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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(11): 818-821

www.thepharmajournal.com
Received: 16-08-2023
Accepted: 22-10-2023

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Effect of zinc and boron on yield maximization of linseed (*Linum usitatissimum* L.) Under irrigated condition

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Abstract
A field experiment was carried at Research Farm of Zonal Research Station, Assam Agricultural University, Shillongani, Nagaon during rabi season of 2019-20, 2020-21 and 2021-22 to validate the response of micro nutrients on growth and yield of linseed (*Linum usitatissimum* L) under limited irrigation. The experiment was laid out in randomized block design with three replications, consisting nine treatments: Recommended Dose of Fertilizer (RDF) i.e. 40- 20- 10 kg N-P_2O_5-K_2O/ha as Control (T_1), RDF + Soil application of $ZnSO_4$ @ 25 kg/ha (T_2), RDF + Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS (T_3), RDF + Soil application of $ZnSO_4$ @ 25 kg/ha + Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS (T_4), RDF + Soil application of Borax @ 1.5 kg/ha (T_5), RDF + Foliar application of Borax @ 0.3% at 45 DAS (T_6), RDF + Soil application of Borax @ 1.5 kg/ha + Foliar application of Borax @ 0.3% at 45 DAS (T_7), RDF + Foliar application of $ZnSO_4$ @ 0.5% + Borax @ 0.3% at 45 DAS (T_8) and RDF + Soil application of $ZnSO_4$ @ 25 kg/ha + Borax @ 1.5 kg/ha (T_9). Pooled estimation of three consecutive years revealed that application RDF along with Soil application of $ZnSO_4$ @ 25 kg/ha + Borax @ 1.5 kg/ha (T_9) as basal recorded highest plant population (7,89,890/ha), seed yield (803.78 kg/ha) as well as benefit cost ratio of 2.83.

Keywords: Foliar application, linseed, limited irrigation, micro nutrient, soil application, zinc sulphate

Introduction

Linseed (*Linum usitatissimum* L.) is a major rabi oilseed crop of the country occupies second position after Rapeseed & Mustard in terms of area and production among the rabi oilseed crops. India occupies fourth largest linseed growing country in the world (10.8%) after Kazakhistan, Canada and Russia. The crop has tremendous scope and medicinal and industrial uses. Every parts of linseed plant have specific economic uses. Linseed is basically an industrial oilseed crop and its each and every part is endowed with commercial and medicinal importance. Linseed is a rich source of protein (20%), oil (41%) and dietary fibre (28%) and omega-3-fatty acid (Mevada *et al.*, 2017) [6]. Major linseed producing states of India are Madhya Pradesh, Karnataka, Chhattisgarh, Jharkhand, Bihar, Maharashtra, Odisha, Uttar Pradesh, West Bengal and Assam. At present linseed is cultivated in about 326.01 thousand ha contributing 173.62 thousand tonnes to the annual oilseed production of the country with the productivity of 545 kg/ha (AICRP on linseed, 2019, Proceedings of Annual Group Meet). In Assam, as regards to the area and production of Linseed the area was highest (10,248ha) in 1999-2000 with a total production of 5323 MT and the productivity was 519 kg/ha. Since then the area is decreasing day by day and it comes to 4629 ha in 2019-20 with an increase in productivity of 615kg/ha (Agril. Statistics of Assam).

Linseed crop has many medicinal as well as industrial importance and used in value addition. It is generally grown as rainfed crop with poor nutrient management, one of the major constraints. In India the productivity of linseed is very low due to age old management practices, inadequate supply of macro as well as micro nutrients. The demand of the crop is constantly increasing in international market. There is a need of increasing seed yield potential of linseed due to its importance in industrial and medicinal purposes. Production potential of the crop can be maximised by cultivating high yielding variety and supplementing a balance nutrition. Balance nutrition can be achieved by providing macro as well as micro nutrients. Micronutrients mainly zinc and boron plays a major and significant role in growth and to plant diseases and enzyme activities involved in the synthesis of metabolites, which in turn increases the crop growth and yield (Badiyala *et. al.*,2011) [4]. The deficiency of these nutrients may restrict the growth and production of the crop to fullest potential. Therefore, the experiment was conducted to investigate and validate a suitable dose of zinc and boron for linseed.

