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Studies on the effect of zinc and boron on growth and yield of linseed (*Linum usitatissimum* L.) under limited irrigation

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Abstract
An experiment was conducted during *rabi* 2018-19 at Oilseed Research Farm, Kalyanpur, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur to study the effect of zinc and boron on growth, yield attributes, seed yield and economics of linseed. The soil of experimental site was sandy loam in texture, low in organic carbon, available nitrogen and medium in available phosphorus and potash with slightly alkaline in reaction. The experiment was conducted in randomized block design with three replications. The treatments comprised soil application of $ZnSO_4$ @ 25 kg ha^{-1}, foliar application of $ZnSO_4$ @ 0.5% at 45 DAS, soil application of $ZnSO_4$ @ 25 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5% at 45 DAS, soil application of borax @ 1.5 kg ha^{-1}, foliar application of borax @ 0.3% at 45 DAS, soil application of borax @ 1.5 kg ha^{-1} + foliar application of borax @ 0.3 at 45 DAS, soil application of $ZnSO_4$ @ 25 kg ha^{-1} + borax @ 1.5 kg ha^{-1}, foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% at 45 DAS compared with control treatment. The source of zinc and boron application were zinc sulphate hepta hydrate and borax. The experimental crop received a total rainfall of 35.2 mm which was exposed to mean minimum temperature 4.6^{0}C during fifty two standard week (24-31 December, 2018) and maximum temperature 39.4^{0}C during 15th meteorological week (9-15 April, 2019) respectively. Results exhibited that among the treatments foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% at 45 DAS found superior in terms of maximum plant growth, yield attributes and seed yield. The significantly maximum seed yield (2047 kg ha^{-1}), gross monetary return (Rs.92115 ha^{-1}) and net monetary return (Rs.65508 ha^{-1}) were recorded with the foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% at 45 DAS and was followed by the soil application of $ZnSO_4$@ 25 Kg ha^{-1} + borax@ 1.5 kg ha^{-1}.

Keywords: Linseed, zinc sulphate, borax, yield attributes, growth, yield

Introduction
Linseed is a major *rabi* oilseed crop of the country next to rapeseed and mustard. India is the third largest linseed growing country in the world (10.8%) after Canada and Kazakhistan but production wise it ranks fifth (523 kg ha^{-1}) in the world after Canada (1405 kg ha^{-1}), USA (1323 kg ha^{-1}), China (1248 kg ha^{-1}) and Kazakhistan**.** Linseed seed rich in protein (20%), oil (41%) and dietary fibre (28%). Each part of linseed has own economic importance. The seed of linseed contains 33-45 percent oil. Linseed oil is used in industry for pulp making, paper paint and fiber (Rowland *et al.*, 1995) [4]. At present linseed is cultivated in about 3.30 million ha and contribute 1.7 million tonnes to the annual oilseed production of the country. Linseed is generally grown under rainfed condition, however, its cultivation is widely extended in irrigated areas because of higher yield potential. Linseed has many industrial, medicinal properties and used for value added product. The productivity of linseed at national level is 523 kg ha^{-1} (Annonymous 2017) while at experiment level it is 1800-2000 kg ha^{-1}.The gap in yield is due to poor management of inputs. The average yield of flax is very low in India due to many constraints like poor soil fertility, inadequate application of macro and micronutrients, competition with other crop and traditional crop management practices. Due to constantly increasing demand of the crop, there is a direct need to increase seed yield potential of flax crop. Its production can be increased by growing high yielding cultivators and by the uses of macro and micronutrients in balance quantity. Micronutrients specially zinc and boron play very important role in increasing growth and yield attributes. The deficiency of these two micronutrients in soil adversely affect the growth and development of linseed.

Zinc is one of the essential micronutrients require for optimum crop growth and deficiency of zinc causes various adverse effect on growth and yield of linseed. Boron plays a key role in diverse range of plant functions including cell wall formation and stability, maintenance of structural and functional integrity of biological membranes, movement of sugar and energy into growing parts of plants, and pollination and seed set. The research were on zinc and boron application and its effect on growth and development of linseed is very meagre. Therefore, An experiment was conducted to find out the suitable dose of zinc and boron for linseed in sole as well as combined application.

