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Effect of boron and zinc on yield, water use efficiency and economic of linseed (*Linum usitatissimum* L.) crop under limited water supply

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Abstract
An experiment was conducted on "Effect of boron and zinc on yield, water use efficiency and economic of linseed (*Linum usitatissimum* L.) crop under limited water supply during rabi 2023-24 at oil seed farm Rama university Mandhana Kanpur. the experiment consisted 9 treatments *viz*. T_1: Control, T_2: Soil application of $ZnSO_4$ @ 25 kg/ ha, T_3: Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS, T_1: Soil Application of $ZnSO_4$ @ 25 kg/ ha + Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS, Ts: Soil application Borax @ 1.5 kg/ha, T_6: Foliar application of Borax @ 0.3% at 45 DAS, T_1: Soil application of Borax @ 1.5 kg/ha, Foliar application of Borax @ 0.3% at 45 DAS, T_8: Foliar application of $ZnSO_4$ @ 0.5% + Borax @ 0.3% at 45 DAS and T_9: Soil application of $ZnSO_4$ @ 25 kg/ha + Borax @ 1.5 kg/ha in soil assigned in randomized block design replicated thrice during rabi season of 2023 -2024. The Linseed c.v. Shekhar was used in the experiment. The soil of the experimental plot was sandy in texture, medium in fertility and slightly acidic in reaction. The weather during the experimental period was by and large normal and devoid of any extreme conditions. The results in significantly maximum plant height, yield attributes, oil content, oil yield and seed yield, stover yield, Root development, minimum water use and ultimately higher seed yield and WUE as compared to other corresponding tested treatments indicated that application of $ZnSO_4$ @ 25 kg/ha + Borax @ 1.5 kg/ha incorporated in the soil have fetched highest net return of Rs 63578 having B:C ratio of 3.11 would be quite remunerative for higher productivity along with water use efficiency in light textured alluvial soils of Uttar Pradesh.

Keywords: Boron, zinc, yield, *Linum usitatissimum* L.

Introduction
India which has total cultivatied area is about 140 m ha and in which contain 70m ha i.e. 50% of total cultivated area of India spread over 290 district including states of Rajasthan, Andhra Pradesh, Uttar Pradesh, Karnataka, Punjab, Haryana & Tamil Nadu etc. The Allocation of the world natural resources of the country is highly uneven over space & time. India, which has 17.86% of the world population, about 4% of the World water resources and about 2.4% of the world land area. (Adhunik Mrida Sanrakshan Evam Jal Prabandh-2022). Over 82-90% of run off in Indian rivers occurs mainly in rainy season i.e. June to September, due to improper policy of water harvesting and water storage, which create the situation of drought in some area of the country & create situation of flood in another part of country over the similar time, these aberrant weather condition lowering the production potential of the country.
India's per capita natural resources, both land and water, are dwindling at an alarming rate. In 1947, the average person had access to 0.43 hectares of cultivated land, which dropped to 0.30 hectares just four years later. By 2008, this figure had shrunk even further to 0.13 hectares, and by 2021, it reached a mere 0.09 hectares per person. Similarly, water availability has plummeted from 6,008 cubic meters per person in 1947 to 5,177 cubic meters in 1951 and a critical 1,486 cubic meters in 2021- a level deemed "water scarce" by the Director General of ICAR, New Delhi.

Linseed (*Linum usitatissimum* L.) is one of the most important and oldest crop plants grown in about fourty seven 47 countries which are growing for production of seed oil and fibre. In Canada and South West part of Asia, Flax is mainly grown for production of oil However in countries like Russia, Egypt and north western part of Europe, Linseed is primarily grown for the yielding of fibre which has high quality that can be used for making linen fabrics and several other products.

Linseed covers an area of 32.23 lakh ha, producing 30.68 lakh tonnes with an average productivity of 952 kg/ha in the world, However in India, Linseed/Flax covers an area of 2.39 lakh ha, yielding 1.67 lakh tonnes with an average productivity 698 kg/ha. According to upag.gov.in 2022-23 India is on 5th position in area. With the ever alarming increase in global population, water for food production in rainfed area is becoming an scarce resources. About 50.5% of total arable land in India comes under rainfed conditions characterized by low productivity, low income, less employment and high poverty. A large number of risks are involved in crop production in these areas due to uncertain and uneven distribution of rainfall. Moisture regime is consider one of the important determinants of crop growth, development and production and hence it play a vital role in food sufficiency status of the nation. The amount of rainwater absorved and stored in soil profile is only source of water for crop production in rainfed areas. Selection of suitable crops and varieties suited to rainfed areas may produce maximum yield per unit of area by better utilization of per unit of available water.

