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Response of sulphur and nitrogen on growth, yield and quality parameters of linseed (*Linum usitatissimum* L.)

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Abstract
In this experiment 12 treatment combinations including four levels of Sulphur as S_0-0 kg S/ha, S_1- 20 kg S/ ha, S_2- 40 kg S/ ha and S_3- 60 kg N/ha, while three levels of nitrogen as N_1-20 kg/ha, N_2-40 kg/ha and N_3- 60 kg/ha. During the experiment, it is observed that the effect of sulphur was found significant on growth and yield of linseed where seed yield responded up to 40 kg/ha sulphur application. Nitrogen application has significant effect on growth and linseed yield. However, 60 kg /ha Nitrogen produced numerically higher seed yield over no application of Nitrogen. Interaction effect of S×N was significant on any crop character. However, the combined application of 40 kg S/ha plus 60 kg N/ha proved to be better than from crop production point of view.

Keywords: Linseed, sulphur, nitrogen, growth, yields and quality

Introduction
Linseed (*Linum usitatissimum* L.) is on the most important oilseed crop in India. It is grown both for its seed as well as fiber which used for manufacture in linin beside seed is used for edible purpose. India rank first in term of area under linseed cultivation and third in production in the world. In India linseed cultivated about 4.68 lakh ha and total linseed production is 1.63 lakh tonne. Madhya Pradesh occupies an area of 219.4 thousand hectares with production of 168.9 thousand tonne and productivity of 7169.8 kg ha^{-1} (Anonymous 2016). It is oil seed crop cultivated in cool reason of world. Seed contains 33-47% oil, protein 20 to 25% which is used for both edible and industrial purpose (paint, varnishes, printing ink, pad ink, soap *etc*). Nitrogen is the most essential element in determining the yield potential of linseed and nitrogenous fertilizer is one of the major inputs to linseed production. Almost every farmer has tendency to apply costly N fertilizer excess to get a desirable yield of linseed but imbalance use of N fertilizer causes harm to the crop and decreases grain yield. The use of sulphur is one of the most important factors in increasing yield. Sulphur plays an important role in the formation of amino acid; synthesis is of protein use of sulphur. Which crop need and soil nutrient and its production of high yield. Sulphur is involved in the formation of chlorophyll, amino acids, activation of enzymes and improvement in crop yield and oil percent. It can be called as master nutrient for Oilseed production. Significant increase in plant height with sulphur application might be attributed to direct and indirect involvement of sulphur in the photosynthetic process of plant. Sulphur is now recognized as the fourth major nutrient in addition to nitrogen, phosphorus and potassium. High yielding cultivars of linseed crop require considerably higher amount of sulphur.

Materials and Methods
The experiment was laid out in Factorial Randomized Block Design with 12 Treatment combinations consisted of three levels of nitrogen (*viz.* N_1-20, N_2-40 and N_3-60 kg ha^{-1}) and four levels of sulphur (*viz.* S_1-0, S_2-20, S_3-40 and S_4-60 kg ha^{-1}). The sowing of linseed variety JSL-66 was done by drilling method keeping 30 cm distance between the rows. Recommended dose of nitrogen *i.e.* 60 kg N ha^{-1} was applied through urea and DAP to all treatments, in two equal splits first at sowing second at flower initiation, sulphur was applied through elemental sulphur as per treatments at the time of sowing.

Results and Discussion
The data recorded during the period of research on various aspects were tabulated and subjected to statistical analysis.

Growth characters

Plant height (cm)

The mean data pertaining to plant height of linseed recorded at 30 and 60 DAS harvest that the mean value for this character revealed that the application of 60 kg Sulphur per hectare (S_4) recorded maximum plant height (13.26 cm) and in case of nitrogen 60 kg ha^{-1} (N_3) recorded maximum plant height (10.86 cm) this are superior to other treatment. Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. The maximum plant height (14.12 cm) was recorded with the treatment S_4N_3 (60 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum plant height (5.66 cm) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}). At 60 DAS The mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum plant height (28.72 cm) and in case of nitrogen 60 kg ha^{-1} (N_3) recorded maximum plant height (23.90 cm) that the application of 0 kg Sulphur per hectare(S_1) the minimum plant height was recorded (17.11) and in case of nitrogen 20 kg ha^{-1} (N_1) the minimum plant height was recorded (22.04) Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. the maximum plant height (30.10 cm) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum plant height (16.94 cm) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}). Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. The maximum plant height (58.18 cm) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum plant height (51.83 cm) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Number of branches plant^{-1}

The mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum Number of branches per plant (3.12) and in case of nitrogen 60 kg per hectare (N_3) recorded Number of branches per plant (2.77) that the application of 0 kg Sulphur per hectare(S_1) the minimum Number of branches plant^{-1} was recorded (1.83) and in case of nitrogen 20 kg ha^{-1} (N_1) the minimum Number of branches plant^{-1} was recorded (2.29). Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. the maximum Number of branches plant^{-1} (3.23) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Number of branches per plant (1.52) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}). At 60 DAS The mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum Number of branches plant^{-1} (4.29) and in case of nitrogen 60 kg per hectare (N_3) recorded Number of branches plant^{-1} (3.70) that the application of 0 kg Sulphur per hectare(S_1) the minimum Number of branches per plant was recorded (2.36) and in case of nitrogen 20 kg ha^{-1} (N_1) the minimum Number of branches plant^{-1} was recorded (2.97). Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. the maximum Number of branches plant^{-1} (4.90) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Number of branches plant^{-1} (2.12) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen per hectare). Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. the maximum Number of branches plant^{-1} (5.79) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Number of branches plant^{-1} (2.80) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Number of leaves plant^{-1}: At 30 DAS The mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum Number of leaves per plant (23.19) and in case of nitrogen 60 kg ha^{-1} (N_3) recorded Number of leaves per plant (20.61) that the application of 0 kg Sulphur ha^{-1} (S_1) the minimum Number of leaves per plant was recorded (12.72) and in case of nitrogen 20 kg ha^{-1} (N_1) the minimum Number of leaves per plant was recorded (17.55). Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. the maximum Number of leaves per plant (24.11) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare), while the minimum Number of leaves plant^{-1} (12.00) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}). At 60 DAS The mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum Number of leaves per plant (74.61) and in case of nitrogen 60 kg per hectare (N_3) recorded Number of leaves per plant (72.59) that the application of 0 kg Sulphur per hectare(S_1) the minimum Number of leaves plant^{-1} was recorded (60.70) and in case of nitrogen 20 kg ha^{-1} (N_1) the minimum Number of leaves plant^{-1} was recorded (65.58). Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. the maximum Number of leaves per plant (81.90) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare), while the minimum Number of leaves per plant (59.66) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}. Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. the maximum Number of leaves plant^{-1} (82.22) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Number of leaves plant^{-1} (72.76) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Table 1: Effect of Sulphur and nitrogen on Number of leaves plant^{-1} at 30 DAS of linseed

Effect of Sulphur	Effect of Nitrogen			
	N_1 (20 kg/ha)	**N_2 (40 kg/ha)**	**N_3 (60 kg/ha)**	**Mean**
S_1 (0 kg/ha)	12.00	12.66	13.5	12.72
S_2 (20 kg/ha)	16.44	18.2	20.59	18.41
S_3 (40 kg/ha)	22.27	23.2	24.11	23.19
S_4 (60 kg/ha)	19.52	20.34	21.84	20.56
Mean	17.55	18.6	20.01	
	S	N	S x N	

SEm±	0.15	0.13	0.27
CD (p=0.05)	0.46	0.40	0.80

Fresh weight of plant (g): The mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum Fresh weight of plant (1.89 g) and in case of nitrogen 60 kg ha^{-1} (N_3) recorded Fresh weight of plant (1.79 g) that the application of 0 kg Sulphur ha^{-1} (S_1) the minimum Fresh weight of plant was recorded (1.45 g) and in case of nitrogen 20 kg ha^{-1} (N_1) the minimum Fresh weight of plant was recorded (1.63 g). Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. The maximum Fresh weight of plant (1.98 g) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Fresh weight of plant (1.45 g) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Table 2: Effect of Sulphur, nitrogen and their interactions on fresh weight of linseed

Effect of Sulphur	Effect of Nitrogen			
	N_1 (20 kg/ha)	**N_2 (40 kg/ha)**	**N_3 (60 kg/ha)**	**Mean**
S_1 (0 kg/ha)	1.45	1.54	1.63	1.54
S_2 (20 kg/ha)	1.59	1.63	1.71	1.64
S_3 (40 kg/ha)	1.82	1.89	1.98	1.89
S_4 (60 kg/ha)	1.68	1.74	1.84	1.75
Mean	1.63	1.70	1.79	
	S	N	S x N	
SEm±	0.005	0.004	0.004	
CD (p=0.05)	0.015	0.012	0.023	

Dry weight of plant (g): The mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum Dry weight of plant (0.94 g) and in case of nitrogen 60 kg per hectare (N_3) recorded Dry weight of plant (0.85 g) that the application of 0 kg Sulphur per hectare (S_1) the minimum Dry weight of plant was recorded (0.62 g) and in case of nitrogen 20 kg per hectare (N_1) the minimum Dry weight of plant was recorded (0.72 g). Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. The maximum Dry weight of plant (1.01 g) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Dry weight of plant (0.53 g) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Yield characters

