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Effect of Phosphorous and Boron on Growth and Yield of Rice Bean

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment titled "Effect of Phosphorus and Boron on Growth and Yield of Rice Bean" conducted during the *Zaid* season of 2022 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj (U.P.) India. To study the Response of Phosphorus and Boron on the growth and yield of Rice Beans. The treatments consist of Phosphorus 20, 40, 60 kg/ha and Boron (Borax 0.01% 20 DAS, Borax 0.02% 40 DAS, and Borax 0.03% 60 DAS). The experiment was laid down in a Randomized Block Design with ten treatments which are replicated thrice. The soil of the experimental plot was sandy loamy in texture, nearly neutral in soil reaction (pH 7.8), and low in organic carbon (0.35%). Results obtained that the higher plant height (106.90 cm), higher number of nodules (30.94), higher number of branches (8.84) higher plant dry weight (49.25 g/plant), a higher number of pods/plant (26.25), higher number of seeds/pod (7.19), higher 1000 seed weight (58.19 g), higher seed yield (2.10 t/ha) and higher stover yield (4.66 t/ha) were significantly influenced with application of Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS. Higher gross return (INR 1,15,500.00 /ha), higher net return (INR 84,155.70/ha) and higher B:C ratio (2.68) were also recorded in treatment-9 (Phosphorus 60 kg/ha + Boron 0.03% 60 DAS).

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1. INTRODUCTION

Rice Bean [*Vigna umbellata* (Thumb) Ohwi and Ohashi Syn. *phaseolus calcaratus* Rosb] also known as Climbing Mountain Bean, Mambi Bean, Oriental Bean and Bamboo Bean is a native of south and southeast Asia. Countries that grow rice beans include India, Burma, Malaysia, Korea, China, Indonesia and Philippines. "Rice bean is now also grown in Fiji, Mauritius, Queensland and East Africa for fodder, green manure, cover crop and food" Thomas et al. [1].

Rice Bean belongs to the family Fabaceae, similar to other vigna species. "Worldwide the seed yield of rice beans is about 2,250 kg/ha. It is 1,300-2,750 kg/ha in Zambia, Brazil and India. In India, fodder yield was reported to range from 5-7 t DM/ha in May and June and 8-9 t DM /ha in November and December" Singh et al. [2].

Rice bean is adapted to high temperature and humidity as well as to heavy soils. Like many other legumes, it has a capacity of nodulation for biological nitrogen fixation and fits in rice bean wheat (late) rotation in Punjab. It has been reported that this species is completely free from the yellow mosaic virus which takes a heavy toll on other Vintage species. Its seeds are also free from serious insect Bruchids Singh et al. [2]. Several strains of rice bean exhibit photo-thermo-sensitivity in terms of flowering and reproduction. The germination in rice bean is epigeal and generally excellent under field conditions and possesses good synchrony in pod maturity in its cultivars, which is of considerable importance and significance in comparison with all other Asian Vigna species (Mung, Urad and Moth bean); lack of synchrony is an important breeding problem and harvesting/picking of pods is a labour-intensive operation.

As a legume crop, it is effective in Nitrogen fixation in the soils, thus improving the soil fertility and has a positive effect in increasing the production of the following crops. Rice bean offers good scope for increasing pulse production. In addition, it is also a valuable fodder crop. In this sense, cultivation of rice beans is considered to be important in contributing towards food and nutritional security and utilize uncultivated marginal land Gautam [3].

"Though conventional pulses are being grown in India, the production has not been able to meet the entire demand due to various reasons. Hence, there is a growing need for grain legumes to meet the protein requirements of predominantly vegetarian countries like India. In this context, the domestication of under-utilized and under-exploited pulses like rice bean which is of better nutritional quality would be a better alternative to meet the nutritional requirements of the existing population. Boron is very important in cell division and pod and seed formation" [4]. **"**Reproductive growth, especially flowering, fruit and seed set is more sensitive to B deficiency than vegetative growth" (Noppakoonwong *et al.* 1997). Boron influences the absorption of N, P, and K and its deficiency changed the equilibrium of the optimum of those three macronutrients. The N and B concentrations of grain for Rice bean were markedly influenced by B treatment indicating that the B had a positive role in protein synthesis (Iqtidar and Rahman, 1984) and found that essential amino acid increased with increasing B supply. Therefore, applications of micronutrients in addition to essential major elements have gained practical significance.