Materials and Methods

The experiment was conducted during Rabi season of 2023 - 2024 in Farm of Rama University of Agriculture and Technology, Kanpur in alluvial soil. Soil of the experimental plot was sandy in texture and slightly calcareous having organic carbon 1.33%, total nitrogen 133kg/ha, available P_2O_5 .21.79 Kgha-1, available K_2O 112 kg ha-1, pH6.6, E.C.0.28 ds/m, maximum water holding capacity 27.05%, bulk density 1.48 g/cc, and porosity 43.5.The 9 treatments *viz*: T_1: control(3:2:1 NPK), T_2 - Soil application of $ZnSO_4$ @ 25 kg $ha^{-1,}$ T_3 -Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS, T_4 - Soil Application of $ZnSO_4$ @ 25 kg ha^{-1}+ Foliarapplication of $ZnSO_4$ @ 0.5% at 45 DAS,T_5-Soil application Borax @ 1.5 kg ha,$^{-1}$ T_6 - Foliar application of Borax @ 0.3% at 45 DAS, T_7 - Soil application of Borax @ 1.5 kg ha^{-1} Foliar application of Borax @ 0.3% at 45 DAS, T_8 - Foliar application of $ZnSO_4$ @ 0.5% + Borax @ 0.3% at 45 DAS, T_9 - Soil application of $ZnSO_4$ @ 25 kg ha^{-1}+ Borax @ 1.5 kg ha^{-1}, were replicated three times in Randomized Block design. The seeds of Shekhar were pretreated with Chlorpyriphos and Carbendazim + Mancozeb @ 6.5 mL and 2 g per kg of seed respectively and were sown on 19th October, 2024. with a spacing of 25 cm between rows and 10 cm between plants. Inorganic nitrogen (urea) was applied in 2 splits (as basal dose and at 30 DAS). Full dose of P (SSP) and K (MOP) was applied to all the plots as basal dose according to the treatments (Recommended dose of fertilizers were 30-40-50 N, P_2O_5, K_2O kg ha^{-1}). Application of gypsum @ 500 kg ha^{-1} and earthing up was done at pegging stage (45 DAS). The crop was supplied with adequate water as and when needed. To maintain weed-free condition in the plots for good crop growth, two manual weedings were carried out at 15 DAS and 30 DAS in the experimental field.Crop is harvested at physiological maturity on 20/03/2024.The linseed variety used for sowing was Shekhar. Spacing 25cm row to row and 10cm plant to plant, seed rate used 30 kg /ha. The crop was supplied with adequate water as and when needed. To maintain weed-free condition in the plots for good crop growth, two manual weedings were carried out at 15 DAS and 30 DAS in the experimental field.crop is harvested at physiological maturity on 20-03-24.

Results Discussion

The plant height of linseed at different growth stages (30 DAS, 60 DAS, 90 DAS, and at harvest) was influenced by the application of micronutrients. At 30 DAS, there was no significant difference in plant height because no foliar micronutrient application was made. However, at 60 DAS, 90 DAS, and harvest, plant height varied significantly due to the application of micronutrients (Zn and B). The highest plant height was observed with the combined application of borax at 1.5 kg/ha as a soil application and 0.3% as a foliar application at 45 DAS (Treatment T_7), with heights of 66.67 cm, 83.63 cm, and 84.00 cm, respectively. The shortest plant height was recorded in Treatment T_1, with measurements of 56.74 cm at 60 DAS, 75.12 cm at 90 DAS, and 78.14 cm at harvest.

Among the various treatments, the soil application of borax at 1.5 kg/ha combined with a foliar application of borax at 0.3% at 45 DAS (T_7) produced the highest number of capsules per plant. This result was comparable to the following treatments: foliar application of $ZnSO_4$ at 0.5% plus borax at 0.3% at 45 DAS (T_8), soil application of $ZnSO_4$ at 25 kg/ha plus foliar application of $ZnSO_4$ at 0.5% at 45 DAS (T_4), soil application of $ZnSO_4$ at 25 kg/ha plus borax at 1.5 kg/ha (T_9), and foliar application of $ZnSO_4$ at 0.5% at 45 DAS (T_3 and T_6). The control treatment with a foliar spray of water (T_1) had the fewest capsules per plant. The number of capsules per plant was significantly influenced by the interaction between flax cultivars and micronutrient (Zn, B) application under new soil conditions. The Sakha-2 cultivar, when sprayed with 600 ppm of micronutrients, showed the highest mean values for seed yield characteristics.

The data revealed that all micronutrient treatments produced a significantly higher number of seeds per capsule compared to the control (water spray) (T_1). Among the micronutrient treatments, the soil application of borax at 1.5 kg/ha combined with a foliar application of borax at 0.3% at 45 DAS (T_7) recorded the highest number of seeds per capsule. The lowest number of seeds per capsule was observed in the control treatment (T_1). Nofal *et al*. (2011) [13] reported that the highest rate of seeds per capsule was found when the zinc concentration was 70 mg/l, while the no-spraying treatment resulted in a lower rate. Similar results were also reported by Bakry *et al*. (2015) [1].