Number of capsules plant^{-1}: Data indicated that the number of capsules plant^{-1} at harvest. The mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum Number of capsules plant^{-1} at harvest (57.23) and in case of nitrogen 60 kg ha^{-1} (N_3) maximum recorded Number of capsules per plant at harvest (53.97) that the application of 0 kg Sulphur per hectare (S_1) the minimum Number of capsules per plant at harvest was recorded (47.68) and in case of nitrogen 20 kg per hectare (N_1) the minimum Number of capsules plant^{-1} at harvest was recorded (51.63). Looking to the statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. The maximum Number of capsules per plant at harvest (58.37) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Number of capsules plant^{-1} at harvest (46.44) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Table 3: Effect of Sulphur, nitrogen and their interactions on No. of capsules plant^{-1} at harvest of linseed

Effect of Sulphur	Effect of Nitrogen			
	N_1 (20 kg/ha)	**N_2 (40 kg/ha)**	**N_3 (60 kg/ha)**	**Mean**
S_1 (0 kg/ha)	46.44	47.39	49.23	47.68
S_2 (20 kg/ha)	50.02	51.02	52.98	51.34
S_3 (40 kg/ha)	56.10	57.23	58.37	57.23
S_4 (60 kg/ha)	53.97	54.27	55.33	54.52
Mean	51.63	52.48	53.97	
	S	N	S x N	
SEm±	0.055	0.047	0.093	
CD (p=0.05)	0.0161	0.140	0.0280	

Number of seeds capsule^{-1} (g): It is seen from the table that the number of seed per capsule ranged between 6.10 g to 9.45 g. The mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum number of seed per capsule at harvest (8.44 g) and in case of nitrogen 60 kg per hectare (N_3) maximum recorded number of seed per capsule at harvest (8.54 g) that the application of 0 kg Sulphur per hectare (S_1) the minimum number of seed capsule^{-1} at harvest was recorded (7.03 g) and in case of nitrogen 20 kg ha^{-1} (N_1) the minimum number of seed capsule^{-1} at harvest was recorded (6.70 g). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was found significant. The maximum Number of capsules per plant at harvest (9.45 g) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Number of capsules plant^{-1} at harvest (6.10 g) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Capsule weight (g): It is seen from the table that the capsule weight ranged between 9.29 g to 23.93 g. The mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum capsule weight at harvest (22.33 g) and in case of nitrogen 60 kg per hectare (N_3)

maximum recorded capsule weight at harvest (19.30 g) that the application of 0 kg Sulphur per hectare (S_1) the minimum capsule weight at harvest was recorded (11.80 g) and in case of nitrogen 20 kg per hectare (N_1) the minimum capsule weight at harvest was recorded (15.46 g). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction were found significant. The maximum capsule weight at harvest (23.93 g) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum capsule weight at harvest (9.29 g) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Seed yield plant^{-1} (g): The mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum Seed yield plant^{-1} (4.35 g) and in case of nitrogen 60 kg per hectare (N_3) maximum recorded Seed yield plant^{-1} (4.02 g) that the application of 0 kg Sulphur per hectare (S_1) the minimum Seed yield per plant was recorded (2.52 g) and in case of nitrogen 20 kg ha^{-1} (N_1) the minimum Seed yield plant^{-1} was recorded (2.67 g). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction were found significant. The maximum Seed yield plant^{-1} (5.18 g) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha-1), while the minimum Seed yield plant^{-1} (2.00 g) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Seed yield (q) ha^{-1}: The mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum Seed yield ha^{-1} (11.91 q) and in case of nitrogen 60 kg ha^{-1} (N_3) maximum recorded Seed yield ha^{-1} (10.82 q) that the application of 0 kg Sulphur ha^{-1} (S_1) the minimum Seed yield per hectare was recorded (7.72 q) and in case of nitrogen 20 kg per hectare (N_1) the minimum Seed yield per hectare was recorded (8.55 q). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction were found significant. The maximum Seed yield per hectare (13.20 q) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare), while the minimum Seed yield per hectare (6.60 q) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Test weight (1000 seed): The mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum Test weight (8.94 g) and in case of nitrogen 60 kg per hectare (N_3) maximum recorded Test weight (8.65 g) that the application of 0 kg Sulphur per hectare (S_1) the minimum Test weight was recorded (7.35 g) and in case of nitrogen 20 kg per hectare (N_1) the minimum Test weight was recorded (7.57 g). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction were found significant. The maximum Test weight (9.40 g) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Test weight (6.78 g) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