Materials and Methods

The experiment was conducted during rabi season of 2019-20, 2020-21 and 2021-22 at Research Farm, Zonal Research Station, Shillongani, Assam, which is situated at an altitude of 50.2 meters above mean sea level, with longitude $90^0$45'E and latitude of $26^0$21'N with an average annual rainfall of 2500 mm. The soil of the experimental area was sandy loam in nature with pH of 5.3, available nitrogen was 259.6 kg/ha, available phosphorous was 21.4 kg/ha, available potash was 133.1 kg/ha, available zinc 0.76 ppm, available boron 1.69 ppm and organic matter was 0.88%. The highest total rainfall and maximum temperature received by the experimental block during the year 2019-20 (Fig 1). The experiment was laid out in randomized block design with three replications. The treatments consisted of nine micronutrient application practices *viz*, RDF as Control (T_1), RDF + Soil application of $ZnSO_4$ @ 25 kg/ha (T_2), RDF + Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS (T_3), RDF + Soil application of $ZnSO_4$ @ 25 kg/ha + Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS (T_4), RDF + Soil application of Borax @ 1.5 kg/ha (T_5), RDF + Foliar application of Borax @ 0.3% at 45 DAS (T_6), RDF + Soil application of Borax @ 1.5 kg/ha + Foliar application of Borax @ 0.3% at 45 DAS (T_7), RDF + Foliar application of $ZnSO_4$ @ 0.5% + Borax @ 0.3% at 45 DAS (T_8) and RDF + Soil application of $ZnSO_4$ @ 25 kg/ha + Borax @ 1.5 kg/ha (T_9). The linseed variety 'Shekhar' was taken with a seed rate of 15 kg/ha in row spacing of 25 cm. A recommended dose of 40 kg N, 20 kg P and 10 kg K /ha were applied to the crop. Sowing was done 7th November, 21st November and 2nd November in the year 2019-20, 2020-21 and 2021-22 respectively and harvested on 13th March, 19th March and 7th April 2020, 2021 and 2022 respectively. Weed management and plant protection measures were taken as per package of practice and as an when needed. One irrigation was given to the crops after first weeding i.e. 25 days after sowing. The growth parameter Plant height, plant population and Branches/plant were recorded as per the standard procedure by sampling from three places in each plot. Seed yield was recorded from net plot area and converted to kg/ha and economic analysis was done at prevailing market price. All the data recorded analysed statistically at 5% level of significance.

