) [1]. Both S uptake and S translocation in linseed crop vary as a function of growth stages and plant part. Application of S significantly increased yield as well as quality (Kumar *et al.*, 2008) [5].

However, majority of linseed cultivated areas are deficient in P and S. To meet the P and S nutrient requirements, it is important to supplement them to the deficient soil in concentrated and readily available form, *i.e.*, fertilizers. It is also critical to understand the appropriate P and S nutrient levels for improved crop growth and productivity. Despite the fact that many researchers have studied on this issue, the requirements for P and S nutrients differ from soil to soil and location to location. Even agro-climatic circumstances have a significant impact on a crop's P and S nutritional requirements. Therefore, it is crucial to figure out the most advantageous supply and level of P and S nutrients in terms of production, nutrient absorption, and linseed quality. Hence, the current study attempted to investigate the influence of P and S treatment on growth characteristics and growth rate of linseed cultivated in sandy loam soil.

Materials and Method

The experiment was laid out in the Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj. The Crop Research Farm is situated at 25°77 N latitude, 81°50 E longitude and 98 m altitude from the mean sea level (MSL). The experiment was conducted during 2022 in randomized block design (RBD) taking nine treatments *viz.*, T1: Recommended dose of fertilizer (RDF) + 40 kg P ha^{-1} + 30 kg S ha^{-1}, T2: RDF + 40 kg P ha^{-1} + 40 kg S ha^{-1}, T3: RDF + 40 kg P ha^{-1} + 50 kg S ha^{-1}, T4: RDF + 50 kg P ha^{-1} + 30 kg S ha^{-1}, T5: RDF + 50 kg P ha^{-1} + 40 kg S ha^{-1}, T6: RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}, T7: RDF + 60 kg P ha^{-1} + 30 kg S ha^{-1}, T8: RDF + 60 kg P ha^{-1} + 40 kg S ha^{-1} and T9: RDF + 60 kg P ha^{-1} + 50 kg S ha^{-1} and each treatment was replicated thrice. Early maturing linseed variety *Neelam* was taken as a test crop. The recommended dose of N, P and K for linseed in Prayagraj region is 30, 60 and 80 kg ha^{-1}, respectively. Urea, di-ammonium phosphate (DAP), muriate of potash (MOP) and bentonite sulphur was used to supply the NPKS to the crop. Sowing of linseed seeds were sown in method of line sowing. Before sowing of crop, light irrigation was administered, thereafter four irrigations were provided based on the need and weather condition. Linseed was harvested by the help of sickle and cut was made 5 cm above the soil surface to avoid contamination from soil. During harvesting yield attributes of linseed was recorded *i.e.*, number of capsules/plant and number of seed/capsule. After threshing and drying seed yield, stover yield, biological yield and 1000 grain weight per plot was recorded and harvest index (HI) was calculated as follows:

$$Harvest\ index\ (\%) = \frac{\text{Economic yield}}{\text{Total biological yield}} \times 100$$

Moreover, cost of cultivation, gross return, net return and benefit:cost (B:C ratio) was calculated. The data recorded for different characteristics were subjected to statistical analysis by adopting the method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984) [4]. The significant difference values were computed for 5 percent probability of error.

Results and Discussion

Effect of phosphorus and sulphur application on yield attributes of linseed

The observation showed that the highest number of capsules/plant (51.68) was observed in treatment T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}), whereas the lowest number of capsules/plant (38.20) was found in treatment T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}) (Table 1). However, T7 (RDF + 60 kg P ha^{-1} + 30 kg S ha^{-1}) are found statistically at par to T6 with respect to number of capsules/plant. The findings revealed that the highest number of seed/plant (7.64) was observed in treatment T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}), however the lowest number of seed/plant (5.84) was found in treatment T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}). Although, T4 (RDF + 50 kg P ha^{-1} + 30 kg S ha^{-1}) and T5 (RDF + 50 kg P ha^{-1} + 40 kg S ha^{-1}) are found statistically at par with T6 with respect to number of seed/plant. The maximum test weight (8.28 g) was observed in treatment T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}), whereas the minimum test weight (6.41 g) was noted in T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}) (Table 1). Moreover, T7 (RDF + 60 kg P ha^{-1} + 30 kg S ha^{-1}), T8 (RDF + 60 kg P ha^{-1} + 40 kg S ha^{-1}), T9 (RDF + 60 kg P ha^{-1} + 50 kg S ha^{-1}) are found statistically at par with T6 with respect to test weight. This might be because of vigorous growth of crop due to availability of P leading to increase number of capsules/plant and number of capsules/plant and the results are in accordance with Sune *et al.* (2006) [8] and Vyas *et al.* (2020) [10].

