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Effect of boron and molybdenum on growth and yield of Lentil (*Lens culinaris* L.)

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Abstract
A field experiment was conducted at the crop research farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) India, a field experiment was carried out during the Rabi season of 2024. Effect of Boron and Molybdenum on Lentil Growth and Yield (*Lentils culinaris* L.) is the title of the current study. The randomized block design (RBD) used in this experiment included 10 distinct treatment combinations that were reproduced three times with application of Different levels of Boron (0.25, 0.50 and 1.0 kg/ha and Molybdenum 1 g/kg, 2 g/kg and 3 g/kg Seed along with RDF: - 20:40:20 kg NPK/ha). The result showed that significantly higher growth parameters *viz.,* Plant (39.36 cm), number of nodule/plant (30.93), Number of branch/plant (7.10), maximum plant dry weight (7.67 g/plant), Crop growth rate (6.54 g/m2/day) was recorded with the application of Boron at 1.0 kg/ha along with Molybdenum at 3 g/kg Seed. And significantly maximum number of pod/plant (84.97), number of seed/pod (2.84), Grain yield (1.77 t/ha), Straw yield (3.61 t/ha). Maximum gross returns (INR 136828.00 /ha), Net return (INR 93725.10 /ha) and benefit cost ratio (2.17) was recorded in (T_9) with application of Boron at 1.0 kg/ha + Molybdenum at 3 g/kg Seed.

Keywords: Boron, economics, growth, lentil, molybdenum, yield

Introduction

An essential crop type that offers high-quality protein to India's largely vegetarian populace are pulses. Due to their compatibility with crop rotation and the mixed or intercropping systems used in various agro-ecological zones, pulses are an essential part of cropping systems in India. Despite being the world's biggest producer and consumer of pulses, India's average productivity is extremely poor. As per Abraham et al. (2011) [1], the acreage, production, and productivity of pulse crops are 252.59 lakh hectares, 16.47 million tonnes, and 652 kg/ha, respectively. As a result, our nation needs to produce more pulses.

One of the most ancient and nutrient-dense pulse crops is Lentil (*Lens culinaris* L.). Its cultivation dates back to the early days of agriculture. In troublesome places, it is often utilized as a cover crop to prevent soil erosion. Most people use it as "dal." The grain that was eaten whole either split or decorticated. The color of the cotyledons is either orange yellow or deep orange red. Some of the meals call for the whole seeded grain, sometimes referred to as "Masoor." One of India's major pulse crops, lentils may thrive in a variety of soil types and climates (Ray et al., 2015) [14].

India is the world's second-largest producer of lentils, after Canada, and ranks fifth in terms of production of pulse crops, after mungbean, urdbean, chickpeas, and pigeon peas (Singh et al., 2015) [15]. With an average yield of 765 kg/ha and a production of 0.97 million tonnes, lentils are grown on roughly 1.27 million hectares of land nationwide. (Roy and others, 2006) [13]. As a leguminous pulse crop, lentils fix atmospheric nitrogen through root nodules produced by Rhizobium bacteria. When nitrogenase enzyme is present, atmospheric nitrogen is transformed into a form that plants can use. Therefore, lentils keep the soil alive and productive by restoring soil fertility and enhancing soil health. Its cultivation dates back to the early days of agriculture. In troublesome places, it is often utilized as a cover crop to prevent soil erosion. Most people use it as "dal." The grain that was eaten whole either split or decorticated. The color of the cotyledons is either orange yellow or deep orange red. Some of the meals call for the whole seeded grain, sometimes referred to as "Masoor." With twice as much protein as cereals, lentils are prized for their high protein content. Because it is the least expensive and most concentrated form of nutritional protein, it is sometimes known as "a poor man's meat." In addition to trace amounts of iron, calcium, phosphorus, and magnesium, it contains 23.25% protein, 59% carbs, 1.8% oil, and 0.2% ash. Lentil is an excellent source of easily digestible protein, lower in anti-nutritional factors like haemagglutinins, oligosaccharides and flavones compared to other legumes (Sharma *et al.*, 2010) [16].

