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Effect of Soil and Foliar Application of Boron on Yield and Economics of Green Gram (*Vigna radiata* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment entitled "Effect of soil and foliar application of boron on yield and economics of green gram" was carried out during *Kharif* 2019-20 at ZARS, UAS, GKVK, Bengaluru. The field experimental results revealed that significant ($p < 0.05$) variation in number of pods plant^{-1} (25.74), number of seeds pod^{-1} (14.48), test weight of 100 seeds (5.12 g), grain yield (10.19 q ha^{-1}), haulm yield (2.17 t ha^{-1}) and B:C ratio (1.96) were recorded in treatment T_{10} which received soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1 % along with package of practice. The number of nodules plant^{-1} (20.12) was significantly ($p < 0.05$) highest in treatment T_{12} which received soil application of borax at 5.00 kg ha^{-1} + foliar application of boric acid at 0.1% along with RDF over absolute control (14.75). So, from this experiment treatment T_{10} which received soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1% along with package of practice shows better results, Since, the present study result one year experiment; further long term and multi-locational trial must be done to confirm the finding.

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1. INTRODUCTION

Pulses are least preferred by farmers because of high risk and less remunerative than cereals; consequently, the production of the pulses is significantly low to meet the demand of pulses. Majority of Indian population is vegetarian, pulses are cheap and best source of protein for Indian diet. It contains 20-25 % protein, which is more than two times of cereals [1].

Among the pulse crops, green gram (*Vigna radiata* L.) is one of the third main pulse crop in India after pigeon pea, chickpea and main source of vegetable protein as far as an Indian dietary is concerned. Green gram is rich in carbohydrates (60-62 %), protein (20-24 %), fat (1.5 %), fiber (4.0 %), ash (3.0 %) and water (10 %), mineral, vitamin A, B and ascorbic acid [2]. Green gram contributes about 41 lakh ha of total area and 19 lakh tonnes of production under pulse crop in our country, whereas, Karnataka covers an area of 3.97 lakh ha and producing about 0.96 lakh tonnes [3].

Although, green gram is well adapted to a wide range of growing conditions and soils, its cultivation is neglected by farmers because yield potential of green gram is very low due to insufficient portioning of assimilates, poor pod setting due to flower abscission, slow rate of dry matter accumulations and attack of pest and diseases. Boron deficiency is more widespread in majority of Indian soils next to zinc. Boron deficiency is more widespread in majority of Indian soils next to zinc [4]. Its deficiency is found approximately 33 % in Indian soils [5].

Application of boron enhance growth and yield attributes of crop including, cell division and cell elongation and meristematic tissue differentiation, cell wall formation, maintenance of structural and functional integrity of biological membranes, root elongation, sugar translocation, leaf photosynthates migration from source to sink, nitrogen fixation and nitrate assimilation, boron had a vital role in plant reproduction, germination of pollen and pollen tube growth, increase in flower count, pollination, seed set and disease resistance.

Therefore, attention should be given to boron nutrition for green gram to overcome deficiency by application of boron fertilizers at proper rate, source, method, formulations and timing of application in soil or to plants. But management of boron deficiency is a major concern because of narrow difference range between its deficiency and toxicity and total soil boron content can range from around 2 to 200 mg kg^{-1}; though only a fewer fraction (approximately 3 to 5 %) is available to the crops [6]. Soil application of boron was widely followed by farmers as a basal dose along with RDF. As for boron is considered as a micronutrient which receive in small amounts, other methods like foliar application and seed priming might be equally effective against as soil application and become more economic since they will require much smaller amount boron. Therefore, keeping in above facts, the present investigation on "effect of soil and foliar application of boron on soil properties on harvest of green gram" was carried out.

2. MATERIALS AND METHODS

2.1 General Characteristics of Experimental Site

A field experiment was carried out to assess effect of soil and foliar application of boron on soil properties on harvest of green gram at zonal agricultural research station, college of agriculture (13^0 05" N latitude and 77^0 34" E longitude), GKVK, Bengaluru, Karnataka, during *Kharif* 2019-20. The soil of the experimental site was sandy loam in texture, acidic in soil reaction (6.1), electrical conductivity (0.11 dS/m), organic carbon (0.55%), available nitrogen (261.61 kg ha^{-1}), available phosphorus (26.31 kg ha^{-1}), available potassium (154.2 kg ha^{-1}), available Sulphur (10.36 kg ha^{-1}) and available boron (0.31 mg kg^{-1}).

