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Effect of zinc and boron nutrition on growth, yield and economics of linseed (*Linum usitatissimum* L.)

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Abstract
A field experiment was conducted during *rabi*, 2020-21 at MARS, UAS, Raichur, to study the effect of zinc and boron nutrition on growth, yield and economics of linseed (*Linum usitatissimum* L.). The experiment was laid out in randomized complete block design with 10 treatments and replicated thrice. The results revealed that soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS recorded significantly higher plant height (44.41 cm), leaf area (40.42 cm^2 $plant^{-1}$) and dry matter production (9.51 g $plant^{-1}$) which has resulted in higher seed yield (998 kg ha^{-1}), straw yield (1852 kg ha^{-1}), net returns (Rs. 34617 ha^{-1}) and BC ratio (3.27).

Keywords: Linseed, zinc, boron, yield, BC ratio

Introduction
Linseed (*Linum usitatissimum* L.) is a self-pollinated crop widely adapted to temperate climates of the world. It is an annual plant belongs to the genus Linum and the family Linaceae. Linseed is more important than other oilseeds because of its many uses and unique features. This crop's ability to withstand biotic and abiotic stresses is a key feature. In India, linseed is cultivated in about 183 thousand ha with the contribution of 111 thousand tonnes to the annual oilseed production of the country with the productivity of 605 kg ha^{-1} (Anon., 2020) [2]. In Karnataka, it is grown over an area of 26.00 thousand ha with a production of 25.27 thousand tonnes and productivity of 972.00 kg ha^{-1} (Anon., 2020) [2]. It is primarily grown for the seeds, which are used to extract oil, as well as the fibre, which is used to make linen. The oil content of the seed varies from 33 to 47 per cent depending on the linseed crop accessions. One of the limiting factors for low yield was found to be imbalance and indiscriminate use of fertilizers and emergence of micronutrient deficiencies. Micro-nutrients are defined substances that are crucial for crop growth and development. In the absence of micronutrients, plant shows physiological disorders which eventually lead to low crop yield and fair quality.

Among the micronutrients zinc is an important micronutrient that is mostly absorbed as Zn^{++}. Zinc is also necessary for the generation of biomass (Cakmak, 2008) [3]. Zinc is essential for the action of many types of enzymes (dehydrogenases, RNA and DNA polymerases), carbohydrate metabolism, and protein synthesis in oilseed crops

Boron is essential for sugar transport, cell wall formation and maintenance, membrane integrity, RNA, Indole Acetic Acid (IAA) and plant metabolism, among other metabolic processes. Boron has a synergistic effect on N uptake, which is directly linked with amino acids, RNA, and protein synthesis and chlorophyll content. Boron is essential for cell division, as well as the production of capsules and seeds (Vitosh *et al*., 1997) [11]. Keeping these points in view, an experiment was conducted to study the influence of zinc and boron nutrition on growth, yield and economics of linseed.

Materials and Methods
A field experiment was conducted during *rabi* season of 2020-21 at Main Agricultural Research Station farm, Raichur. The centre is situated between 16° 12' N latitude and 77° 20' E longitude with an altitude of 389 meters above the mean sea level and is located in North Eastern Dry Zone of Karnataka. The experiment was laid out in randomized complete block design with 10 treatments *viz*., control, soil application of $ZnSO_4$ @ 25 kg ha^{-1}, foliar application of $ZnSO_4$ @ 0.5 per cent at 45 DAS, soil application of $ZnSO_4$ @ 25 kg ha^{-1} +

foliar application of $ZnSO_4$ @ 0.5 per cent at 45 DAS, soil application of Borax @ 1.5 kg ha^{-1}, foliar application of Borax @ 0.3 per cent at 45 DAS, soil application of Borax @ 1.5 kg ha^{-1} + foliar application of Borax @ 0.3 per cent at 45 DAS, foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS, soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1}, soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS along with RDF (40:20:20 NPK ha^{-1}) common to all the treatments and replicated thrice. Foliar spray of zinc and boron were sprayed in the form of zinc sulphate and borax @ 0.5 per cent and 0.3 per cent, respectively at 45 DAS according to the treatment details. The soil of the experimental site was deep black cotton soil and is clay loamy in texture with pH of 8.20, organic carbon of 0.53 per cent and electrical conductivity of 0.34 dS m^{-1}. The available N, P_2O_5 and K_2O were 225, 33 and 241 kg ha^{-1}, respectively.

The experimental data obtained were subjected to statistical analysis adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984) [5]. The level of significance used in "F" test was given at 5 per cent. Critical difference (CD) values are given in the table at 5 per cent level of significance, wherever the "F" test was significant at 5 per cent level.

Results and Discussion

Effect on growth parameters of linseed

In the present study, soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS recorded significantly higher plant height (44.41 cm), leaf area (40.42 cm^2 plant^{-1}) and dry matter production (9.51 g plant^{-1}) as compared to rest of the treatments (Table 1.) This might be due to zinc and boron application, where zinc tends to increase the auxin biosynthesis, IAA production which helps in promoting plant growth whereas boron is involved in metabolism of carbohydrates, development of cell wall, translocation and metabolism of RNA, elongation of roots and differentiation of tissues in plants which helps in increasing the plant height. It is due to higher mineral nutrient availability which is the cause for higher source activity coupled with larger leaf area and as a result there was enhanced supply of photosynthates to growth and development of plant leading to higher dry matter production. Results reported by Gokhale *et al*. (2008) [4], Malik *et al*. (2008) [8], Raghavendra *et al*. (2020) [10] and Ahmad *et al*. (2021) [1] are in close conformity with these findings.