A micronutrient essential to the development and well-being of all crops is boron (B). It is found in the cell walls and reproductive organs of plants. It is likely to travel around in the soil because it is a mobile nutrient. Delivering B as uniformly as possible throughout the area is crucial because it is needed in tiny quantities. Conventional fertilizer mixtures that contain B have trouble distributing nutrients evenly. B is the second most common micronutrient shortage issue globally, after zinc, despite the necessity of this essential ingredient. A wide range of plant processes, including as the development and stability of cell walls, the preservation of the structural and functional integrity of biological membranes, the transfer of sugar or energy into the plant's expanding sections, pollination, and seed set, depend on boron. Effective nitrogen fixation and nodulation in legume crops also depend on enough B (Khan et al. 2014 and Praveena et al. 2018) [9, 11].

Molybdenum is an essential micronutrient (Mo) for legume crops because it aids in both symbiotic and non-symbiotic N fixation and use. Molybdenum (Mo) is a structural element of nitrogenase, an enzyme activity that free-living nitrogen-fixing organisms use to fix nitrogen in the root nodule bacteria of leguminous crops. Accordingly, a plant may experience a nitrogen shortage as a result of a molybdenum deficiency (Nasar and Shah, 2017) [10]. The symptoms of a nitrogen deficit are probably the first to appear. Additionally, it contributes to the production of ascorbic acid and the physiological availability of iron in plants. The enzyme 'nitrogenase' mediates the reduction of N_2 to NH two components make up nitrogenase: one contains iron and molybdenum, and the other has iron alone. In essence, N-fixation is an anaerobic process. The presence of leghaemoglobin surrounding the bacteroid prevents it from receiving oxygen Chakraborty, (2009) [3].

Material and Methods

A field experiment was carried out in alluvial soil at the Department of Agronomy's Crop Research Farm at SHUATS in Prayagraj, Uttar Pradesh, during the Rabi season of 2024. The sandy loam soil used in the experimental plot had a pH of 7.6, a virtually neutral soil response, an electrical conductivity of 0.538 (ds/m), a medium amount of available potassium (253.4 kg/ha) and nitrogen (245.5 kg/ha), and a low amount of accessible phosphorous (36.6%). On November 10, 2024, lentils were planted 30 cm apart by 10 cm. Nine treatment combinations and three replications were used in the Randomized Block Design trial. The treatment combination are, Boron 0.25 kg/ha + Molybdenum 1 g/kg seed, Boron 0.25 kg/ha. + Molybdenum 2 g/kg seed, Boron 0.25 kg/ha + Molybdenum 3 g/kg seed, Boron 0.5 kg/ha + Molybdenum 1 g/kg seed, Boron 0.5 kg/ha + Molybdenum 2 g/kg seed, Boron 0.5 kg/ha + Molybdenum 3 g/kg seed, Boron 1.0 kg/ha + Molybdenum 1 g/kg seed, Boron1.0 kg/ha + Molybdenum 2 g/kg Seed, Boron 1.0 kg/ha + Molybdenum 3 g/kg seed, Control :- 20:40:20 kg NPK/ha. Using a manual hoe, 4-5 cm deep furrows were formed along the seed rows in order to apply fertilizers as band placement. In accordance with the suggested dosage of 20-40-20 kg NPK/ha, urea, single super phosphate (SSP), and murate of potash (MOP) were used as the fertilizer sources. Ten to twelve days after sowing, the gaps were closed by transplantation. Where necessary, plants were trimmed out to maintain a 30 cm x 10 cm spacing. To reduce crop weed competition, khurpi was used to assist in manual weeding at 15 and 30 days following sowing. On March 20, 2024, the crop was harvested. Pods/plant, seeds/pod, test weight (g), seed yield (kg/ha), stover yield (kg/ha), and harvest index (%) were measured at harvest, while plant growth parameters, such as plant height (cm), dry weight (g/plant), number of nodules/plant, and number of branches, were measured at regular intervals from germination until harvest. Analysis of variance (ANOVA), which is relevant to randomized block design, was used to statistically assess the observed data (Gomez and Gomez, 1984 and Mohan et al. 2024) [12].

Results and Discussion

Growth and Yield attributes

1. Plant height (cm)

The experiment demonstrates that the stages of plant growth had a significant impact on the height of the lentil plants. 1.0 kg of boron per hectare and 3 g of molybdenum per kilogram of seed, in contrast to the other treatments. The impact of molybdenum and boron on plant height this is because boron was applied, which increased the amount of protein, amides, and amino acids in the cell sap. This led to the elongation and multiplication of the cells, which in turn increased the height of the plant. This outcome was consistent with the data that Praveena et al. (2018) [11] had collected. Stem elongation and an increase in the number of nodes per plant as a result of mutual shadowing are most likely the causes of the height increase observed at greater plant densities. As the density of the plant population increased, so did the intermodal lengths. Additionally, the administration of micronutrients may be the cause of improved tissue cell division and soil nitrogen absorption. Singh et al. (2015) [15] and Priya et al. (2024) reported similar results.

