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Studies on effect of nitrogen and sulphur on growth and yield parameters in linseed (*Linum usitatissimum* L.) varieties

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Abstract
Plant nutrition is the route for increasing productivity of the crop. Production capability of any crop depends mainly on the essential nutrients supplied to the crop for their growth. This study aims to evaluate the effects of two major nutrients, nitrogen and sulphur on the growth and yield in linseed varieties. A field investigation was carried out during rabi season 2021-22 at AICRP, Safflower; VNMKV, Parbhani (M.S.). The experiment was laid out in a factorial randomized block design with eighteen treatment combinations consisting of two varieties *viz.* LSL-93 (V_1) and NL-260 (V_2), three levels of nitrogen *viz.* N_1 @ 0 kg/ha, N_2 @ 40 kg/ha and N_3 @ 60 kg/ha and three levels of sulphur *viz.* S_1 @ 0 kg/ha; S_2 @ 25 kg/ha and S_3 @ 50 kg/ha replicated twice. The results indicated that the growth and yield attributing characters of linseed *viz.* number of branches plant^{-1}, number of capsules plant^{-1}, number of seeds capsule^{-1}, seed yield plant^{-1}, test weight (g) were appreciably higher in the variety LSL-93 (V_1) except for plant height which was higher in the other variety NL-260 (V_2). The variety LSL-93 (V_1) was also found to be significantly more effective in producing higher seed yield over the variety NL– 260 (V_2). Among the different levels of nitrogen, application of N @ 60 kg/ha i.e (N_3) was found to be most effective whereas, among the different sulphur levels, S @ 50 kg/ha i.e (S_3) showed better results compared to other levels of sulphur in improving the growth and productivity of linseed. Among the treatment combinations, $V_1N_3S_3$ (LSL-93:N60:S50) was found to be the most effective treatment compared to the rest of the treatment combinations.

Keywords: Linseed, nitrogen, sulphur, growth, yield, varieties

Introduction
Among oilseeds, linseed enjoys an important place, being used for domestic, medicinal, edible and industrial purposes. Linseed (*Linum usitatissimum* L.) is one of the approximately 230 species of the family Linaceae which comprises of nearly 14 genera. The specific epithet "usitatissimum" means most useful. Linseed (*Linum usitatissimum* L.) is primarily grown for seed oil in Turkistan, Afghanistan, India, USA, Canada and China. While in Asia and South Russia, it is cultivated traditionally for edible and industrial fibre purposes. India ranks fifth in the world after Canada in terms of area and third with respect to production. Almost every part of the linseed plant is utilized either directly or after processing for commercial purpose. The seeds contain 23% (18:3) Omega-3 fatty acids (mostly ALA) and 6% (18:2) Omega-6 fatty acids. Linseed being a rich source of Omega-3 fatty acids is helpful in the regulation of metabolism in the human body and also prevents many neurological and brain related issues. Linseed cake, which is the oilcake left after the oil has been pressed out, is a very good source of manure and animal feed. The meal of the linseed cake contains about 36 percent protein and is fed to both milch and fattening animals. It is also used as an organic manure which contains about N (5%), P_2O5 (1.4%) and K_2O (1.8%) (Ahlawat, 2008) [1].
The average yield of 544 kg/ha in India was found to be very low compared to the world average yield of 927 kg/ha and highest average yield of 1497 kg/ha in Canada (FAOSTAT, 2018) [4]. The major factors found responsible for low yield of oilseed crops are poor fertile conditions of the soil, traditional crop management practices and inadequate supply of fertilizers. Among these, the imbalance of nutrients appears to be the most crucial one. Research studies have validated that the crop yield can be elevated by choosing varieties of linseed that are high yielding along with considerable supply of nutrients through fertilizers. Among the major and essential elements, nitrogen and sulphur play an indispensable role in enhancing the produce quality and marketability. Taking this into account, this experiment was undertaken to evaluate the effects of different levels of nitrogen and sulphur on growth and yield in linseed varieties.

Materials and Methods

The experiment was carried out in a factorial randomized block design with eighteen treatment combinations replicated twice. The treatments consisted of combination of three rates each of nitrogen (0, 40, 60 kg N/ha), sulphur (0, 25, 50 kg S/ha) and two linseed varieties, LSL-93 (V_1) and NL-260 (V_2). Nitrogen and sulphur were supplied through urea and bensulf respectively according to the treatments at the time of sowing.