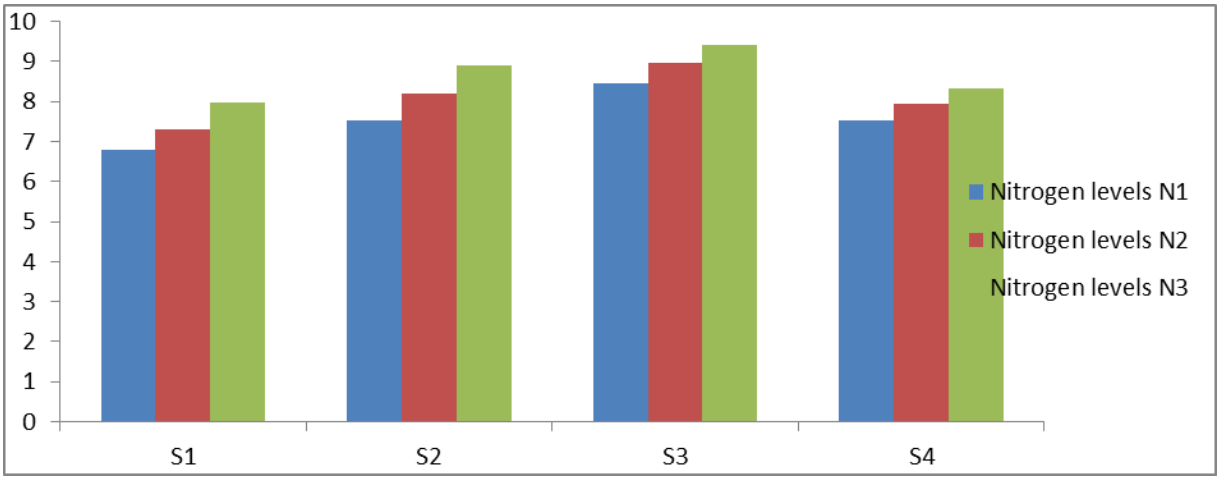

Fig 1: Effect of Sulphur, nitrogen and their Interaction on Test weight (g) (1000 seed) of linseed

Moisture percent at time of harvest: The Moisture percent at time of harvest was recorded 12.5% it is a very suitable to harvest of Linseed crop, Batter oil content and storage of linseed.

Straw yield (q) ha^{-1}: The mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum Straw yield per hectare (25.51 q) and in case of nitrogen 60 kg per hectare (N_3) maximum recorded Straw yield ha^{-1} (24.34 q) that the application of 0 kg Sulphur per hectare (S_1) the minimum Straw yield per hectare was recorded (20.35 q) and in case of nitrogen 20 kg per hectare (N_1) the minimum Straw yield ha^{-1} was recorded (21.73 q). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction were found significant. The maximum Straw yield ha^{-1} (26.80 q) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Straw yield ha^{-1} (18.75 q) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

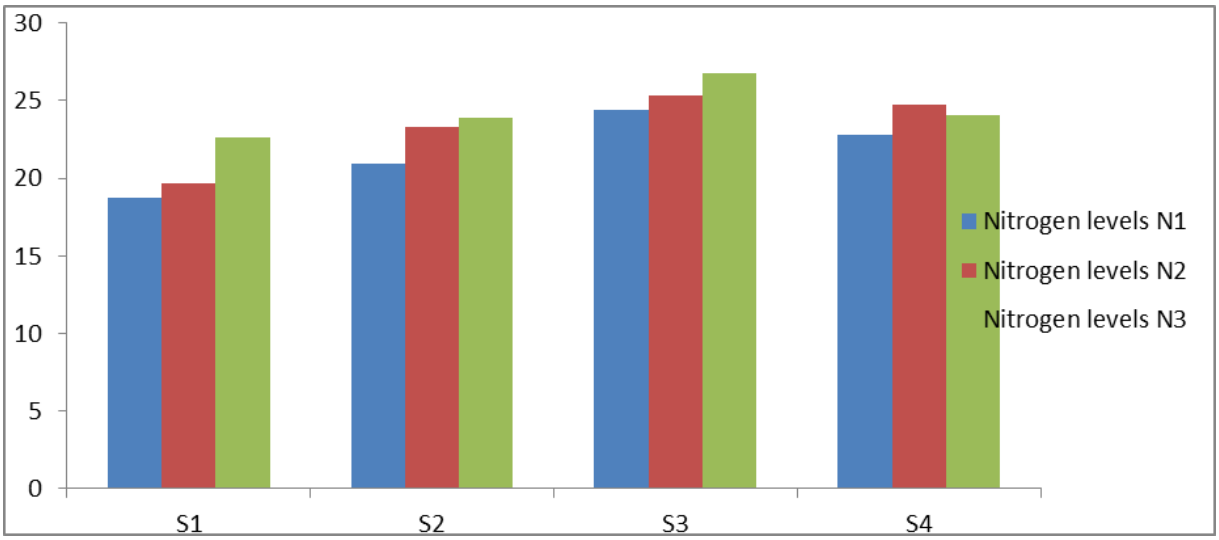

Fig 2: Effect of Sulphur, nitrogen and their Interaction on Straw yield (q) ha^{-1} of linseed

