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Interaction Effect of the Phosphorus and Sulphur Levels on Growth and Yield Attributes of Linseed (*Linum usitatissimum*) Crop under Rainfed Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Linseed (*Linum usitatissimum*) belonging to family Linaceae, is a blue flowering annual herb that produces small linseed varying from golden yellow to reddish brown color. In India linseed is mainly cultivated in Madhya Pradesh, Maharashtra, Chhattisgarh and Bihar. Phosphorus occurs in most plants at 0.1 and 0.4% on dry weight basis. Like nitrogen, phosphorus is also a constituent of important metabolites, like phosphorylated sugars involved in photosynthesis, respiration and other metabolic processes. The oilseeds require more amount of sulphur for its growth and development than other crops. Plant height was influenced by sulphur and phosphorus levels up to 60 DAS but at 90 DAS all sulphur and phosphorus interaction level produced plant population. Various yield attributes of linseed number of capsule/plant, seed/ capsule, seed yield/plant, stover yield/plant, 1000 seed test weight. The number of capsule/plant and seed /capsule significantly increased with decreased in sulphur and phosphorus levels. Important role 15 kg/ha sulphur and 40 kg/ha phosphorus to increase maximum number capsule and seed/plant. The increase in stover yield of linseed as a result of PXS application may be due to improvement in root development and

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vegetative growth. Yield and yield attributes also showed significantly effect of sulphur and phosphorus viz. number of capsule/plant, number of seed/capsule, seed yield/plant and stover yield/plant. 1000 seed test weight in sulphur showed non significant as compare to phosphorus. Tha plant height was significantly increase 15 kg/ha sulphur was at par 10 kg/ha of sulphur than phosphorus 40 kg/ha was at par in 30 kg/ha. Number of branches increased with decrease 40 kg/ha phosphorus and 15 kg/ha in sulphur was at with 10 kg/ha sulphur and 30 kg/ha phosphorus. The significant effect of sulphur and phosphorus on root length 40 kg/ha phosphorus was at par with 30 kg/ha and 15 kg/ha sulphur was at par with 10 kg/ha.

Keywords: Linseed; phosphorus; sulphur; yield; growth.

1. INTRODUCTION

Linseed, also known as jawas in India, is a major oil seed crop. It has been grown for flax since ancient times (fibre) as well as for seed, which is high in oil. It is mainly a temperate climates rabi crop moderate and Cool weather patterns are ideal for growth. The lowest temperature regime is the lowest temperature is 100 degrees Celsius, while the maximum temperature is 380 degrees Celsius. As a result, the main growing season for linseed is from October to December, November, subject to the availability of moisture in the soil. In various regions, early sowing helps the crop avoid the invasion of powdery mildew, rust, and flaxseed bud fly. Depending on the variety, the crop matures in 120-140 days. Drought and hot temperatures during the early and seed filling stages are both damaging to yield and quality. Flax seed contains 23% 18:3 Omega-3 fatty acids (primarily ALA) and 6% 18:2 Omega-6 fatty acids. One of the major ingredients of flax is lignin, that also includes plant oestrogen as well as anti-oxidants (linseed contains up to 800 times the amount of lignans as other plant foods). Linseed, also known as flax, is a valuable crop with numerous applications. Its oil is used to make wants to paint, varnish, oil cloth, and hardwood. Oil with a high concentration of conjugated linoleic acid and a low concentration of oleic acid. However, it is beneficial for human utilization, and its fibre has been prized for thousands of years in the manufacture of cotton and rough webbing. 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. Phosphorus and sulphur, among other nutrients, play an important role in improving the quality and amount of linseed [1]. The large percentage of cultivated area linseed requires fertilization for excellent crop because soil phosphrous and sulphur content is low. In the seedling stage, phosphorus stimulates root development and growth. It also promotes fruit development and seed formation [1]. Sulphur is involved in the formation of chlorophyll and promotes vegetative growth. Sulphur is required for the production of certain amino acids and oils [2]. Sulphur is required for protein biosynthesis because it is a component of amino acids (cystine, cysteine, and methionine). It is associated with the formation of chlorophyll as well as the synthesis of oils [3,4]. Sulphur uptake and genetic mutation in linseed crop differ depending on enhancing growth and plant part. Sulphur application increased quality and yield significantly [5]. The objective of this experiment:

1. To study about the appropriate dose of phosphorus and sulphur on linseed crop under rainfed condition.
2. To study about the effect of phosphorus and sulphur on growth yield attributing characteristic of linseed crop in chitrakoot condition .
3. To study about the interaction effect of phosphorus and sulphur on linseed crop.