Table 1: Treatment details of the experiment

Sr. No.	Symbol	Treatment Details
1.	$V_1N_1S_1$	LSL-93 Control
2.	$V_1N_1S_2$	LSL-93; 0N: 25S kg/ha (Bensulf – 10 gm.)
3.	$V_1N_1S_3$	LSL-93; 0N: 50S kg/ha (Bensulf – 20 gm.)
4.	$V_1N_2S_1$	LSL-93; 40N: 0S kg/ha (Urea - 31gm)
5.	$V_1N_2S_2$	LSL-93; 40N: 25S kg/ha (Urea - 31gm; Bensulf – 10 gm.)
6.	$V_1N_2S_3$	LSL-93; 40N: 50S kg/ha (Urea - 31gm; Bensulf – 20 gm.)
7.	$V_1N_3S_1$	LSL-93; 60N: 0S kg/ha (Urea - 47gm)
8.	$V_1N_3S_2$	LSL-93; 60N: 25S kg/ha (Urea - 47gm; Bensulf – 10 gm.)
9.	$V_1N_3S_3$	LSL-93; 60N: 50S kg/ha (Urea - 47gm; Bensulf – 20 gm.)
10.	$V_2N_1S_1$	NL-260 Control
11.	$V_2N_1S_2$	NL-260; 0N: 25S kg/ha (Bensulf – 10 gm.)
12.	$V_2N_1S_3$	NL-260; 0N: 50S kg/ha (Bensulf – 20 gm.)
13.	$V_2N_2S_1$	NL-260; 40N: 0S kg/ha (Urea – 31 gm.)
14.	$V_2N_2S_2$	NL-260; 40N: 25S kg/ha (Urea - 31gm; Bensulf – 10 gm.)
15.	$V_2N_2S_3$	NL-260; 40N: 50S kg/ha (Urea - 31gm; Bensulf – 20 gm.)
16.	$V_2N_3S_1$	NL-260; 60N: 0S kg/ha (Urea – 47 gm.)
17.	$V_2N_3S_2$	NL-260; 60N: 25S kg/ha (Urea – 47 gm; Bensulf – 10 gm)
18.	$V_2N_3S_3$	NL-260; 60N: 50S kg/ha (Urea – 47 gm; Bensulf – 20 gm)

All the important observations like growth, yield attributes, yield etc. were recorded. For recording the growth and yield attributes, five representative plants of respective treatments were randomly selected and tagged. The collected data was statistically analyzed by using the technique of analysis of variance (Panse and Sukhatme, 1967) [9]. The critical difference (C.D.) was worked out at 5 per cent level of significance for treatment comparison where the 'F' test revealed the significant effect.

Results and Discussions

Effect of nitrogen and sulphur levels on growth attributes

Plant height (cm)

Plant height (cm) was recorded at harvest and the data is presented in Table 2. The mean data pertaining to plant height revealed that application of N @ 60 kg/ha recorded maximum plant height (51.27 cm) and in case of sulphur, S @ 50 kg/ha recorded maximum height (48.95 cm). Based on the analysis, the effect of different levels of nitrogen and sulphur were found to be significant. The increment in plant height could be due to the enhanced supply of nutrient levels. Similar results were reported by Chopra and Badiyala (2016) [2], Singh *et al.,* (2013) [12].

Number of branches per plant

Table 2 depicts the data on number of branches per plant and it indicates that the different levels of nitrogen and sulphur had a significant effect on the number of branches per plant. The nitrogen level N @ 60 kg/ha recorded highest number of branches (8.63) and in case of sulphur level S @ 50 kg/ha significantly recorded highest number of branches (7.85). The increase in number of branches per plant might be due to the increasing levels of nitrogen which favours the plant growth and development due to adequate levels of nutrient supply. The above results were found to be similar with the findings of Khajani *et al.,* (2012) [7] and Singh *et al.,* (2013) [12].

Number of capsules per plant

The application of N @ 60 kg/ha recorded highest number of capsules (32.18) and in case of sulphur level S @ 50 kg/ha significantly recorded highest number of capsules (26.58) per plant. The data regarding this has been given in Table 2. The statistical analysis revealed that the increase in levels of nitrogen and sulphur had a significant effect on the number of branches per capsule and this could be due to the sufficient supply of nutrients. The results obtained were in conformity with those of Khajani *et al.,* (2012) [7] and Pohare *et al.,* (2015) [10].