"It is primarily needed to maintain the growth of the apical growing point. Boron is important in reproductive growth, especially flowering, fruit and seed set is more sensitive to B deficiency than vegetative growth. Boron influences the absorption of N, P, and K nutrients. Micronutrients like boron is one of the mineral nutrients required for normal plant growth. The most important functions of boron in plants are thought to be its structural role in cell wall development, cell division, seed development and stimulation or inhibition of specific metabolic pathways for sugar transport and hormone development" Ahmad et al. [5].

Considering the facts and to bridge the research gap highlighted above, the present experiment entitled**,** "Effect of phosphorus and boron on growth and yield of Rice Bean", was conducted at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during *Zaid* 2023.

2. MATERIALS AND METHODS

At the Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, the experiment was carried out during Rabi of 2022. Ten treatments, each replicated three times, were used in the experiment's Randomised Block Design. Each treatment's plot was 3m by 3m. The treatments consist of Phosphorus 20, 40, and 60 kg/ha and Boron (Borax 0.01% 20 DAS, Borax 0.02% 40 DAS, and Borax 0.03% 60 DAS) are contributing factors. At the time of sowing, N, P and Zn were supplied, and three were used as basal. On March 26, 2023, the Rice bean variety was sowed with a 30 cm 15 cm spacing. All agronomical operations were kept accordingly and each plot's 1 m^2 was used for harvesting. Five plants were randomly chosen from it to observe the yield and growth metrics. Here are the specifics of the treatment:

T_1 - Phosphorus 20 kg/ha + Boron 0.01% at 20 DAS, T_2 - Phosphorus 20 kg/ha + Boron 0.02% at 40 DAS, T_3 - Phosphorus 20 kg/ha + Boron 0.03% at 60 DAS, T_4 - Phosphorus 40 kg/ha + Boron 0.01% at 20 DAS, T_5 - Phosphorus 40 kg/ha + Boron 0.02% at 40 DAS, T_6 -Phosphorus 40 kg/ha + Boron 0.03% at 60 DAS, T_7 - Phosphorus 60 kg/ha + Boron 0.01% at 20 DAS, T_8 - Phosphorus 40 kg/ha + Boron 0.02% at 40 DAS, T_9 - Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS, T_{10} - N 20 Kg/ha + P 40 kg/ha +K 20 kg/ha. Plant height, nodules per plant, dry weight, grain production, and stover yield were all observed and reported. By using the analysis of variance approach, the data were statistically analysed [6].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Plant height – Treatment 9 Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS produced plants with a considerably higher height (106.90 cm) at 100 DAS. To be statistically comparable to treatment 9 Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS, treatment 8 Phosphorus 60 kg/ha + Boron 0.02% at 40 DAS was used.

With the application of phosphorus at a rate of 60 kg/ha, a noticeably greater plant height (106.90 cm) was seen. The application of phosphorus to the soil may have caused plants to grow significantly taller because it increased the crop's ability to access and absorb soil nutrients. Higher nutrient availability may have improved photosynthetic capacity and metabolite translocation to various regions, which eventually improved the root and shoot growth of the crop. These results support those of Yumnam et al. [7]. A further explanation for the slow rise in plant height is that boron may have a role in several physiological processes, including the activation of enzymes, electron transport, chlorophyll synthesis, and stomatal control might be attributed to higher levels of chlorophyll synthesis and photosynthetic activity brought on by boron fertilisation, which in turn improved vegetative development. These observations support the conclusions reached by Myageri and Dawson (2022).