2. METHODS AND MATERIALS

The field experiment conducted at the Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya's Agriculture farm (Rajola) in Chitrakoot, Satna (M.P.) This farm is located in northern Madhya Pradesh's Bundelkhand Zone. Chitrakoot is located at 24031' N latitude and 81015' E longitude, at a height of approximately 306 metres above mean sea level.

2.1 Treatment Details

The 09 treatment combination were tested in a randomized block design (R.B.D.) replicated thrice. In each replication different treatment were allocated randomly to different plot. The actual allocation of treatment in the plots of the three replications is shown in layout plan, while the detail of layout are given here below.

Chart 1. Actual Allocation of Treatment

Name of crop	Linseed
Cultivated variety	Ajad
Design	R.B.D.
Number of replication	03
Total no. of plots	27
Length of each plot	5m
Width of each plot	3m
Total length of experimental field	29.5m
Total width of experimental field	19m
Total area	560.5m^2
Net cultivated area	486 m^2
Width of main irrigation channel	1m
Spacing row to row	30 cm
Spacing plant to plant	10 cm
Sowingdate	19/10/2019

3. RESULTS

3.1 Growth Parameter

3.1.1 Plant height (cm)

Maximum plant height (17.44 cm) was in 15 kg/ha sulphur level at recommended dose of other fertilizers at 30 DAS, followed by (15.51 cm) 10 kg/ha sulphur level, and minimum (13.48 cm) plant height was observed of linseed in 0 kg/ha sulphur level. There was a significant difference in plant height between 0 and 10 kg/ha sulphur level (2.03 cm) and between 15 and 10 kg/ha sulphur level (1.93 cm). Plant height (16.84 cm) was found to be significantly higher in 40 kg/ha phosphorus levels than in 30 kg/ha (15.24 cm), indicating that both sulphur and phosphorus were present and phosphorus level have combine effect on the plant height with critical difference of (2.17) and standard error of mean (0.17). At 60 DAS, the maximum plant height (44.11 cm) was in 15 kg/ha sulphur level at recommended dose of other fertilizers, followed by (42.74 cm) 10 kg/ha sulphur level, and the minimum plant height (37.71 cm) was in 0 kg/ha sulphur level. There was a significant difference in plant height between 0 and 10 kg/ha sulphur level (5.03 cm) and between 15 and 10 kg/ha sulphur level (1.37 cm). Plant height (43.30 cm) was found to be significantly higher in 40 kg/ha phosphorus level than in 30 kg/ha (41.66 cm), indicating that both sulphur and phosphorus levels have a combined effect on plant height with a critical difference of (1.72) and standard error of mean. At 90 DAS, the maximum plant height (67.00 cm) was in 15 kg/ha sulphur level at recommended dose of other fertilizers, followed by (65.91 cm) 10 kg/ha sulphur level, and linseed 0 kg/ha sulphur level (62.51 cm). There was a significant difference in plant height between 0 and 10 kg/ha sulphur level (3.4 cm) and between 15 and 10 kg/ha sulphur level (2.91 cm). Plant height (66.00 cm) was found to be significantly higher in 40 kg/ha phosphorus level than in 30 kg/ha (65.28 cm), indicating that both sulphur and phosphorus levels have a combined effect on plant height with a critical difference of (0.66) and standard error of mean (0.22).