It is clearly shown that 1000 – seed weight of linseedwas not significantly affected due to application of micronutrients. However, maximum1000- seed weight were recorded under treatment of soil application of borax @ 1.5 kgha-1 and foliar application of borax @ 0.3% at 45 DAS (T_7) and minimum noted in foliar spray of water (control) treatment (T_1)

The data clearly shows that the soil application of borax at 1.5 kg/ha, along with a foliar application of borax at 0.3% at 45 DAS (T_7), resulted in the highest seed yield among the micronutrient applications. Conversely, the lowest seed yield of 1319 kg/ha was significantly observed in the control treatment, which involved foliar spraying of water (T_1).

The stover yield data revealed that the highest stover yield per hectare throughout the entire experiment was achieved with the soil application of borax at 1.5 kg/ha and the foliar application of borax at 0.3% at 45 DAS (T_7). This result was comparable to the treatments involving the foliar application of $ZnSO_4$ at 0.5% at 45 DAS (T_6 and T_3). The minimum stover yield was recorded in the control treatment, which included foliar spraying of water (T_1).

The findings revealed that different micronutrients (B, Zn) did not influence the harvest index. Nevertheless, the highest harvest index (HI) was observed with the soil application of borax at 1.5 kg/ha and foliar application of borax at 0.3% at 45 DAS (T_7). Conversely, the lowest harvest index was noted in the control treatment, where water was sprayed foliarly (T_1).

Oil content was found significant difference among treatments, the highest oil content was recorded under soil application of borax @ 1.5 kg ha-1 and foliar application of borax @ 0.3% at 45 DAS (T_7), The lowest oil content recorded under foliar spray of water (control) treatment (T_1).

The soil application of $ZnSO_4$ @ 25 kgha^{-1}+ foliar application of $ZnSO_4$ @ 0.5% 45 DAS (T_4), computed the highest cost of cultivation (Rs.2150 ha^{-1}) due to higher treatment cost. However lowest was noted under application of water spray control (T_1).

The treatment involving soil application of borax at 1.5 kg/ha combined with a foliar application of borax at 0.3% at 45 DAS (T_7) yielded the highest gross return. Similarly, this treatment also resulted in the highest net return and B:C ratio. In contrast, the lowest net return, gross return, and B:C ratio were observed under treatment (T_1).

Table 1: Plant height (cm) at different intervals of linseed as influenced by different (B, Zn) micronutrients application. Plant height

Treatment	30 DAS		60 DAS	90 DAS harvest	
T_1	Control	15.69	56.74	75.12	78.14
T_2	Soil application of $ZnSO_4$ @ 25 kg/ha	17.40	60.88	76.47	79.34
T_3	Foliar application of $ZnSO_4$ @ 0.5% a T_4 5 DAS	18.82	61.51	78.65	80.27
T_4	Soil application of $ZnSO_4$ @ 25 kg/ha + foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	20.74	63.15	81.51	82.77
T_5	Soil application of borax @ 1.5 kg/ha	16.86	59.68	75.57	78.99
T_6	Foliar application of borax @ 0.3% at 45 DAS	19.52	62.20	80.44	80.78
T_7	Soil application of borax @ 1.5 kg/ha + foliar application of borax @ 0.3% at 45 DAS	22.84	66.67	83.63	84.00
T_8	Foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% at 45 DAS	21.30	65.81	82.06	83.79
T_9	Soil application of $ZnSO_4$ @ 25 kg/ha + borax @ 1.5 kg/ha	20.61	63.07	81.42	82.21
	SEm±	0.45	1.86	1.84	1.26
	CD(P=0.05)	NS	5.57	5.51	3.79

Table 2: Yield attributing character of linseed as influenced by different micronutrients (B,Zn) application.

Treatment		Capsulesplant^{-1} (No.)	Seedscapsule^{-1} (No.)	1000-seedsweight (g)
T_1	Control	49.27	7.47	6.50
T_2	Soil application of $ZnSO_4$ @ 25 kg/ha	54.25	7.83	6.60
T_3	Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	57.72	8.07	6.69
T_4	Soil application of $ZnSO_4$ @ 25 kg/ha+ foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	59.93	8.30	6.84
T_5	Soil application of borax @ 1.5 kg/ha	52.24	7.67	6.57
T_6	Foliar application of borax @ 0.3% at 45 DAS	58.10	8.10	6.75
T_7	Soil application of borax @ 1.5 kg/ha +foliar application of borax @ 0.3% 45DAS	62.81	8.47	6.94
T_8	Foliar application of $ZnSO_4$ @ 0.5% +borax @ 0.3% at 45 DAS	61.57	8.33	6.91
T_9	Soil application of $ZnSO_4$ @ 25 kg/ha+ borax @ 1.5 kg/ha	59.38	8.13	6.81
SEm±		2.72	0.19	0.18
CD(P=0.05)		8.15	0.57	NS

Table 3: Seed yield, stover yield and harvest index of linseed as influenced by different micronutrients (B,Zn) application.