Effect on yield and yield parameters of linseed

Significantly higher number of capsules per plant (43.05), seeds per capsule (8.07), seed yield (998 kg ha^{-1}) and straw yield (1852 kg ha^{-1}) was recorded in the treatment where soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS was applied over all other treatments. This might be due to application of zinc and boron at proper stages and in balanced proportion helps in increasing all the yield attributes of linseed which finally contributes to higher grain yield and straw yield as a result of activation of some physiological processes like stomata regulation, chlorophyll formation and enzyme activation. Zinc is well known for its role as enzyme activator and helps in biosynthesis of auxin harmone in various metabolic activities, carbohydrate synthesis and cell elongation. Boron application enhanced the pollen tube germination, fertilization, increased root growth and protein synthesis. The results are in close conformity with the findings of Guggari *et al*. (1995) [6] and Khan *et al*. (2010) [7].

Economics

Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS recorded significantly higher gross returns (Rs. 49900 ha^{-1}) as compared to all other treatments.

Significantly higher net returns (Rs. 34617 ha^{-1}) was recorded with soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS as compared to all other treatments and was found on par with foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS (Rs. 29629 ha^{-1}) and soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} (Rs. 29597 ha^{-1}).

The data revealed that significantly higher BC ratio was recorded with soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS (3.27) (Table 3) and it was found on par with foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS (3.11), soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} (3.02) and soil application of Borax @ 1.5 kg ha^{-1} + foliar application of Borax @ 0.3 per cent at 45 DAS (2.99). The increase in net returns, B: C can be attributed to higher yield of linseed per hectare. These results are in harmony with the findings of Yadav *et al*. (2009) [12] and Raghav *et al*. (2016) [9].

Table 1: Effect of zinc and boron nutrition on growth parameters of linseed at 60 DAS

Treatments	Plant height (cm)	Leaf area (cm^2 plant^{-1})	Dry matter production (g plant^{-1})
T_1: Control	29.07	26.71	5.19
T_2: Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	34.41	31.25	6.62
T_3: Foliar application of $ZnSO_4$ @ 0.5 per cent at 45 DAS	34.21	30.97	6.28
T_4: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5 per cent at 45 DAS	39.07	35.74	7.68
T_5: Soil application of Borax @ 1.5 kg ha^{-1}	34.32	31.15	6.45
T_6: Foliar application of Borax @ 0.3 per cent at 45 DAS	34.37	31.19	6.51
T_7: Soil application of Borax @ 1.5 kg ha^{-1} + foliar application of Borax @ 0.3 per cent at 45 DAS	39.14	35.77	7.78
T_8: Foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS	39.38	35.94	7.97
T_9: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1}	39.41	35.97	8.04
T_{10}: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS	44.41	40.42	9.51
S.Em.±	1.63	1.41	0.29
C.D. at 5%	4.85	4.18	0.87

Table 2: Effect of zinc and boron nutrition on yield parameters of linseed

Treatments	Number of capsules per plant	Number of seeds per capsule	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1: Control	30.30	6.21	680	1380
T_2: Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	34.21	7.04	782	1548
T_3: Foliar application of $ZnSO_4$ @ 0.5 per cent at 45 DAS	31.61	6.80	752	1441
T_4: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5 per cent at 45 DAS	35.51	7.80	838	1625
T_5: Soil application of Borax @ 1.5 kg ha^{-1}	31.88	7.00	765	1482
T_6: Foliar application of Borax @ 0.3 per cent at 45 DAS	32.96	7.02	767	1485
T_7: Soil application of Borax @ 1.5 kg ha^{-1} + foliar application of Borax @ 0.3 per cent at 45 DAS	36.22	7.82	841	1610
T_8: Foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS	37.47	7.86	873	1678
T_9: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1}	39.16	7.89	885	1700
T_{10}: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS	43.05	8.71	998	1852
S.Em.±	1.25	0.26	34	48
C.D. at 5%	3.71	0.78	100	142

Table 3: Effect of zinc and boron nutrition on economics of linseed cultivation

Treatments	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T_1: Control	34000	20618	2.54
T_2: Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	39094	24587	2.69
T_3: Foliar application of $ZnSO_4$ @ 0.5 per cent at 45 DAS	37591	23697	2.71
T_4: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5 per cent at 45 DAS	41910	26891	2.79
T_5: Soil application of Borax @ 1.5 kg ha^{-1}	38256	24742	2.83
T_6: Foliar application of Borax @ 0.3 per cent at 45 DAS	38356	24442	2.76
T_7: Soil application of Borax @ 1.5 kg ha^{-1} + foliar application of Borax @ 0.3 per cent at 45 DAS	42060	28014	2.99
T_8: Foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS	43655	29629	3.11
T_9: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1}	44236	29597	3.02
T_{10}: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS	49900	34617	3.27
S.Em.±	1743	1743	0.13
C.D. at 5%	5178	5178	0.37

Conclusion
The experimental results indicated that there were marked variations in the productivity of linseed owing to varied micronutrient application methods. Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS recorded higher growth and yield components. Economic analysis also revealed that higher gross returns, net returns and BC ratio was obtained with soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1} and foliar application of $ZnSO_4$ @ 0.5 per cent + Borax @ 0.3 per cent at 45 DAS.

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