3.1.2 Number of branches per plant

The data clearly shows that at 30 DAS, the maximum number of branches (3.15) was in 15 kg/ha sulphur level at recommended dose of other fertilizers, followed by (2.77) 10 kg/ha sulphur level, and the minimum number of branches (1.95) was observed of linseed in 0 kg/ha sulphur level. There was a significant difference in the number of branches between 0 and 10 kg/ha sulphur level (0.82) and between 15 and 10 kg/ha sulphur level (0.38). The interaction effect was found to be significant signifying both sulphur and phosphorus level have combine effect on the number of branches with critical difference of (0.50) and standard error of mean (0.16). Maximum number of branches (8.51) was observed at 15 kg/ha sulphur level at recommended dose of other fertilizers at 60 DAS, followed by (7.28) 10 kg/ha sulphur level, and minimum (5.04) number of branches was observed of linseed at 0 kg/ha sulphur level. The number of branches (7.84) was higher in 40 kg/ha phosphorus than in 30 kg/ha (7.00), while the number of branches (6.00) was lowest in 0 kg/ha phosphorus. At 90 DAS, the maximum number of branches (12.48) was observed in the 15 kg/ha sulphur level at the recommended dose of other fertilizers, followed

by (10.51) in the 10 kg/ha sulphur level, and the minimum (8.46) in the 0 kg/ha sulphur level. There was a significant difference in the number of branches between 0 and 10 kg/ha sulphur level (2.05) and between 15 and 10 kg/ha sulphur level (1.97). The number of branches (11.46) was higher in 40 kg/ha phosphorus than in 30 kg/ha (10.48), while the number of branches (9.51) was lowest in 0 kg/ha phosphorus.

3.2 Yield Attributes

3.2.1 Number of capsules per plant (m^2)

The highest capsule/plant (28.12) was in 15 kg/ha sulphur level at recommended dose of other fertilizers, followed by (25.30) 10 kg/ha sulphur level, and the lowest (20.96) capsule/plant was in linseed 0 kg/ha sulphur level. There was a significant difference in capsule/plant between 0 and 10 kg/ha sulphur level (4.34) and between 15 and 10 kg/ha sulphur level (2.82). Capsule/plant (26.30) was comparatively higher in 40 kg/ha phosphorus level than 30 kg/ha (25.13), whereas linseed had the lowest (22.95) capsule/plant in 0 kg/ha phosphorus level. The interaction effect was discovered to be significant, indicating that both sulphur and phosphorus levels have a combined effect on the capsule/plant, with a critical difference of (1.42) and standard error of mean (0.47).

Table 1 . Interaction effect of different phosphorus and sulphur levels on plant height (cm) of linseed crop

Treatment	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
P_0-0	13.48	37.71	62.51
P_1-30	15.51	42.74	65.91
P_2-40	17.44	44.11	67.00
=S. E m. ±	0.41	0.32	0.12
C.D.(P=0.05)	1.25	0.99	0.38
S_0-0	14.35	39.33	64.13
S_1-10	15.84	41.66	65.28
S_2-15	16.24	43.30	66.00
S.E m. ±	0.41	0.32	0.12
C.D.(P=0.05)	1.25	0.99	0.38
Interaction	2.17	1.72	0.66

Table 2. Interaction effect of phosphorus and sulphur on number of branches per plant of linseed crop

Treatment	Number of branches		
	30 DAS	60 DAS	90 DAS
P_0-0	1.95	5.04	8.46
P_1-30	2.77	7.28	10.51
P_2-40	3.15	8.51	12.48
=S. E m. ±	0.09	0.19	0.22
C.D.(P=0.05)	0.28	0.60	0.68
S_0-0	2.24	6.00	9.51
S_1-10	2.68	7.00	10.84
S_2-15	2.95	7.84	11.46
S.E m. ±	0.09	0.19	0.22
C.D.(P=0.05)	0.28	0.60	0.68
Interaction	0.50	1.04	1.18

Table 3. Interaction effect of phosphorus and sulphur on capsule/plant of linseed crop