Nodules/plant – The treatment with the highest number of nodules per plant (5.61) at 100 DAS was treatment 9 (phosphorus 60 kg/ha + boron 0.03% at 60 DAS). The statistical comparison between treatment 8 (Phosphorus 60 kg/ha + Boron 0.02% 40 DAS) and treatment 9 (Phosphorus 60 kg/ha + Boron 0.03% 60 DAS) was nonetheless statistically equal.

With the application of phosphorus at a rate of 60 kg/ha, a significant and higher number of nodules/plants were produced. According to Patel et al. [8] green gram phosphorus administration enhanced the number of nodules/plants. Furthermore, as a micronutrient, boron performs crucial roles as an electron transporter, a component of organic structures, an enzyme activator, and in osmoregulation. At various times during the nodule development and nodule function phases of the symbiotic association, micronutrients may also affect N_2 fixation in legumes and nonlegumes. Rhizobium-legume cell-surface interaction and pea nodule development are influenced by boron. Bolanos et al. [9], among other things.

Number of branches/plant - At 100 DAS, treatment-9 Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS had considerably more branches per plant (7.84). To be statistically comparable to treatment 9 Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS, treatment 8 Phosphorus 60 kg/ha + Boron 0.02% at 40 DAS was applied.

The significant number of branches per plant (8.84) was observed with the application of

Phosphorus 60 kg/ha. A significantly higher number of branches/plants were recorded with the application of phosphorus 50 kg/ha. This might be due to Phosphorus, being the constituent of nucleic acid and different forms of proteins, might have stimulated cell division resulting in increased growth of plants similar results reported by [10], and Also**,** boron might be attributed to the favourable influence on plant metabolism and biological process activity and stimulating effect on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth. The results were by Krishna et al. [11].

Dry weight/plant- Treatment 9 Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS had a considerably greater plant dry weight (49.25 g) at 100 DAS. Treatment 8 Phosphorus 60 kg/ha + Boron 0.02% at 40 DAS was statistically comparable to Treatment 9 Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS.

With the application of phosphorus, a significant and increased dry weight is seen. Increases in dry weight brought on by an improvement in photosynthetic capacity and the distribution of metabolites, which eventually led to an improvement in crop shoot growth, are consistent with the findings of Unni and Debbarma [12]. Furthermore, when the amount of boron grew, dry weight increased dramatically. Because boron typically affects cell division and nitrogen uptake from the soil may promote plant development, which is reflected in terms of plant dry weight. Naik et al. [13] also came to similar conclusions.

Crop Growth Rate (g/m2/day) - At 60–80 DAS, treatment 9 Phosphorus 60 kg/ha + boron 0.03% at 60 DAS had a significantly higher crop growth rate (40.2 g/m^2/day); however, treatment 8 Phosphorus 60 kg/ha + boron 0.02% at 40 DAS, was discovered to be statistically equal to treatment 9 Phosphorus 60 kg/ha + boron 0.03% at 60 DAS. With the application of phosphorus at a rate of 60 kg/ha, a noticeably greater crop growth rate (40.2 g/m2/day) was seen. Phosphorus, an essential component of nucleic acid, ADP, and ATP, may be the cause of the rise in growth parameters. It increases agricultural produce quality, hastens maturity, and has positive impacts on nodulation, root development, growth, and other factors Choudary et al. [14].

3.2 Yield Attributes

Number of pods/plant- “A significant and higher number of pods/plant (26.25) were observed in treatment-9 with Phosphorus 60 kg/ha + Boron 0.03 % at 60 DAS, which was significantly superior over the rest of the treatments. However, treatment-8 Phosphorus 60 kg/ha + Boron 0.02 % at 40 DAS, was found to be statistically at par with treatment-9 Phosphorus 60 kg/ha + Boron 0.03 % at 60 DAS” [15].