Harvest index (%)

The mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum Harvest index (31.79%) and in case of nitrogen 60 kg per hectare (N_3) maximum recorded Harvest index (30.64%) that the application of 0 kg Sulphur per hectare (S_1) the minimum Harvest index was recorded (27.20%) and in case of nitrogen 20 kg per hectare (N_1) the minimum Harvest index was recorded (28.04%). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction were found significant. The maximum Harvest index (32.99%) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare), while the minimum Harvest index (26.04 q) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Oil content (%)

It is seen from the table that the Oil content (%) ranged between 9.29 g to 23.93 g. The mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum Oil content (%) (39.22%) and in case of nitrogen 60 kg ha^{-1} (N_3) maximum recorded Oil content (%) (37.69%) that the application of 0 kg Sulphur ha^{-1} (S_1) the minimum Oil content (%) was recorded (33.44%) and in case of nitrogen 20 kg ha^{-1} (N_1) the minimum Oil content (%) was recorded (34.51%). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction were found significant. The maximum Oil content (%) (39.89%) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare), while the minimum Oil content (%) (31.62%) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Economic analysis

Cost of cultivation (Rs/ha): Result revealed that the mean value for this character revealed that the application of 40 kg Sulphur ha^{-1} (S_3) recorded maximum cost of cultivation (22741.33 Rs/ha) and in case of nitrogen 60 kg ha^{-1} (N_3) maximum recorded cost of cultivation (30127.33 Rs/ha) that the application of 0 kg Sulphur ha^{-1} (S_1) the minimum cost of cultivation was recorded (22041.33 Rs/ha) and in case of nitrogen 20 kg per hectare (N_1) the minimum cost of cultivation was recorded (29844.00). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was the maximum cost of cultivation (22833.00Rs/ha) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum cost of cultivation (21908.00Rs/ha) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Gross Monetary Returns (Rs/ ha): Result revealed that the mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum Gross Monetary Returns (57368.33 Rs/ha) and in case of nitrogen 60 kg ha^{-1} (N_3) maximum recorded Gross Monetary Returns (69625.67 Rs/ha) that the application of 0 kg Sulphur per hectare (S_1) the minimum Gross Monetary Returns was recorded (37547.00 Rs/ha) and in case of nitrogen 20 kg per hectare (N_1) the minimum Gross Monetary Returns was recorded (55383.67 Rs/ha). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was the maximum Gross Monetary Returns (57368.33 Rs/ha) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}), while the minimum Gross Monetary Returns (32235.00 Rs/ha) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Net Monetary Return (Rs/ ha): Result revealed that the mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum Net Monetary Return (34627.00 Rs/ha) and in case of nitrogen 60 kg per hectare (N_3) maximum recorded Net Monetary Return (39498.33 Rs/ha) that the application of 0 kg Sulphur per hectare (S_1) the minimum Net Monetary Return was recorded (15505.67 Rs/ha) and in case of nitrogen 20 kg per hectare (N_1) the minimum Net Monetary Return was recorded (25539.67 Rs/ha). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was the maximum Net Monetary Return (40567.00 Rs/ha) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare), while the minimum Net Monetary Return (10327.00 Rs/ha) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Benefit: Cost Ratio: Result revealed that the mean value for this character revealed that the application of 40 kg Sulphur per hectare (S_3) recorded maximum B:C Ratio (2.52) and in case of nitrogen 60 kg per hectare (N_3) maximum recorded B:C Ratio (3.08) that the application of 0 kg Sulphur per hectare (S_1) the minimum B:C Ratio was recorded (1.70) and

in case of nitrogen 20 kg per hectare (N_1) the minimum B:C Ratio was recorded (2.47). The statistical analysis, effect of different levels of Sulphur, nitrogen and their interaction was the maximum B:C Ratio (2.78) was recorded with the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare), while the minimum B:C Ratio (1.47) was recorded under the treatment S_1N_1 (0 kg Sulphur and 20 kg nitrogen ha^{-1}).