Dry matter accumulation

The data for dry matter accumulation was recorded and has been presented in Table 2. The statistical analysis concluded that the dry matter accumulation was significantly affected due to the different levels of nitrogen and sulphur. The highest mean dry matter was recorded with the application of N @ 60 kg/ha (4.38) and sulphur level, S @ 50 kg/ha (3.66). It could be due to the enhancement of the growth characters due to the supply of nutrients in sufficient quantity and favourable growth conditions. The obtained results were found to be in accordance with Singh *et al.,* (2013) [12], Gupta *et al.,* (2017) [6] and Gaikwad *et al.,* (2020) [5].

Effect of Nitrogen and Sulphur Levels on yield and yield attributes

Number of seeds per capsule

Table 3 depicts the data on number of seeds per capsule and it shows that the nitrogen levels had a significant effect on the number of seeds per capsule. The maximum number of seeds per capsule was recorded in treatment of N @ 60 kg/ha (9.37), whereas sulphur did not have a significant effect on the number of seeds per capsule. This could be due to the supply of nitrogen as it helps in better capturing of sunlight for photosynthesis, which also increases the sink potential of the plants. The above results were found to be in accordance with Dubey *et al.,* (1997) [3], Pohare *et al.,* (2015) [10], Chopra and Badiyala (2016) [2].

Table 2: Growth studies of linseed as influenced by different treatments

Treatments	Plant Height (AH)	No. of branches per plant	No. of capsules per plant	Dry matter Accumulation (AH)
A Varieties (V)				
V1 – LSL-93	36.68	8.62	28.47	3.52
V2 - NL-260	59.57	6.62	20.44	3.22
S.E. ±	0.18	0.004	0.25	0.06
C.D. at 5%	0.53	0.011	0.73	0.18
B Nitrogen Levels (N)				
N1 - @ 0 kg/ha	44.63	6.64	18.26	2.50
N2 - @ 40 kg/ha	48.46	7.58	22.92	3.23
N3 - @ 60 kg/ha	51.27	8.63	32.18	4.38
S.E. ±	0.22	0.004	0.30	0.07
C.D. at 5%	0.65	0.013	0.90	0.21
C Sulphur Levels (S)				
S1 - @ 0 kg/ha	47.39	7.38	22.53	3.10
S2 - @ 25 kg/ha	48.02	7.62	24.25	3.35
S3 - @50 kg/ha	48.95	7.85	26.58	3.66
S.E. ±	0.22	0.004	0.30	0.07
C.D. at 5%	0.65	0.013	0.90	0.21
D Interactions (4)				
V x N				
S.E. ±	0.31	0.006	0.43	0.10
C.D. at 5%	0.92	0.018	1.27	NS
V x S				
S.E. ±	0.31	0.006	0.43	0.10
C.D. at 5%	NS	NS	NS	NS
N x S				
S.E. ±	0.38	0.005	0.52	0.12
C.D. at 5%	NS	0.015	1.56	NS
V x N x S				
S.E. ±	0.54	0.011	0.74	0.17
C.D. at 5%	NS	NS	NS	NS
General Mean	48.12	7.62	24.45	3.37

Thousand seed weight

The data for 1000 seed weight was recorded and the data is presented in Table 3. It indicates that N @ 60 kg/ha recorded the maximum 1000 seed weight (8.07) whereas in case of sulphur, S @ 50 kg/ha recorded the maximum 1000 seed weight (8.00). Both the nitrogen and sulphur treatments affected the test weight significantly. The increase in nitrogen and sulphur levels favoured the growth and yield attributes which resulted in significant increase of the 1000 seed weight. The above findings were found to be similar with those reported by Singh *et al.*, (2013) [12], Minz *et al.*, (2017) [8] and Sameer *et al.*, (2021) [11].

Seed yield per plant

The seed yield per plant (gm) was significantly influenced due to the different levels of nitrogen and sulphur and the concerned data has been presented in Table 3. In case of nitrogen, N @ 60 kg/ha recorded the maximum (2.02) whereas, S @ 50 kg/ha recorded the maximum (1.64) seed yield per plant amongst the levels of sulphur. The above findings were found to be similar with those of Khajani *et al.*, (2012) [7], Minz *et al.*, (2017) [8] and Gaikwad *et al.*, (2020) [5].

Straw yield per plant

The straw yield per plant (gm) was recorded and the data was analyzed. The results showed that N @ 60 kg/ha recorded the highest straw yield per plant (2.30) and S @ 50 kg/ha, among the sulphur levels recorded the maximum (1.86). Both the nitrogen and sulphur levels influenced the straw yield per plant significantly. The above findings were found to be familiar with those of Minz *et al.*, (2017) [8].