With 60 kg/ha of phosphorus, a considerable and increased number of pods per plant (30.25) was seen. It's because there was a superior supply of phosphorus, which led to higher photosynthetic activity, less premature flower and young pod loss, and eventually more pods per plant. Malik et al. (2010) findings back up these findings. Additionally, a plant can produce more pods per plant by using boron (2 kg/ha), which aids in the development of flowers and pollen grains. Similar results were found to agree with Padbhushan and Kumar [16].

A number of seeds/pod - Treatment 9 with Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS, which was much better than the other treatments, had a considerable and greater number of Seeds/pod (7.19). Although it was discovered that treatment-8 Phosphorus 60 kg/ha + Boron 0.02% at 40 DAS) was statistically equivalent to treatment-9 Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS, this was not the case.

The application of phosphorus at a rate of 60 kg/ha resulted in a considerable and increased number of Seeds/pod (7.19). The highest number of seeds or pods were produced in response to the application of phosphorus (60 kg/ha), which may be explained by the increased availability of other plant nutrients that promoted an increase in carbohydrate development and their re-mobilization to the closest sinks in the plant's reproductive parts. Since phosphorus is known to boost flowering and fruiting, this may have encouraged the plants to create more pods and allowed for higher plant growth, which in turn allowed for increased development of seed/pod numbers. Shah *et al*. [17] reported the same outcomes. Boron's important function in plant metabolism and the creation of nucleic acids may be the cause of its beneficial effects. Similar results were found in Kumar et al. [18] conformance study.

Test Weight (g) - A significant and higher test weight (58.19 gm) was observed in treatment-9 with Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS, which was significantly superior over the rest of the treatments. However, treatment-8 Phosphorus 60 kg/ha + Boron 0.02% at 40 DAS, was found to be statistically at par with treatment-9 Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS.

With the application of phosphorus at a rate of 60 kg/ha, a substantial and higher test weight (58.19 gm) was seen. The increase in test weight associated with phosphorus application (60 kg/ha) may be due to a boost in the symbiotic nitrogen fixation capacity, which in turn causes an increase in the number of plants, the length of pods, the number of grains per pod, the test weight, and eventually grain production. Parashar et al. [19] reported a comparable result.

Seed Yield (t/ha) - Treatment 9 with Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS had the highest and considerably greater seed yield (2.02 t/ha), and it outperformed the other treatments by a wide margin. Treatment 8 Phosphorus 60 kg/ha + Boron 0.02% at 40 DAS, however, was shown to be statistically equivalent to treatment 9 Phosphorus 60 kg/ha + Boron 0.03% at 60 DAS.

With the application of Phosphorus at a rate of 60 kg/ha, a considerable and greater seed production (2.10 t/ha) was noted. According to the number of pods/plant and number of seeds/pod, phosphorus may be accountable for the crop's improved development and yield-attributing qualities through higher photosynthesis and assimilating translocation to various plant sections. The extra assimilates that were first held in the leaves were later transferred to sink development, which eventually helped to increase seed output. The most effective boron application method was determined as soil + foliar boron application but other application methods were more effective than control applications which influenced floral development and led to higher pod setting Oktem [20]. Yumna et al. [7]. Furthermore, boosting seed output may be caused by the application of boron (2 kg/ha). It plays a crucial role in doing so since phosphorous and boron are involved in many physiological processes of plants, including chlorophyll synthesis, stomatal control, and starch utilisation, all of which increase seed yield. In addition to being essential for numerous physiological processes and plant growth, nutrition is also important for boosting crop yields and quality. These findings corroborate the findings of Naik et al. [13] research.