Discussion

It has been attempted to establish the cause and effect relationship in light of variable evidences and literature. For the sake of convenience, this chapter has been divided under the following subhead.

Influence on growth characters: Result revealed from the differences among the various levels of Sulphur, nitrogen and their interact ion were found significant for plant height (cm) at 30 and 60 DAS of linseed plant. Result revealed from table that differences among the various levels of Sulphur, nitrogen and their interact ion were found significant for number of branches per plant at 30 DAS, at 60 DAS maximum number of branches $plant^{-1}$ recorded under the treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare). Similar findings have also been reported by Analysis data of fresh weight (g) of plant showed that effect of nitrogen gave significant result whereas; effect of sulphur and their interaction gave significant result. Treatment S_3 (40 kg Sulphur ha^{-1}) and S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}) gave maximum fresh weight of plant (1.98 g, respectively). Analysis data of dry weight (g) of plant showed that effect of Sulphur, nitrogen and their interaction gave significant result. Treatment S_3 (40 kg Sulphur ha^{-1}), N_3 (60 kg nitrogen ha^{-1}) and S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare) gave maximum fresh weight of plant *i.e.*, 0.94 g, 0.85 g and 1.01 g, respectively. Similar findings were also recorded by Sune *et al.* (2006) [13], Makeen *et al.* (2008), Rao *et al.* (2013) [11] and Patil *et al.* (2018) [9].

Influence on yield attributes

Number of capsules per plant showed that effect of Sulphur and nitrogen gave significant result whereas, interaction effect of S and N showed significant result. Maximum number of capsules per plant was recorded under treatment S_3 (40 kg Sulphur per hectare) *i.e.* 57.23 and it was at par with treatment S_1 (0 kg Sulphur per hectare) *i.e.* 47.68. Maximum number of capsules per plant was recorded under treatment N_3 (60 kg nitrogen ha^{-1}) *i.e.* 53.97. Number of seeds $capsule^{-1}$ showed significant result for Sulphur, nitrogen and their interaction. Maximum seeds per capsule was recorded under treatment S_3 (40 kg Sulphur ha^{-1}) *i.e.* 8.44. Statistically seed yield (g) $plant^{-1}$ showed significant result for Sulphur, nitrogen and their interaction. Number of capsules weight showed that effect of Sulphur and nitrogen gave significant result whereas, interaction effect of S and N showed significant result. Maximum capsules weight was recorded under treatment S_3 (40 kg Sulphur ha^{-1}) *i.e.* 22.33 g and it was at par with treatment S_1 (0 kg Sulphur ha^{-1}) *i.e.* 11.80 g. Maximum capsules weight was recorded under treatment N_3 (60 kg nitrogen ha^{-1}) *i.e.* 19.30 g. Analysis data for seed yield (q) ha^{-1} showed that effect of Sulphur and nitrogen gave significant result and their combinations showed significant result. Maximum seed yield (11.91 q) ha^{-1} with treatment S_3 (40 kg Sulphur ha^{-1}) statistically it was at par with treatment N_3 (60 kg nitrogen ha^{-1}) *i.e.* (10.82 q). Higher seed yield of linseed was obtained mainly due to improvement in yield components. Test weight is an important yield contributing trait of linseed which is significantly influenced by the Sulphur and nitrogen gave significant result whereas, interaction effect of S and N showed significant result. Maximum Test weight was recorded under treatment S_3 (40 kg Sulphur ha^{-1}) *i.e.* 8.94 g and Maximum Test weight was recorded under treatment N_3 (60 kg nitrogen ha^{-1}) *i.e.* 8.65 g. Analysis data for straw yield (kg) ha^{-1} showed that effect of Sulphur and nitrogen gave significant result and their combinations showed significant result. In case of Sulphur, straw yield (25.51 q) ha^{-1} with treatment S_3 (40 kg Sulphur ha^{-1}) and in case of nitrogen highest straw yield (24.35 q) ha^{-1} with treatment N_3 (60 kg nitrogen ha^{-1}). Analysis data for Harvest index (%) showed that effect of Sulphur and nitrogen gave significant result and their combinations showed significant result. Maximum Harvest index (31.79%) with treatment S_3 (40 kg Sulphur ha^{-1}) statistically it was at par with treatment N_3 (60 kg nitrogen ha^{-1}) *i.e.* (30.64). Higher Harvest index of linseed was obtained mainly due to improvement in yield components. Similar findings were also recorded by Rahimi *et al*. (2011) [10], Mishra and Gaur (2013), Choudhary *et al.* (2016) [2] and Hezaki Jimo *et al.* (2017) [5].