Levels	P - levels (kg/ha)			
S – levels kg/ha	0	30	40	**Mean**
0	20.03	22.10	20.76	20.96
10	23.53	27.33	25.03	25.30
15	25.30	29.46	29.60	28.12
Mean	22.95	25.13	26.30	
Factors	**C.D.(P=0.05)**	**SE(m) ±1**		
S	0.82	0.27		
P	0.82	0.27		
Interaction	1.42	0.47		

3.2.2 Number of seeds per capsule

The highest number of seeds/capsule (8.61) was observed in 15 kg/ha sulphur level at recommended dose of other fertilizers, followed by (6.01) 10 kg/ha sulphur level, and the lowest number of seeds/capsule (5.41) was observed in 0 kg/ha sulphur level. There was a (0.6) difference in the number of seeds/capsule between 0 and 10 kg/ha sulphur level and a (2.6) difference between 15 and 10 kg/ha sulphur level. The number of seeds/capsule (7.14) was higher in 40 kg/ha phosphorus level than in 30 kg/ha (6.52) level, while the number of seeds/capsule (6.36) was lowest in 0 kg/ha phosphorus level. The interaction effect was found to be significant signifying both sulphur and phosphorus level have combine effect on the number of seeds/capsule with critical difference of (0.67) and standard error of mean (0.22).

3.2.3 Weight of 1000 – seeds

The maximum 1000 seed test weight (27.77 g) was observed in 15 kg/ha sulphur level at recommended dose of other fertilizers, followed by (27.75 g) in 10 kg/ha sulphur level, and the minimum (27.72 g) in 0 kg/ha sulphur level. There was a significant difference in 1000 seed test weight between 0 and 10 kg/ha sulphur level and between 15 and 10 kg/ha sulphur level of (0.03 g). 1000 seed test weight (28.43 g) was higher in 40 kg/ha phosphorus level than in 30 kg/ha (27.57 g), but linseed had the lowest 1000 seed test weight (27.24 g) in 0 kg/ha phosphorus level. The interaction effect was found to be significant signifying both sulphur and phosphorus level have combine effect on the 1000 seed test weight with critical difference of (1.49) and standard error of mean (0.49).

3.3 Yields of linseed

3.3.1 Seed yield (kg/ha)

The maximum number of seed yield/plant (8.76 g) was observed in 15 kg/ha sulphur level at recommended dose of other fertilizers, followed by (8.54 g) in 10 kg/ha sulphur level, and the minimum (7.53 g) in 0 kg/ha sulphur level. There was a significant difference in seed yield/plant between 0 and 10 kg/ha sulphur level and between 15 and 10 kg/ha sulphur level of (1.01 g). Seed yield/plant (8.80) was higher in 40 kg/ha phosphorus level than in 30 kg/ha (8.33 g), but linseed seed yield/plant was lowest (7.71 g) in 0 kg/ha phosphorus level. The interaction effect was found to be significant signifying both sulphur and phosphorus level have combine effect on the seed yield/plant with critical difference of (0.35) and standard error of mean (0.11).

Table 4. Interaction effect of sulphur and phosphorus on seed/capsule of linseed crop

Levels	P - levels (kg/ha)			
S -levels kg/ha	0	30	40	**Mean**
0	5.13	5.46	5.63	5.41
10	5.60	7.03	5.40	6.01
15	8.36	8.93	8.53	8.61
Mean	6.36	6.52	7.14	
Factors	**C.D.(P=0.05)**	**SE(m) ±1**		
S	0.38	0.12		
P	0.38	0.12		
Interaction	0.67	0.22		

Table 5. Interaction effect of phosphorus and sulphur on 1000 seed test weight of linseed crop

Levels	P - levels (kg/ha)			
S – levels kg/ha	0	30	40	**Mean**
0	27.46	26.40	29.40	27.75
10	28.43	27.50	27.23	27.72
15	25.83	28.83	28.66	27.77
Mean	27.24	27.57	28.43	
Factors	**C.D.(P=0.05)**	**SE(m) ±1**		
S	NS	0.28		
P	0.86	0.28		
Interaction	1.49	0.49		

Table 6. Interaction effect of phosphorus and sulphur on seed yield/plant of linseed crop