Effect of phosphorus and sulphur application on yield and harvest index of linseed

The data showed that T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}) recorded the highest seed yield (1243.66 kg ha^{-1}) and lowest seed yield (946.52 kg ha^{-1}) was in T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}) (Table 2). Similarly, in case of straw yield, the maximum value (2417.19 kg ha^{-1}) was observed in T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}) whereas the lowest straw yield (1930.80 kg ha^{-1}) noted in T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}). Straw yield was statistically at par among the treatments T4 (RDF + 50 kg P ha^{-1} + 30 kg S ha^{-1}), T5 (RDF + 50 kg P ha^{-1} + 40 kg S ha^{-1}) and T6. The highest biological yield (3660.85 kg ha^{-1}) was observed in treatment T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}), however the lowest biological yield (2877.32 kg ha^{-1}) was found in treatment T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}). The findings revealed that the highest harvest index (36.44%) was recorded in treatment T2 (RDF + 40 kg P ha^{-1} + 40 kg S ha^{-1}), whereas the lowest harvest (32.90%) was found in treatment T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}). Increase in the seed and stover yield might be due to vigorous growth which might have helped in higher dry production resulting in more photosynthate accumulation in the sink which ultimately reflected interms of higher seed and stover yield (Awasti *et al*., 1989) [2] and (Vashistha *et al*., 1993) [9].

Effect of phosphorus and sulphur application on cost of cultivation and benefit: cost of linseed

The observation showed that the maximum cost of cultivation (Rs. 51140) was observed in treatment T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}), whereas the lowest cost of cultivation (Rs. 49610) was found in treatment T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}) (Table 3). The findings revealed that the highest gross return (Rs. 130584.30) was observed in treatment T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}), however the lowest gross return (Rs. 99384.60) was found in treatment T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}). Similarly, the maximum net return (Rs. 79444.30) was observed in treatment T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}), whereas the minimum net return (Rs. 49774.60) was noted in T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}). The data showed that T6 (RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1}) recorded the highest B:C ratio (1.55) and lowest B:C ratio (1.00) was in T1 (RDF + 40 kg P ha^{-1} + 30 kg S ha^{-1}). These results are in confirmation with the findings of (Patil *et al.*, 2011) [6] and (Patil *et al.*, 2014) [7].

Table 1: Effect of phosphorus and sulphur application on yield attributes of linseed

Treatments	Number of capsules/plant	Number of seed/capsule	Test weight (g)
T1	38.20	5.84	6.41
T2	46.11	6.62	6.86
T3	47.10	6.40	6.50
T4	47.37	7.24	6.93
T5	49.52	7.37	8.04
T6	51.68	7.64	8.28
T7	49.10	6.18	7.49
T8	46.78	6.30	7.59
T9	48.10	6.41	7.44
SEd (±)	0.47	0.20	0.15
CD (5%)	0.99	0.42	0.32

Table 2: Effect of phosphorus and sulphur application on yield and harvest index of linseed

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
T1	946.52	1930.80	2877.32	32.90
T2	1118.16	1950.20	3068.36	36.44
T3	1114.8	1962.22	3077.02	36.23
T4	1201.57	2409.61	3611.18	33.27
T5	1203.98	2412.06	3616.04	33.30
T6	1243.66	2417.19	3660.85	33.97
T7	1109.78	1979.30	3089.08	35.93
T8	1109.03	1983.61	3092.64	35.86
T9	1110.49	1994.81	3105.30	35.76
SEd (±)	0.75	1.45	1.56	0.02
CD (5%)	1.59	3.06	3.23	0.05

Table 3: Effect of phosphorus and sulphur application on cost of cultivation and benefit: cost of linseed

Treatments	Cost of cultivation	Gross return (INR/ha)	Net return (INR/ha)	B:C ratio
T1	49610	99384.60	49774.60	1.00
T2	50260	117406.80	67146.80	1.34
T3	50910	117054.00	66144.00	1.30
T4	49840	126164.85	76324.85	1.53
T5	50490	126417.90	75927.90	1.50
T6	51140	130584.30	79444.30	1.55
T7	50070	116526.90	66456.90	1.33
T8	50720	116448.15	65728.15	1.30
T9	51370	116601.45	65231.45	1.27
SEd (±)	0.86	1.82	1.26	0.01
CD (5%)	9.48	15.74	12.36	0.03

Conclusion
In conclusion, it is inferred from the present investigation that application of RDF + 50 kg P ha^{-1} + 50 kg S ha^{-1} in addition to the full doses of N and K is recommended for obtaining highest yield attribute and yield of linseed. Moreover, The treatment T6 recorded the maximum gross return, net return and B:C ratio.

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