Stover Yield (t/ha) - Treatment 9 with (Phosphorus 60 kg/ha + Boron 0.03% 60 DAS), which was much better than the other treatments, had a considerable and higher stover yield (4.66 t/ha). Although it was discovered that treatment-8 (Phosphorus 60 kg/ha + Boron 0.02% 40 DAS) was statistically equivalent to treatment-9 (Phosphorus 60 kg/ha + Boron 0.03% 60 DAS), this was not the case. “With the application of phosphorus (60kg/ha), a significant and greater production of stover was seen. Plants have grown and developed more in terms of height, branches, and dry matter, possibly as a result of the enhanced nutritional environment of the rhizosphere and plant system, which led to greater plant metabolism and photosynthetic activity”. Yadav and others, 2017. The improved dry matter yield of straw may be responsible for the additional increase in stover yield. B plays a role in stabilising specific components of cell walls and plasma membranes, promoting cell division, tissue differentiation, and metabolism of nucleic acids, carbohydrates, proteins, auxins, and phenols. According to Padbhushan and Kumar [16], similar results were obtained.

3.3 Economic Analysis

Economics- The result revealed that Maximum gross return (1,15,500.00 INR/ha), Maximum net return (84,155.70 INR/ha) and highest benefit-cost ratio (2.68) was recorded in treatment-9 (Phosphorus 60 kg/ha + Boron 0.03 % 60 DAS) as compared to other treatments (Table 3). Higher gross Return, net return and benefit-cost ratio was recorded with the application of (Phosphorus 60 kg/ha + Boron 0.03 % 60 DAS) it might be due to the higher growth and yield attributes resulting in more seed and stover yield with the recommended dose of Phosphorus and Boron [21-25].

Table 1. Influence of Phosphorus and Boron on growth parameters of Rice Bean

S. No.	Treatments	Plant height (cm)	Number of nodules/plants	Number of branches	Plant Dry weight (g)	Crop growth rate (g/m2/day)
1.	Phosphorus 20 kg/ha + Boron 0.01 % 20 DAS	87.59	4.11	5.48	39.68	35.73
2.	Phosphorus 20 kg/ha + Boron 0.02 % 40 DAS	89.20	4.22	5.71	42.14	35.63
3.	Phosphorus 20 kg/ha + Boron 0.03 % 60 DAS	91.53	4.80	6.07	42.84	36.68
4.	Phosphorus 40 kg/ha + Boron 0.01 % 20 DAS	93.75	4.69	6.35	43.91	36.36
5.	Phosphorus 40 kg/ha + Boron 0.02 % 40 DAS	98.31	4.79	6.77	45.02	36.35
6.	Phosphorus 40 kg/ha + Boron 0.03 % 60 DAS	98.87	5.04	6.75	45.40	36.34
7.	Phosphorus 60 kg/ha + Boron 0.01 % 20 DAS	101.08	5.11	7.11	46.51	37.20
8.	Phosphorus 60 kg/ha + Boron 0.02 % 40 DAS	105.05	5.27	6.94	47.84	39.60
9.	Phosphorus 60 kg/ha + Boron 0.03 % 60 DAS	106.90	5.61	7.84	49.25	40.15
10.	Control (RDF 20:40:20 NPK kg/ha)	87.56	4.66	4.98	38.76	35.75
	F test	S	S	S	S	S
	S Em.(±)	0.63	0.20	0.26	0.68	0.93
	CD (p=0.05)	1.87	0.59	0.84	2.03	2.67