Treatment		Seed Yield (kg ha^{-1})	Stover Yield (kgha^{-1})	Harvest Index
T_1	Control	1319	3078	30.00
T_2	Soil application of $ZnSO_4$ @ 25 kg/ha	1519	3562	29.89
T_3	Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	1590	3683	30.16
T_4	Soil application of $ZnSO_4$ @ 25 kg/ha + foliar application of $ZnSO_4$ @ 0.5%at 45 DAS	1766	4132	29.94
T_5	Soil application of borax @ 1.5 kg/ha	1442	3356	30.06
T_6	Foliar application of borax @ 0.3% at 45 DAS	1625	3796	29.98
T_7	Soil application of borax @ 1.5 kg/ha + foliar application of borax @ 0.3% at 45 DAS	1853	4338	29.93
T_8	Foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% at 45 DAS	1801	4160	30.21
T_9	Soil application of $ZnSO_4$ @ 25 kg/ha + borax @ 1.5 kg/ha	1696	3997	29.79
	SEm±	103.18	238.72	0.20
	CD(P=0.05)	309.35	715.67	NS

Table 4: Oil content and oil yield of linseed as influenced by different micronutrients (B,Zn) application.

Treatment		Oil content (%)	Oil yield (kgha^{-1})
T_1	Control	36.1	476.16
T_2	Soil application of $ZnSO_4$ @ 25 kg/ha	37.9	575.70
T_3	Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	36.8	585.12
T_4	Soil application of $ZnSO_4$ @ 25 kg/ha + foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	38.3	676.38
T_5	Soil application of borax @ 1.5 kg/ha	37.6	542.19
T_6	Foliar application of borax @ 0.3% at 45 DAS	37.6	611.00
T_7	Soil application of borax @ 1.5 kg/ha + foliar application of borax @ 0.3% at 45 DAS	38.7	717.11
T_8	Foliar application of $ZnSO_4$ @ 0.5% + borax @ 0.3% at 45 DAS	38.6	695.19
T_9	Soil application of $ZnSO_4$ @ 25 kg/ha + borax @ 1.5 kg/ha	38.1	646.18
	S.Em±	0.84	28.05
	CD (P=0.05)	2.50	82.96

Table 5: Economics of linseed as influenced by different micronutrients application

Treatment	Cost of cultivation^{-1} (Rs ha)	Gross returns^{-1} (Rs ha)	Net returns^{-1} (Rs ha)	B:C ratio
T_1: - Control	19604	59803	40200	2.05
T_2: Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	21104	68863	47759	2.26
T_3: - Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS	20004	72061	52058	2.60
T_4: Soil Application of $ZnSO_4$ @ 25 kg ha^{-1}+ Foliar application of $ZnSO_4$ @ 0.5% a$T_4$5 DAS	21504	80057	58554	2.72
T_5: -Soil application Borax @ 1.5 kg ha^{-1}	19904	65375	45472	2.28
T_6: - Foliar application of Borax @ 0.3% at 45 DAS	20154	73684	53530	2.66
T_7: - Soil application of Borax @ 1.5 kg ha^{-1} Foliar application of Borax @ 0.3% at 45 DAS	20454	84031	63578	3.11
T_8: -Foliar application of $ZnSO_4$ @ 0.5% + Borax @ 0.3% at 45 DAS	20304	81616	61312	3.02
T_9: - Soil application of $ZnSO_4$ @ 25 kg ha^{-1}+ Borax @ 1.5 kg ha^{-1}	21404	76929	55525	2.59

Conclusion

The application of micronutrients, particularly borax and zinc, significantly influenced various growth parameters and yield components of linseed. Plant height, capsules per plant, seeds per capsule, seed yield, stover yield, harvest index, oil content, and economic indicators such as cost of cultivation, gross return, net return, and benefit-cost ratio were all impacted by these micronutrient applications. Among the treatments studied, the combined application of borax at 1.5 kg/ha as soil application and 0.3% as foliar application at 45 DAS (Treatment T_7) consistently produced superior results across multiple parameters, demonstrating its effectiveness in enhancing linseed productivity and economic returns. These findings underscore the importance of micronutrient management strategies in optimizing crop performance and profitability in linseed cultivation.

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