2. Number of nodules per plant

According to this study, differing treatments of boron and molybdenum at different growth phases also had a substantial impact on the number of nodules per plant in lentils. In comparison to the other treatments, treatment 9 (Boron at 1.0 kg/ha. + Molybdenum at 3 g/kg) had a noticeably greater number of nodules/plant (14.53) at harvest. The growth parameters of leguminous crops, especially the number of nodules per plant, are significantly impacted by boron and molybdenum. According to studies, applying these micronutrients can promote overall plant growth and yield as well as nodule formation. For example, compared to the other treatment, produced a notable increase in the number of nodules per plant in a research on summer groundnuts Similarly, the application of 1 kg/ha Molybdenum resulted in a maximum number of nodules per plant was observed by Kathyayani *et al*. (2021) [8].

Number of branches per plant

At different phases of plant growth, the effects of boron and molybdenum treatments on lentil plants can be clearly identified in terms of the number of branches per plant. When compared to the other treatments, treatment 9 (boron at 1.0 kg/ha + molybdenum at 3 g/kg) had a considerably larger number of branches per plant (7.10) after 80 DAS. Numerous agricultural contexts have examined the impact of boron and molybdenum on the number of branches per plant. The highest number of branches per plant was obtained in a South Gujarat study using a combination of boron foliar spray at 4 mg/l and molybdenum seed treatment at 2 mg/l. This mixture improved growth factors like plant height in a synergistic way, number of branches per plant, and number of clusters per plant, which in turn led to better flowering, pod setting, and higher pod yield Kathyayani *et al*. (2021) [8].

Plant dry weight (g)

The number of Seeds per plant was considerably impacted by treatment at 80 days after sowing, and the number of pods on lentil plants. Early development and growth were observed. When compared to the other treatments, treatment 9 (Boron at 1.0 kg/ha + Molybdenum at 3 g/kg) had a noticeably greater plant dry weight (7.67 g) at 80 DAS. Therefore, throughout the vegetative stage, the plant's growth is largely controlled by its nitrogen nutrition. With increasing plant population, light interception per plant decreases, resulting in a depletion in whole-plant photosynthesis and biomass accumulation. Similar results have been reported by Praveena et al. 2018) [11]. The higher performance of growth at higher fertility levels could be ascribed to the luxuriant growth.

Number of Pods/ Plant

The quantity of pods per plant was significantly impacted by the insertion of Boron Molybdenum. In comparison to the other treatments, treatment 9—which included boron at 1.0 kg/ha and molybdenum at 3 g/kg—had the highest number of pods/plant (84.97) at harvest. However, it was determined that treatment-8 (1.0 kg/ha. + Molybdenum at 2 g/kg) and treatment-7 (1.0 kg/ha. + Molybdenum at 1 g/kg; 83.94) were statistically equivalent to treatment-9 (1.0 kg/ha. + Molybdenum at 3 g/kg). As plant density increases, the number of pods per plant decreases. The largest number of pods per plant observed at the highest boron levels with molybdenum may be the consequence of enhanced net photosynthetic rate and assimilate translocation to storage organs since there is more space available for nutrient and moisture absorption per plant and no shadowing effect. These results align with those of Praveena et al. (2018) [11] and Khan et al. (2014) [9].

Number of Seeds/ Plant

According to the report, there were minor but significant differences in the quantity of seed pods. In comparison to the other treatments, treatment 9—which included boron at 1.0 kg/ha and molybdenum at 3 g/kg—had the highest number of seeds/pods (2.84). Boron at 1.0 kg/ha. + Molybdenum at 2 g/kg (2.73), treatment-7 Boron at 1.0 kg/ha. + Molybdenum at 1 g/kg (2.52), and treatment-8 Boron at 1.0 kg/ha. + Molybdenum at 3 g/kg were shown to be statistically equivalent to treatment-9. With increasing plant density, there are fewer seeds per pod. The greatest number of seeds per pod was linked to the highest boron and nitrogen levels. This could be because there is no shadowing effect and each plant has a larger surface area available for absorbing nutrients and moisture which ultimately speeds up the rate of net photosynthates and the translocation of assimilates to storage organs. These outcomes are consistent with Praveena *et al*. 2018 and Khan *et al.* 2014) [11, 9].