Levels	P - levels (kg/ha)			
S – levels kg/ha	0	30	40	**Mean**
0	7.30	8.30	7.00	7.53
10	8.80	8.80	8.03	8.54
15	8.90	9.30	8.10	8.76
Mean	7.71	8.33	8.80	
Factors	**C.D.(P=0.05)**	**SE(m) ±1**		
S	0.20	0.06		
P	0.20	0.06		
Interaction	0.35	0.11		

Table 7. Interaction effect of phosphorus and sulphur on stover yield/plant of linseed crop

Levels	P - levels (kg/ha)			
S – levels kg/ha	0	30	40	**Mean**
0	18.60	15.70	18.36	17.55
10	20.66	17.33	22.83	19.21
15	20.70	18.43	18.50	20.27
Mean	17.15	19.90	19.98	
Factors	**C.D.(P=0.05)**	**SE(m) ±1**		
S	0.56	0.18		
P	0.56	0.18		
Interaction	0.97	0.32		

3.4 Stover Yield (kg/ha)

The maximum stover yield/plant (20.27 g) was in 15 kg/ha sulphur level at recommended dose of other fertilizers followed by (19.21 g) 10 kg/ha sulphur level whereas, minimum (17.55 g) stover yield/plant was observed of linseed in 0 kg/ha sulphur level. There was a significant difference of (1.66 g) stover yield/plant between 0 and 10 kg/ha sulphur level and that of (1.06 g) between 15 and 10 kg/ha sulphur level. Stover yield/plant (19.98 g) was comparatively higher in 40 kg/ha phosphorus level than 30 kg/ha (19.90 g) whereas, minimum (17.15 g) stover yield/plant was observed of linseed in 0 kg/ha phosphorus level. The interaction effect was found to be significant signifying both sulphur and phosphorus level have combine effect on the stover yield/plant with critical difference of (0.97) and standard error of mean (0.32).

4. DISCUSSION

Plant height was influenced by sulphur and phosphorus levels up to 60 DAS but at 90 DAS all sulphur and phosphorus interaction level produced plant population at par. The effect of sulphur and phosphorus level on plant height was found [6,7].

Number of branches/plant also increased with increasing level of application with up to 15 kg S/ha it might be due to proper nutrition of sulphur might have increased the cell division

and sulphur might have enhanced the cell division and elongation or expansion which increased the number of branches/plant. The level of sulphur and phosphorus increased number of branches up to 60 DAS at par with 90 DAS. The similar result was found [8,9].

Various yield attributes of linseed number of capsule/plant, seed/ capsule, seed yield/plant, stover yield/plant, 1000 seed test weight.

The number of capsule/plant and seed /capsule significantly increased with decresed in sulphur and phosphorus levels. Important roal 15 kg/ha sulphur and 40 kg/ha phosphorus to increase maximum number capsule and seed/plant. The different levels PXS observed by [10,2].

1000 seed test weight of linseed crop on sulphur level was non significant over the phosphorus level showed the significant. Phosphorus play an important roal to increase test weight of linseed in 40 kg/ha. was at par 30 kg/ha phosphorus level different P levels and S levels increase in yield as a result of P application may be due to impr ovement in root development and vegetative growth. A positive response of linseed to P application was also observed by [12,13].

Stover yield obtained under sulphur 15 kg/ha and phosphorus 40 kg/ha treatment was significantly higher but was at par with 10 kg/ha sulphur and phosphorus 30 kg/ha. However, the lower stover yield was observed under control. The increase in stover yield of linseed as a result of PXS application may be due to improvement in root development and vegetative growth. Similar increase in stover yield due to application of PXS was found by [8,14,15].

5. CONCLUSION

The average yield of linseed 747 kg/ha and yield attributes also showed significantly effect of sulphur and phosphorus viz. number of capsule/plant, number of seed/capsule, seed yield/plant and stover yield/plant. 1000 seed test weight in sulphur showed non significant as compare to phosphorus. The ultimate aim of linseed grower is to secure maximum income per unit area out of the present resources including available plant material.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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