Effect on quality parameters: Statistically Sulphur, nitrogen and their interaction effect found significant result. Maximum oil content in linseed (47.00%) was recorded by treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare). As Sulphur is a major part of fatty acid, so higher accumulation of Sulphur fertilizer results in increased oil content. Similar findings were also recorded by Choudhary *et al.* (2016) [2], Hezaki Jimo *et al.* (2017) [5] and Upadhyay *et al.* (2019).

Economics: The different treatment combinations were registered more or less a good value of benefit: cost ratio. This indicated that the sowing of linseed with proper Sulphur and nitrogen doses is economical. The application of Sulphur at the rate of 40 kg ha^{-1} and nitrogen at the rate of 60 kg ha^{-1} (S_3N_3) achieve the higher yield of 13.20 q/ha and recorded the highest benefit: cost ratio of 2.78 with net realization of 40567.00 Rs/ha. The second highest net realization (33686.00 Rs/ha) was recorded under treatment S_3N_2 with benefit: cost ratio of 2.48. Similar findings were also recorded by Dubey (2001) [4]. Result clearly announced that the conjoint use of nitrogen and phosphorus increased the yield of crop and thereby gave remunerative return. Plant height: Application of Sulphur had a significant effect on plant height at all growth stages, except at 60 DAS. There was an increase in plant height with increasing levels of sulphur. Highest plant height was recorded with application 40 kg S ha^{-1} which was significantly more over 0 kg S ha^{-1} and remained at par with 20 kg S ha^{-1} and 60 kg S ha^{-1} at 60 DAS. The significant increase in plant height with sulphur application might be attributed to direct and indirect involvement of sulphur in the photosynthetic process of plant. Similar results were also reported by Rao *et al.* (2013) [11] and Patil *et al.* (2018) [9]. Number of branches $plant^{-}$: Nitrogen application influenced the number of branches $plant^{-1}$ significantly at all growth stages, except at 60 DAS. Maximum numbers of branches $plant^{-1}$ were recorded with application of 60 kg nitrogen ha^{-1} which was significantly superior over its lower levels at 60 DAS. Similar results were also obtained by Khare *et al.* (1996) [6]. Application of sulphur had a significant influence

on number branches plant^{-1} of linseed at all stages of growth except at 60 DAS. Maximum number of branches plant^{-1} were recorded with application of 40 kg S ha^{-1} which was significantly superior over 0, 20 and 60 kg S ha^{-1} at 60 DAS. Similar results were also obtained by Sune *et al.* (2006) [13]. Number of capsules plant^{-1}: Application of each increasing level of nitrogen significantly increased the number of capsules plant^{-1}. Application of 60 kg nitrogen ha^{-1} recorded significantly highest number of capsules plant^{-1} (53.97) over 20 (51.63) and 40 kg phosphorus ha^{-1} (52.48). The numbers of capsules plant^{-1} were increased significantly with increasing nitrogen levels. This might be because of better growth of plant due to more availability of nitrogen and essential nutrient. Increases in yield attributes with increase in the levels of nitrogen were also reported by Khare *et al.* (1996) [6] and Saxena *et al.* (2005) [12]. Different levels of sulphur significantly influenced the number capsules plant^{-1}. Application of 40 kg S ha^{-1} recorded maximum number of capsules plant^{-1} which was significantly superior over 0, 20 and 60 kg S ha^{-1}. The numbers of capsules plant^{-1} were increased significantly with increase in sulphur levels. Increase in yield attributes with increase in the levels of sulphur was also reported Sune *et al.,* (2006) [13] and Hezaki Jimo *et al*. (2017) [5]. The seed yield ha^{-1} was significantly influenced by different levels of nitrogen. Highest seed yield of 10.82 q ha^{-1} was recorded with application of 60 kg nitrogen ha^{-1} which was significantly superior over seed yield obtained with 20 (8.55 q ha^{-1}) and 40 kg nitrogen ha^{-1} (9.94 q ha^{-1}). The results are in confirmation with the findings of Dubey *et al.* (2001) [4], and Dohat *et al.* (2017). Data revealed that various levels of sulphur significantly influenced the seed yield ha^{-1}. Highest seed yield of 11.91q ha^{-1} was recorded with the application of 40 kg S ha^{-1} which was significantly superior over yields obtained with 0 kg (7.72 q). 20 kg S ha^{-1} (9.20 q) and 60 kg S ha^{-1} (10.26 q). This might be because of better growth of plant due to availability of sulphur leading to increased number of capsule plant^{-1} as seed yield is directly related to the growth and yield attributes. Similar results were also reported by Choudhary *et al*. (2016) [2], Hezaki Jimo *et al*. (2017) [5] and Patil *et al*. (2018) [9]. Each incremental level of nitrogen increased the straw yield of linseed significantly. Highest straw yield (24.35 q ha^{-1}) was obtained by application of 60 kg nitrogen ha^{-1} which was significantly superior over application 20 or 40 kg nitrogen ha^{-1} (21.73, 23.24 q ha^{-1} respectively). Similar results were also reported by Nimje and Gandhi (1994), Dubey *et al.* (2001) [4] and Dohat *et al.* (2017). Effect of sulphur levels on straw yield ha^{-1} was found significant. Application of 40 kg S ha^{-1} recorded the highest straw yield (25.51q ha^{-1}) which significantly superior over application of 0 kg S ha^{-1} (20.35 q ha^{-1}), 20 kg S ha^{-1} (22.72 q ha^{-1}) and 60 kg S ha^{-1} (23.86 q ha^{-1}). Similar results were also reported by Sune *et al*., (2006) [13], Choudhary *et al.* (2016) [2] and Hezaki Jimo *et al.* (2017) [5].