Seed yield (kg per net plot)

The application of N @ 60 kg/ha recorded the highest seed yield (kg per net plot) compared to the nitrogen levels (0.409) and among the different levels of sulphur, S @ 50 kg/ha recorded the maximum (0.372) seed yield kg per net plot. The different levels of both nitrogen and sulphur influenced the seed yield significantly. This could be attributed to the favourable effect of the increasing levels of nutrient supply on yield attributing characters which finally resulted in higher seed yield. These results were found to be in accordance with Singh *et al.*, (2013) [12], Gaikwad *et al.*, (2020) [5] and Sameer *et al.*, (2021) [11].

Straw yield (kg per net plot)

The data for straw yield (kg per net plot) was recorded after harvest and the data has been presented in Table 3. The maximum straw yield was observed with the application of N @ 60 kg/ha (0.513) and S @ 50 kg/ha (0.481). The straw yield (kg per net plot) was observed to be increased with the increment in the levels of nitrogen and sulphur and was influenced in a significant manner by the nitrogen and sulphur treatments. This could be due to the favourable effect of the increasing levels in nutrient supply which finally resulted in higher straw yield. These results were found to be similar with Minz *et al.*, (2017) [8], and Sameer *et al.*, (2021) [11].

Harvest index

The harvest index was worked out based on the economic and biological yield of respective treatments and subjected to analysis. The application of S @ 50 kg/ha recorded the highest harvest index (26.12) and in case of nitrogen, N @ 60

kg/ha recorded the maximum (28.27) harvest index. The harvest index varied significantly due to the different levels of nitrogen and sulphur. The variation in harvest index could be due to the better yield, yield attributes and also better relationship of the source and sink. The above results were found to be similar with those of Gaikwad *et al.*, (2020) [5].

Table 3: Yield studies of linseed as influenced by different treatments

	Treatments	No. of seeds per capsule	1000 Seed Weight	Seed Yield (g plant^{-1})	Straw Yield (g plant^{-1})	Seed Yield (kg per net plot)	Straw Yield (kg per net plot)	Harvest Index
A	**Varieties (V)**							
	V1 – LSL-93	9.21	8.79	1.72	1.80	0.373	0.467	26.14
	V2 - NL-260	8.84	7.12	1.33	1.62	0.338	0.432	24.38
	S.E. ±	0.06	0.004	0.03	0.05	0.005	0.008	0.59
	C.D. at 5%	0.19	0.012	0.10	0.14	0.015	0.024	1.75
B	**Nitrogen Levels (N)**							
	N1 - @ 0 kg/ha	8.67	7.83	1.17	1.31	0.303	0.377	21.72
	N2 - @ 40 kg/ha	9.02	7.95	1.40	1.54	0.355	0.459	25.79
	N3 - @ 60 kg/ha	9.37	8.07	2.02	2.30	0.409	0.513	28.27
	S.E. ±	0.08	0.005	0.04	0.06	0.006	0.010	0.72
	C.D. at 5%	0.23	0.015	0.12	0.18	0.019	0.029	2.15
C	**Sulphur Levels (S)**							
	S1 - @ 0 kg/ha	8.90	7.91	1.41	1.59	0.338	0.415	24.42
	S2 - @ 25 kg/ha	9.02	7.95	1.54	1.68	0.357	0.453	25.24
	S3 - @50 kg/ha	9.15	8.00	1.64	1.86	0.372	0.481	26.12
	S.E. ±	0.08	0.005	0.04	0.06	0.006	0.010	0.72
	C.D. at 5%	NS	0.015	0.12	0.18	0.019	0.029	NS
D	**Interactions (4)**							
	V x N							
	S.E. ±	0.11	0.007	0.06	0.08	0.009	0.014	1.02
	C.D. at 5%	NS	0.021	0.17	NS	NS	NS	NS
	V x S							
	S.E. ±	0.11	0.007	0.06	0.08	0.009	0.014	1.02
	C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
	N x S							
	S.E. ±	0.13	0.008	0.07	0.10	0.011	0.017	1.25
	C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
	V x N x S							
	S.E. ±	0.19	0.012	0.10	0.14	0.016	0.024	1.76
	C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
	General Mean	9.02	7.95	1.53	1.71	0.355	0.449	25.26

Conclusion

Based on the results obtained, it can be concluded that the supply of nitrogen, N @ 60 kg/ha and sulphur, S @ 50 kg/ha was found to be effective for the better growth and development of the crop resulting in superiority for growth and yield attributing characters like plant height, number of branches, number of capsules, seed yield etc. as compared to rest of the treatments. The increment in the levels of nitrogen and sulphur had a significant effect for most of the characters attributing to growth and yield resulting in overall development and better yield of the crop.

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