Table 2. Influence of Phosphorus and Boron on yield attributes of Rice Bean

S. No.	Treatments	Pods/plants	Seeds/pod	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1.	Phosphorus 20 kg/ha + Boron 0.01 % 20 DAS	20.01	5.69	47.18	1.12	3.36	28.90
2.	Phosphorus 20 kg/ha + Boron 0.02 % 40 DAS	21.47	6.07	47.84	1.31	3.85	28.02
3.	Phosphorus 20 kg/ha + Boron 0.03 % 60 DAS	23.17	6.34	49.25	1.41	4.09	28.04
4.	Phosphorus 40 kg/ha + Boron 0.01 % 20 DAS	21.58	6.21	48.21	1.59	4.19	27.86
5.	Phosphorus 40 kg/ha + Boron 0.02 % 40 DAS	22.69	6.75	51.75	1.67	4.29	28.53
6.	Phosphorus 40 kg/ha + Boron 0.03 % 60 DAS	24.06	7.03	54.03	1.77	4.43	28.86
7.	Phosphorus 60 kg/ha + Boron 0.01 % 20 DAS	22.84	6.78	53.11	1.81	4.52	27.91
8.	Phosphorus 60 kg/ha + Boron 0.02 % 40 DAS	24.74	6.91	56.91	1.97	4.52	29.78
9.	Phosphorus 60 kg/ha + Boron 0.03 % 60 DAS	26.25	7.19	58.19	2.10	4.66	30.18
10.	Control (RDF 20:40:20 NPK kg/ha)	22.43	26.43	46.76	1.30	3.83	27.09
	F-Test	S	S	S	S	S	N S
	S Em±	0.54	0.20	0.59	0.03	0.18	0.99
	CD (P=0.05)	1.62	0.60	1.74	0.08	0.54	---

Table 3. Influence of Phosphorus and Boron on Economics of Rice Bean

S. No.	Treatments	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	B:C Ratio
1.	Phosphorus 20 kg/ha + Boron 0.01 % 20 DAS	27,137.40	61,600.00	34,462.60	1.27
2.	Phosphorus 20 kg/ha + Boron 0.02 % 40 DAS	28,137.40	72,050.00	43,912.60	1.56
3.	Phosphorus 20 kg/ha + Boron 0.03 % 60 DAS	29,137.40	77,550.00	48,412.60	1.66
4.	Phosphorus 40 kg/ha + Boron 0.01 % 20 DAS	28,240.80	87,450.00	59,209.20	2.10
5.	Phosphorus 40 kg/ha + Boron 0.02 % 40 DAS	29,240.80	91,850.00	62,609.20	2.14
6.	Phosphorus 40 kg/ha + Boron 0.03 % 60 DAS	30,240.80	97,350.00	67,109.20	2.22
7.	Phosphorus 60 kg/ha + Boron 0.01 % 20 DAS	29,344.30	99,550.00	70,205.70	2.39
8.	Phosphorus 60 kg/ha + Boron 0.02 % 40 DAS	30,344.30	1,08,350.00	78,005.70	2.57
9.	Phosphorus 60 kg/ha + Boron 0.03 % 60 DAS	31,344.30	1,15,500.00	84,155.70	2.68
10.	Control (RDF 20:40:20 NPK kg/ha)	27,240.80	71,500.00	44,259.20	1.62