Summary

The result presented and discussed in preceding chapters is summarized in this chapter.

Effect on growth parameters

Effect of Sulphur: Sulphur application significantly altered the plant height at 60, and Harvest. These parameters had obtained highest value with Sulphur dose at 40 kg ha^{-1} (S_3) *i.e.* 57.74, respectively. But on plant height at 30 and 60, number of branches plant^{-1} at 30 and 60 DAS it was observed that the effect of Sulphur found to be significant. Effect of nitrogen: Nitrogen application significantly altered the plant height at 60. These parameters had obtained highest value with nitrogen dose at 60 kg ha^{-1} (N_3) *i.e.* 56.04, respectively. But on plant height at 30 and 60, number of branches plant^{-1} at 30 and 60 DAS, it was observed that the effect of nitrogen found to be significant. Interaction effect: Interaction effect between Sulphur and nitrogen levels significantly affect the plant height at 60 DAS and number of branches plant^{-1} at 60 DAS. Maximum plant height at 60 DAS was recorded under treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}) *i.e*. 30.10, respectively whereas, maximum number of branches plant^{-1} at 60 DAS was recorded under the same treatment *i.e*., 4.90, respectively.

Effect on yield parameters:

Effect of Sulphur: The Sulphur application significantly influenced the yield parameters of linseed. Application of Sulphur at the rate of 40 kg ha^{-1} gave maximum number of capsules plant^{-1} (57.23), seed yield ha^{-1} (11.91 q), straw yield ha^{-1} (25.51 q) was observed that the effect of Sulphur levels found to be significant. Effect of nitrogen: 60 kg nitrogen ha^{-1} (N_3) gave maximum number of capsules per plant (53.97), seed yield ha^{-1} (10.82q) and straw yield per hectare (24.35q). Whereas, number of seeds capsule^{-1} and seed yield ha^{-1} were found to be significant. Interaction effect: Interaction effect of Sulphur and nitrogen on yield parameters such as number of capsules plant^{-1} (58.37), seed yield ha^{-1} (13.20 q) and straw yield ha^{-1} (26.80 q) were recorded maximum with the application of Sulphur and nitrogen at the rate of (40 kg Sulphur and 60 kg nitrogen ha^{-1}). Were found to be significant.

Effect on quality parameters

Effect of Sulphur: The Sulphur application significantly influenced the quality parameters of linseed. Application of phosphorus at the rate of 40 kg ha^{-1} (S_3) gave higher oil content (39.22%). Effect of nitrogen: Nitrogen has significant effect on oil content (%). Application of nitrogen at the rate of 60 kg per hectare (N_3) gave higher oil content (37.69%). Interaction effect: Oil content was significantly influenced by interact ion of Sulphur and nitrogen. Higher oil content (39.89%) was recorded with treatment S_3N_3 (40 kg Sulphur and 60 kg nitrogen per hectare). Effect on economics: From the economics point of view, application of Sulphur at the rate of 40 kg/ha and nitrogen at the rate of 60 kg/ha (S_3N_3) gave highest net realization of 40567.00 Rs/ha and benefit: cost ratio of 2.78.

Conclusion

On the basis of results obtained in present investigation, it could be concluded that according to mean data, Sulphur S_3 (40 kg Sulphur ha^{-1}) and nitrogen N_3 (60 kg ha^{-1}) recorded higher seed yield *i.e.,* 11.91 q/ha and 10.82 q/ha, respectively in linseed. The highest net income (40567.00 Rs/ha) with highest benefit: cost ratio (2.78) was recorded under treatment combination S_3N_3 (40 kg Sulphur and 60 kg nitrogen ha^{-1}).

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