3. Test Weight

The 1000-seed test weight did not show any significant differences between the treatments. Treatment 9, which applied boron at 1.0 kg/ha and molybdenum at 3g/kg seed, had the highest test weight at harvest (28.74). The information was statistically insignificant, though. Because boron increases photosynthetic activity and plant metabolism, the seed was at its highest. The outcomes have been similar. The findings were comparable to those of Jat et al. (2013) [7]. Balanced nutrition and healthy vegetative growth, which later transitioned into the reproductive phase and may have produced more seeds, are likely the causes of the notable increase in seed yield. The outcomes mirrored those of Venkatesh et al. (2020) [18] in Lentil.

Grain Yield (t/ha)

After harvesting, the lentil crop data showed that treatment 9 (Boron at 1.0 kg/ha and Molybdenum at 3 g/kg) had the highest seed yield (1.77 t/ha) when compared to the other treatments. However, it was shown that treatments 7 and 8 (Boron at 1.0 kg/ha. + Molybdenum at 2 g/kg) (1.68 t/ha) and Boron at 1.0 kg/ha. + Molybdenum at 1 g/kg (1.66 t/ha) were statistically equivalent to treatment 9. With closure spacing, the pace at which nitrogen was applied enhanced the seed production considerably. Increasing rate of nitrogen application significantly increased the seed yield with closure spacing. These results are in accordance with the findings of Ayerza and Coates (1996) and Yeboah *et al.* (2014). The higher seed yield was attributed to the effect of Boron, which produced the plants to manufacture more quantity of photosynthesis in reproductive stage Praveena et al. 2018 and Khan et al. 2014) [11, 9].

Stover yield (t/ha)

In comparison to the other treatments, treatment 9's highest straw yield (3.61 t/ha) was significantly higher due to the addition of boron (1.0 kg/ha) and molybdenum (3 g/kg). However, it was discovered that treatments 7 and 8 (Boron at 1.0 kg/ha. + Molybdenum at 2 g/kg) (3.53 t/ha) were statistically equivalent to treatment 9 (Boron at 1.0 kg/ha. + Molybdenum at 3 g/kg seed.)

Harvest Index

Observation regarding Harvest index of lentil are given in the table 4.7. At highest number of Harvest index % (39.24) was observed in treatment 10 in control plot. However, the data was statistically non-significant.

Economic Analysis

It provides results of cost of cultivation, gross return, net return, benefit-cost ratio (B:C ratio) of Boron and molybdenum on lentil. Gross returns (136828.00INR/ha) were found to be highest in treatment-9 Boron at 1.0 kg/ha. + Molybdenum at 3 g/kg and minimum gross returns (93248.00 INR/ha) was found to be in treatment-10 NPK - 20: 40: 20 kg/ha (Control) as compared to other treatments. And Net returns (93725.10 INR/ha) were found to be highest in treatment-9 Boron at 1.0 kg/ha. + Molybdenum at 3 g/kg and minimum net returns (51145.10 INR/ha) was found to be in (treatment-10) NPK - 20: 40: 20 kg/ha (Control) as compared to other treatments along with Benefit Cost ratio (2.17) was found to be highest in (treatment-9) Boron 1.0 kg/ha + Molybdenum at 3 g/kg and minimum Benefit of cost (1.21) was found to be in treatment-10 NPK - 20: 40: 20 kg/ha (Control) as compared to other treatments. The enhanced economical returns with Molybdenum treatments agree with the earlier findings that indicate.

Conclusion

It is determined that the combination of molybdenum and boron the application of Boron at 1.0 kg/ha. + Molybdenum at 3 g/kg seed in (Treatment 9) was found to have a greater yield and benefit-cost ratio in lentils, and as a result, it may be suggested in cases of increased productivity and profitability.