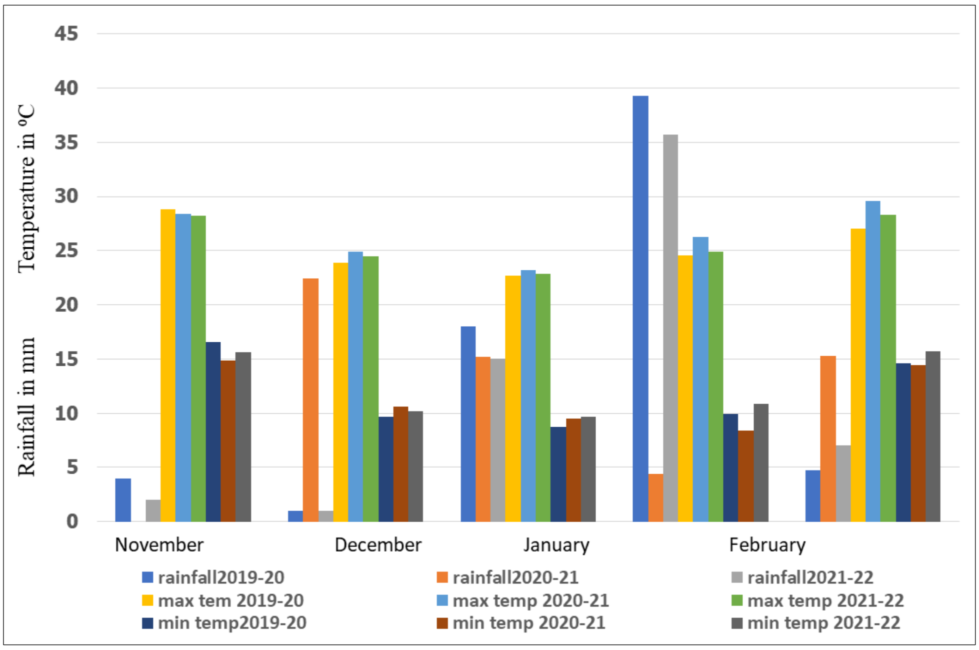

Fig 1: Monthly weather parameter of three consecutive years

Results and Discussion

Effect of Zinc and Boron on Growth Parameters

Plant height is the ultimate structure of a typical mature individual can attain in their life cycle. Plant height was not significantly varying in this experiment due to zinc and boron application. In pooled estimation, the highest was recorded in T_5 i.e. RDF + Soil application of Borax @ 1.5 kg/ha. Similarly, the no. of branches/plant were not showed any significance differences with application of zinc and boron. However, the maximum branches/plant were noticed in T_5 i.e. RDF + Soil application of Borax @ 1.5 kg/ha and RDF + Soil application of Borax @ 1.5 kg/ha + Foliar application of Borax @ 0.3% at 45 DAS (T_7) (Table 1). Application of zinc and boron had significant effect on plant population/ha in all three years of experiment. At harvest the treatment with RDF + Foliar application of $ZnSO_4$ @ 0.5% at 45 DAS (T_3) and RDF + Foliar application of Borax @ 0.3% at 45 DAS (T_6) recorded the maximum plant population which was however statistically at par with RDF + Soil application of $ZnSO_4$ @ 25 kg/ha + Borax @ 1.5 kg/ha (T_9) (Table 1). The increased in plant height, Plant population and number of primary branches observed, these may be due to availability of the micronutrients to the crop at appropriate stages, which may have increased the nutrient uptake and chlorophyll content and resulted in increased in plant growth. Research findings of Kumari *et al.*, (2021) [5] and Alam *et al.*, (2021) [3] were also suggested that application of boron and zinc along with RDF maximises in attainment of plant growth characters.

Table 1: Growth parameters of linseed as affected by application of zinc and boron (3 years pooled)

Treatment	Plant Height (cm)				No of branches/plant				Plant Population (10^3/ha)			
	2019-20	2020-21	2021-22	Mean	2019-20	2020-21	2021-22	Mean	2019-20	2020-21	2021-22	Mean
T_1	63.2	77.3	63.2	67.9	2.2	3.5	2.2	2.6	715.0	840.0	709.0	752.7
T_2	63.3	73.7	63.3	66.7	2.7	4.1	2.7	3.1	664.0	768.0	650.0	688.9
T_3	69.1	75.7	69.1	71.3	2.8	3.8	2.8	3.2	680.0	803.0	802.0	802.4
T_4	64.3	75.0	64.3	67.8	2.4	4.3	2.4	3.0	806.0	748.0	731.0	737.0
T_5	69.5	76.0	69.5	71.7	3.1	4.1	3.1	3.4	688.0	672.0	754.0	726.3
T_6	67.7	79.3	67.7	71.6	2.8	3.9	2.8	3.2	722.0	797.0	802.0	800.1
T_7	65.7	73.0	65.7	68.1	3.1	4.1	3.1	3.4	640.0	687.0	683.0	684.4
T_8	64.1	72.7	64.1	66.9	3.3	3.3	3.3	3.3	639.0	667.0	658.0	660.8
T_9	61.9	78.7	61.9	67.5	2.8	3.7	2.8	3.1	755.0	772.0	799.0	789.9
S.Em+	3.5	3.7	3.5	1.2	0.5	0.3	0.5	0.2	37.5	39.1	39.8	32.3
CD5%	NS	NS	NS	3.5	NS	NS	NS	NS	131.5	117.2	NS	64.9
CV%	9.3	8.4	9.3	8.9	28.8	14.9	28.8	9.6	9.4	9.0	9.4	9.3

Effect of Zinc and boron on yield attributes and yield of linseed: Analysis of data revealed that capsule no/plant significantly differed with different treatments in all the three years and similar trend was followed in pooled estimation also. From the data it was noticed that capsule no/plant was maximum in treatment receiving RDF + Soil application of Borax @ 1.5kg/ha + Foliar application of Boron @ 0.3% at 45 DAS (T_7) which was at par with RDF + Soil application of $ZnSO_4$ @ 25 kg/ha + Borax @ 1.5 kg/ha(T_9). Yield is the interaction of the environment with all growth and developmental process that occur throughout the crop life cycle. It was observed from the three years of experimentation that seed yield of linseed was increases with application of micro nutrients along with recommended fertilizers. Soil application of RDF + $ZnSO_4$ @ 25 kg/ha + Borax @ 1.5 kg/ha (T_9) recorded highest seed yield over other treatments, in all the years except 2019-20. However, in pooled estimation it was revealed that seed yield was maximum in T_9, which might have influenced the metabolism of carbohydrate positively leading to increased translocation and partitioning of photosynthates towards growth and yield attributing characters, thereby increasing seed yield of linseed. The treatment with RDF+ Soil application of $ZnSo_4$ @ 25kg/ha + Foliar application of $ZnSo_4$ @0.5% at 45 DAS (T_4) was recorded second highest in respect to seed yield (Table 2). Research findings of Tahir *et al.*, (2014) [8] and Kumari *et al.*, (2021) [5], was also in similar accordance with this experimental finding.