** Data was not subjected to the statistical analysis competing interests*

4. CONCLUSION

Based on the mentioned results, it can be stated that Boron 0.03 % 60 DAS combined with Phosphorus applied at a rate of 60 kg per hectare, has improved growth metrics and yield characteristics while also being economically viable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Thomas TA, Dabas BS, Patel DP, Joshi BD. Ricebean – A new pulse for North-Westem Himalayas. Ind Fmg. 1983;33(8):17-23.
2. Singh V, Onte. Rice bean: high valued fodder crop. Indian Farming. 2020;70(06):27-31.
3. Gautam R. Food security through rice bean research in India and Nepal (FOSRIN) Report 1. Distribution of rice bean in India and Nepal; 2007.
4. Vitosh ML, Wameke DD, Lucas RE. Boron. Mishigan State Univ Extension Soil Manag Fert; 1997.
5. Ahmad W, Niaz A, Kanwal S, Rahmatullah RMK. Role of boron in plant growth: a review. J Agric Res. 2009;47(3):329-38.
6. Gomez KA, Gomez AA. Three or more factor experiment. (In:) Statistical Procedure for Agricultural. research 2nd ed. 1976;139-41.
7. Yumnam T, Luikham E, Edwin, Singh, Herojit A. Influence of phosphorous on growth and yield of promising varieties of lentil (*Lens culinaris* L.M). Int J Curr Microbiol Appl Sci. 2018;7(8):162-70.
8. Patel HB, Shah KA, Barvaliya MM, Patel SA. Response of green gram (*Vigna radiata* L.) to different level of phosphorus & organic liquid fertilizer. Int J Curr Microbiol Appl Sci. 2017;6(10):3443-51.
9. Bolanos L, Brewin NJ, Bonilla I. Effects of boron on rhizobium-legume cell-surface interactions and nodule development. Plant Physiol. 1996;110(4):1249-56.
10. Niraj, Prakash V. Effect of phosphorus and sulphur on growth, yield and quality of black gram (*Phaseolus mungo* L.). An Asian J Soil Sci. 2014;9(1):117-20.
11. Krishna BM, Kumar HS, Priyanka G, Naik MV, Umesha C. Influence of boron and zinc on growth and yield of green gram (*Vigna radiata* L.). The Pharm Innov J. 2022;11(3):1674-8.
12. Unni A, Debbarma V. Response of nitrogen and phosphorus on Growth and Yield of Lentil (*Lens culinaris* medik.). Int J Plant Soil Sci. 2022;34(21):328-34.
13. Naik MV, Debbarma V. Influence of nitrogen and boron on growth and yield of lentil (*Lens culinaris* Medikus.). Int J Plant Soil Sci. 2022;34(21):882-7.
14. Choudhary R, Singh K, Manohar RS, Yadav AK, Sangwan A. Response of different sources and levels of phosphorus on yield, nutrient like uptake and net returns on mung bean under rain fed condition. Indian J Agric Res. 2015;35:263-8.
15. Harika D, Debbarma V, Thrupthi MG. Influence of phosphorus and bio-fertilizers on growth and yield of black gram (*Phaseolus mungo* L.). Int J Plant Soil Sci. 2023 May 15;35(13):43-51.
16. Padbhushan R, Kumar D. Influence of soil and foliar applied boron on green gram in calcareous soils. Print ISSN. 2014;7(1):0974-1712.
17. Shah SH, Mahmood MY, Zamir MSI. Qualitative and quantitative response of three cultivars of lentil (Lens culinaris Medic) to phosphorus application. Int J Agric Biol. 2000;2(3):248-50.
18. Kumar D, Padbhushan R. Influence of soil and foliar applied Boron on Green gram calcareous soils. Int J Agric Environ Biotechnol. 2013;7(1):129-36.
19. Parashar A, Jain M, Tripathi L. Effect of sulphur and phosphorus on the growth and yield of black gram (*Vigna mungo* L.). Ind J Pure App Biosci. 2020;8(5):276-80.
20. Öktem AG. Effects of different boron applications on seed yield and some agronomical characteristics of red lentil. Turk J Field Crops. 2022;27(1):112-8.
21. Bhattacharya N, Mukherjee AK. Herbage growth of rice bean under different dates of sowing and levels of phosphorus. Forage-Res. 1998;24(2):121-3.
22. Kumar V, Dwivedi VN, Tiwari DD. Effect of phosphorus and iron on yield and mineral nutrition in chickpea. Annals Plant Soil Res. 2009;11:16-8.
23. Malik MA, Shah SH, Farrukh Saleem M, Sajid Jami M. Determining suitable stand density and phosphorus level for improving productivity of rice bean (*Vigna umbellata*). Int J Agric Biol. 2002;1560-8530/2002/04–1–120–122.

24. Marschner H. Mineral nutrition of higher plants. Academic Press; 2002.
25. Mukherjee AK, Roquib MA, Chatterjee BN. Rice bean K-1 for the scarcity period. Indian Fmg. 1980;29(12):19-26.
26. Myageri PV, Dawson J. Effect of phosphorous and boron levels on growth and yield of lentil (*Lens culinaris* L.). Int J Plant Soil Sci. 2021;34(20):504-10.
27. Yadav PS, Kameriya PR, Rathore S. Effect of phosphorus and iron fertilization on yield, protein content and nutrient uptake in mung bean on loamy sand soil. J Indian Soc Soil Sci. 2002;50:225-6.

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