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Table 1: Effect of Boron and Molybdenum on Growth Attributes of Lentil

S. No.	Treatment combinations	Growth Attributes			
		80 DAS Plant height	80 DAS Dry Weight	80 DAS No of Nodules	80 DAS No of Branches
1.	Boron 0.25 kg/ha + Molybdenum 1 g/kg seed	27.38	3.94	10.48	5.22
2.	Boron 0.25 kg/ha + Molybdenum 2 g/kg seed	29.74	4.27	11.27	5.37
3.	Boron 0.25 kg/ha + Molybdenum 3 g/kg seed	30.93	4.54	11.87	5.61
4.	Boron 0.5 kg/ha + Molybdenum 1 g/kg seed	32.77	4.84	12.40	5.99
5.	Boron 0.5 kg/ha + Molybdenum 2 g/kg seed	34.15	5.30	12.73	6.31
6.	Boron 0.5 kg/ha + Molybdenum 3 g/kg seed	35.41	5.97	13.27	6.49
7.	Boron 1.0 kg/ha + Molybdenum 1 g/kg seed	36.51	6.77	13.60	6.59
8.	Boron 1.0 kg/ha + Molybdenum 2 g/kg seed	37.98	7.40	14.13	6.81
9.	Boron 1.0 kg/ha + Molybdenum 3 g/kg seed	39.36	7.67	14.53	7.10
10.	NPK - 20:40:20 kg/ha (Control)	23.76	3.69	10.27	4.97
F-test		S	S	S	S
SEm(±)		2.07	0.39	0.67	0.36
CD (P=0.05)		6.15	1.16	2.00	1.08

Table 2: Effects of Boron and Molybdenum on yield attribute of Lentil

S. No.	Treatment combinations	yield attribute			yield		
		No. of pods/plant	No. of seeds/pod	Test weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1.	Boron 0.25 kg/ha + Molybdenum 1 g/kg seed	77.24	1.52	26.81	1.33	2.47	34.99
2.	Boron 0.25 kg/ha + Molybdenum 2 g/kg seed	77.80	1.54	26.89	1.54	2.72	35.77
3.	Boron 0.25 kg/ha + Molybdenum 3 g/kg seed	78.82	1.57	26.93	1.55	2.72	37.06
4.	Boron 0.5 kg/ha + Molybdenum 1 g/kg seed	79.98	1.93	27.29	1.57	3.12	33.34
5.	Boron 0.5 kg/ha + Molybdenum 2 g/kg seed	81.36	1.96	27.75	1.61	3.19	34.86
6.	Boron 0.5 kg/ha + Molybdenum 3 g/kg seed	82.51	2.27	28.64	1.62	3.34	32.80
7.	Boron 1.0 kg/ha + Molybdenum 1 g/kg seed	83.43	2.52	28.05	1.66	3.50	31.65
8.	Boron 1.0 kg/ha + Molybdenum 2 g/kg seed	83.94	2.73	28.41	1.68	3.53	32.45
9.	Boron 1.0 kg/ha + Molybdenum 3 g/kg seed	84.97	2.84	28.74	1.77	3.61	33.35
10.	NPK - 20:40:20 kg/ha (Control)	76.22	1.02	26.20	1.21	1.87	39.24
F-test		S	S	NS	S	S	NS
SEm(±)		1.11	0.37	1.86	0.24	0.34	3.77
CD (P=0.05)		3.29	1.10	-	0.72	1.03	-

Table 3: Effect of Boron and Molybdenum on Economic yield Lentil

S. No.	Treatment combinations	Economics			
		COC (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C
1.	Boron 0.25 kg/ha + Molybdenum 1 g/kg seed	42627.90	103710.00	61082.10	1.43
2.	Boron 0.25 kg/ha + Molybdenum 2 g/kg seed	42827.90	119018.00	76190.10	1.78
3.	Boron 0.25 kg/ha + Molybdenum 3 g/kg seed	43027.90	119518.00	76490.10	1.78
4.	Boron 0.5 kg/ha + Molybdenum 1 g/kg seed	42652.90	121248.00	78595.10	1.84
5.	Boron 0.5 kg/ha + Molybdenum 2 g/kg seed	42852.90	124332.00	81479.10	1.90
6.	Boron 0.5 kg/ha + Molybdenum 3 g/kg seed	43052.90	125762.00	82709.10	1.92
7.	Boron 1.0 kg/ha + Molybdenum 1 g/kg seed	42702.90	128450.00	85747.10	2.01
8.	Boron 1.0 kg/ha + Molybdenum 2 g/kg seed	42902.90	130232.00	87329.10	2.04
9.	Boron 1.0 kg/ha + Molybdenum 3 g/kg seed	43102.90	136828.00	93725.10	2.17
10.	NPK - 20:40:20 kg/ha (Control)	42102.90	93248.00	51145.10	1.21

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