Table 2: Yield attributes and seed yield of linseed as affected by application of zinc and boron (3 years pooled)

Treatment	No of capsule/Plant				Seed Yield (kg/ha)			
	2019-20	2020-21	2021-22	Mean	2019-20	2020-21	2021-22	Mean
T_1	37.7	74.2	37.7	49.8	509.0	590.0	509.0	515.9
T_2	41.5	104.2	41.5	62.4	663.0	852.0	662.7	725.8
T_3	31.7	91.4	31.7	51.6	603.0	717.0	602.7	640.9
T_4	51.8	108.1	51.8	70.6	780.0	855.0	733.7	788.4
T_5	34.3	96.1	34.3	54.9	634.0	649.0	633.7	638.7
T_6	39.1	90.2	39.1	56.1	547.0	635.0	546.7	576.2
T_7	54.8	101.5	54.8	70.4	683.0	746.0	682.7	703.9
T_8	31.6	71.0	31.6	44.7	584.0	675.0	583.7	614.1
T_9	46.8	104.3	46.8	66.0	749.0	913.0	749.3	803.8
S.Em+	3.5	5.1	3.5	3.2	28.6	42.8	28.6	27.2
CD5%	10.5	15.4	10.5	9.7	85.5	128.5	83.2	54.6
CV%	15.1	9.5	15.1	9.5	7.7	10.2	7.7	8.6

Effect of micro nutrients on Net Monetary Return and Benefit to cost ratio

Adoption of any agricultural practice in present days can only be viable and acceptable to farmers if it is economically feasible. The economics of linseed were significantly affected by different treatments. The highest Net Monetary Return and benefit cost ratio were recorded in soil application of RDF + $ZnSO_4$ @ 25 kg/ha + Borax @ 1.5 kg/ha (T_9) in all the three years of experiment as well as in pooled analysis (Table 3). The lowest net monetary return and benefit cost ratio were observed in RDF + Foliar application of Borax @ 0.3% at 45 DAS (T_6). These finding are in the close vicinity with those reported by Singh *et al.*, (2020) [7] and Tahir *et al.*, (2014) [8].

Table 3: Net return and benefit cost ratio of linseed affected by application of zinc and boron (3 years pooled)

Treatment	Net Return (Rs. /ha)				Benefit: Cost			
	2019-20	2020-21	2021-22	Mean	2019-20	2020-21	2021-22	Mean
T_1	13250.0	14283.0	13250.0	13594.4	2.1	2.2	2.1	2.1
T_2	19058.0	28526.0	19058.0	22213.8	2.4	3.0	2.4	2.6
T_3	15633.0	21367.0	15633.0	17544.4	2.1	2.5	2.1	2.2
T_4	22642.0	26358.0	22642.0	23880.5	2.4	2.6	2.4	2.5
T_5	19333.0	19083.0	19333.0	19250.0	2.6	2.4	2.6	2.5
T_6	12893.0	17327.0	12893.0	14371.1	1.9	2.2	1.9	2.0

T_7	19543.0	22727.0	19543.0	20604.4	2.3	2.6	2.4	2.4
T_8	14443.0	19010.0	14443.0	15965.5	1.9	2.3	1.9	2.1
T_9	23242.0	31408.0	232420	25963.8	2.6	3.2	2.6	2.8
S.Em+	1430.0	2142.8	1430.0	1388.8	0.1	0.2	0.1	0.5
CD5%	4277.0	6402.4	4277.0	2792.5	0.3	0.04	0.3	0.9
CV%	13.9	16.7	13.9	15.2	7.9	10.5	7.9	8.6

Conclusion

Linseed production of the country has been continuously declining though its export demand is raising. Poor nutrient supply or no use of fertilizer is the main limiting factor for lower yield. An appropriate agronomic measure can definitely boost the production potential of the crop. To obtain higher yield judicious use of fertilizers mainly micro nutrient zinc and boron is the major research finding of three consecutive years. Based on the findings, it can be concluded that application of recommended dose of fertilizers i.e. 40:20:10 kg N-P_2O_5-K_2O/ha along with soil application of zinc sulphate heptahydrate @ 25 kg/ha and borax @ 1.5 kg/ha can be recommended for linseed cultivation with limited irrigation for accomplishing better growth and seed yield as well as for net monetary return and benefit to cost ratio.

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