Materials and Methods

The experiment was conducted during *rabi* season of 2018-19 at the Oilseed Research Farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur situated at Central part of Uttar Pradesh in randomized block design with three replications. The experiment consisted of 9 treatments *viz*. soil application of $ZnSO_4$ @ 25 kg ha^{-1}, foliar application of $ZnSO_4$ @ 0.5% at 45 DAS, soil application of $ZnSO_4$ @ 25 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5% at 45 DAS, soil application of borax @ 1.5 kg ha^{-1}, foliar application of borax @ 0.3% at 45 DAS, soil application of borax @ 1.5 kg ha^{-1} + foliar application of borax @ 0.3 at 45 DAS, soil application of $ZnSO_4$ @ 25 kg ha^{-1} + borax @ 1.5 kg ha^{-1}, foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% at 45 DAS and control. The soil of the experiment site was sandy loam in texture, low in organic carbon (0.35%) and available nitrogen (179 kg ha^{-1}) and medium in available phosphorus (22.5 kg ha^{-1}). Linseed variety ' Shekhar ' was sown in lines 25 cm apart using seed rate of 25 kg ha^{-1} and seed was treated with thiram @2.5 g kg^{-1} of seed. Recommended dose of N, P and K (80 kg N, 40 kg P_2O5, 20 kg K_2O ha^{-1}) were applied through urea, di- ammonium phosphate and muriate of potash, respectively. Half dose of nitrogen and full dose of phosphorus and potash are applied as basal at the time of sowing. The rest dose of nitrogen was applied after first irrigation. Soil application of $ZnSO_4$ hepta hydrate @ 25 kg ha^{-1} and borax were applied @1.5 kg ha^{-1} at the time of sowing and foliar application of $ZnSO_4$ @0.5% and borax @0.3% were applied at 45 DAS. Extra plants were removed by thinning at 20 days stage of the crop to maintain a single plant at a place. Only one irrigation was given at 50 DAS.

Results and Discussion

Growth and yield attributes

It is clear from the table-1 that the growth and yield attributes *viz*., plant height, number of primary branches $plant^{-1}$, number of capsules $plant^{-1}$, number of seeds $capsules^{-1}$, plant population and test weight shown significant improvement with the treatment foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% applied at 45 DAS compared to control treatment**.** The significantly increased plant height and number of primary branches observed in combined application of zinc and boron as foliar may be due to availability of theses micronutrients to the crop at appropriate vegetative stage, which may have increased the nutrient uptake and chlorophyll content and resulted in increased in plant growth. The treatment foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% at 45 DAS significantly increased the plant height, number of branches $plant^{-1}$, number of seeds $capsule^{-1}$, test weigh of linseed in comparison to other treatment and was followed by soil application of $ZnSO_4$ @ 25kg ha^{-1} + borax @ 1.5kg ha^{-1} because of foliar and soil application of micronutrients which effectively fulfil the nutrient requirements of the linseed crop as compared to other treatments. The foliar application of $ZnSO_4$ @ 0.5% + borax @0.3% at 45 DAS recorded significantly higher plant height (57.97cm),number of branches $plant^{-1}$ (4.01), number of capsules $plant^{-1}$ (53.89), number of seeds $capsule^{-1}$ (8.72) and test weight (8.30g) because the plant of these treatments have got better nutrient availability of specially zinc and boron at branching stage for their growth and development there by increasing the number of branches $plant^{-1}$. The treatment soil application of $ZnSO_4$ @ 25 kg ha^{-1} + borax @ 1.5 kg ha^{-1} was next in highest order with respect to plant height (55.19 cm), number of branches $plant^{-1}$ (3.84), number of capsules $plant^{-1}$ (51.60), number of seeds $capsule^{-1}$ (8.35), test weight (8.09g). The control treatment recorded lowest plant height (45.65 cm), number of branches $plant^{-1}$ (3.15), number of capsules $plant^{-1}$ (42.33), number of seeds $capsule^{-1}$ (6.85), test weight (7.65g). Eldaiem *et al.* (2016), Mousa *et al.* (2010) [3] were also recorded similar findings**.**

Table 1: Effect of zinc and boron on growth and yield attributes:

Treatments	Plant population At harvest	Plant Height at harvest (cm)	Number of primary branches/ plants	Number of capsules/ plant	Number of seeds/ capsules	Test weight (gm)
1.Control	79.65	45.65	3.15	42.33	6.85	7.65
2.Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	80.60	50.37	3.51	47.17	7.63	7.75
3.Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	81.25	47.57	3.28	44.08	7.13	7.71
4.Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	80.36	49.75	3.43	46.10	7.46	7.73
5.Soil application of Borax @ 1.5 kg ha^{-1}	81.50	46.76	3.23	43.41	7.02	7.67
6.Foliar application of Borax @ 0.3% at 45 DAS	80.55	46.79	3.25	43.67	7.07	7.67
7.Soil application of Borax @ 1.5 kg ha^{-1} + Foliar application of Borax @ 0.3% at 45 DAS	80.85	50.56	3.49	46.90	7.59	7.75
8.Foliar application of $ZnSO_4$ @ 0.5% +Borax @ 0.3% at 45 DAS	81.40	57.97	4.01	53.89	8.72	8.30
9.Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1}	80.75	55.19	3.84	51.60	8.35	8.09
SE(d)±	1.21	2.66	0.13	1.67	0.35	0.11
C.D at 5%	N.S.	5.65	0.29	3.56	0.75	0.23

Seed yield and economics

The data given in table-2 clearly revealed that seed yield of linseed shown positive response to different treatments. The foliar application of $ZnSO_4$ hepta hydrate @ 0.5% + borax @ 0.3% at 45DAS recorded significantly highest seed yield (2047 kg ha^{-1}) in linseed which might have influenced the metabolism of carbohydrate positively leading increased translocation and partitioning of photosynthates toward growth and yield attributing characters thereby increasing yield of linseed and the increased in seed yield of linseed was 49% over control. The treatment soil application of $ZnSO_4$ @ 25 kg ha^{-1} + borax @ 1.5 kg ha^{-1} was next in highest order with respect to seed yield (1676 kg ha^{-1}) and the increase in seed yield was 22% over control. Foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% at 45 DAS and soil application of $ZnSO_4$ @ 25 kg ha^{-1} + borax @ 1.5 kg ha^{-1} treatments recorded higher seed yield in comparison to other treatment because of better growth and yield attributing characters in these two treatments while contrary was the case for control treatment**.** Tahir *et al.* (2014) was also recorded similar findings.

Data presented in table-2 revealed that highest gross monetary return (Rs 92115 ha^{-1}) with the treatment foliar application of $ZnS0_4$ @ 0.5% + borax @ 0.3% at 45 DAS and was followed by soil application of $ZnSO_4$ @ 25 kg ha^{-1} + borax @ 1.5 kg ha^{-1} and maximum net monetary return (Rs 65508 ha^{-1}) and B:C ratio (3.46) with the treatment foliar application of $ZnS0_4$ @ 0.5% + borax @ 0.3% at 45 DAS and was followed by treatment soil application of Zn SO_4 @ 25 kg ha^{-1} + borax @ 1.5 kg ha^{-1}.

Table 2: Effect of zinc and boron on seed yield and economic parameters

Treatments	Seed yield (kg ha^{-1})	Net monetary return (Rs ha^{-1})	B:C Ratio
1.Control	1365	37775	2.49
2.Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	1533	43879	2.75
3.Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	1434	40080	2.63
4.Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	1500	41873	2.63
5.Soil application of Borax @ 1.5 kg ha^{-1}	1410	38662	2.57
6.Foliar application of Borax @ 0.3% at 45 DAS	1421	38413	2.50
7.Soil application of Borax @ 1.5 kg ha^{-1} + Foliar application of Borax @ 0.3% at 45 DAS	1524	42278	2.60
8.Foliar application of $ZnSO_4$ @ 0.5% +Borax @ 0.3% at 45 DAS	2047	65508	3.46
9.Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Borax @ 1.5 kg ha^{-1}	1676	48991	2.85
SE(d)±	73.89		
C.D at 5%	156.89		

Conclusion

It can be concluded that foliar application of $ZnS0_4$ @ 0.5% + borax @ 0.3% at 45 DAS in limited irrigated linseed improved growth, yield attributes of linseed resulting in highest seed yield (2047 kg ha^{-1}), net monetary return (Rs 65508 ha^{-1}) and benefit cost ratio (3.46) in comparison to other treatments. Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + borax @ 1.5 kg ha^{-1} also recorded higher seed yield, net monetary return and B:C ratio in comparison to rest of the treatments.

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