2.2 Field Experiment

The field experiment was conducted with twelve treatments (Table 1) in Randomized Complete Block Design (RCBD) with three replications in plot of 3.5 × 5.0 m each. The green gram crop of variety KKM 3 (Karnataka Kathalagere Moong 3) was selected for this study. Recommended dose of fertilizer (RDF) was applied at 12.5: 25: 12.5 ($N:P_20_5:K_20$ kg ha^{-1}) + FYM 7.50 t ha^{-1} + $ZnSO_4$ 10 kg ha^{-1} as Di Ammonium Phosphate (DAP), Muriate of Potash (MOP), Zinc Sulphate ($ZnSO_4$), respectively.

Soil application of borax applied at the rate of 2.5, 5.0 and 7.5 kg ha^{-1}. Borax was applied as basal dose for respective plots. Required quantity of borax was thoroughly mixed along with sand to ensure even distribution of borax fertilizer throughout plot because borax was applied in lesser quantity and to reduce toxicity of borax at single location. Foliar application of boric acid at the rate of 0.05, 0.1 and 0.2 % which was sprayed at an interval of 20 DAS at branching and 35 DAS at pre-flowering and pre-pod setting stage by using garden pressure pump sprayer.

The seeds are sown on 24 July 2019 and matured pods were harvested in two picking stage at 1st October of 2019 and 8th October of 2019. Intercultural and operations like hand weeding and plant protection measures were adopted uniformly in each plot as and when required.

2.3 Observations

2.3.1 Plant height (cm)

Plant height was measured with long wooden ruler from base of the plant to the fully opened top leaf. Height of the randomly labeled five plants in each plot was recorded at 30 DAS, 60 DAS and at harvest stage. Average value of each plant was worked out, recorded and expressed in centimeters.

2.3.2 Number of branches plant^{-1}

The number of branches arising from the main shoots was counted from the five tagged plants at 30 DAS, 60 DAS and at harvest. Average value of each plant was recorded and expressed in centimeters.

2.4 Yield parameters

2.4.1 Number of pods plant^{-1}

At harvest labelled five plants from each treatment plot, uprooted separately and number of pods per plants were counted and the average was taken as the number of pods plant^{-1}.

2.4.2 Number of seeds pod^{-1}

At harvest labelled five plants from each treatment plot, uprooted separately and number of seeds per pod were counted and the average was taken as the number of seeds pod^{-1}.

2.4.3 Test weight (g/100 seeds)

One hundred seeds were randomly selected from each net plot seed pool, counted, weighed and expressed as a test weight in grams by using weighing balance.

2.3.4 Number of nodules plant^{-1}

At flowering stage five randomly selected plants from each treatment net plot uprooted separately, number of nodules plant^{-1} are counted and the average was taken as the number of nodules plant^{-}

2.4.5 Seed yield (q ha^{-1})

After harvest, pods were separated from the plants from each net plot. After threshing, winnowing, cleaning and drying, seed weight was recorded. Using net plot yield, seed yield in q ha^{-1} was computed and presented.

2.4.6 Haulm yield (t ha^{-1})

Haulm yield was obtained by subtracting the seed yield from the total biomass weight of the crop harvested from net plot. Haulm yield expressed in t ha^{-1}.

2.5 Statistical Analysis

The comparative study of experimentally collected results was carried out by implementing Fisher's system of measurement of variance as described by Gomez and Gomez [7]. The significance level used in the 'F' evaluation was offered at 5 %. Critical difference (CD) values are presented at a significance level of 5 % in the table, wherever the' F' measure was found to be relevant at 5 %.

3. RESULTS AND DISCUSSION

3.1 Yield parameters

3.1.1 Number of pods plant^{-1}

The mean number of pods plant^{-1} significantly ($p < 0.05$) differs due to soil and foliar application of boron on green gram (Table 2). However, treatment receiving soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1 % along with RDF (T_{10}) shows significantly highest ($p < 0.05$)number of pods plant^{-1} (25.74) and was on par with treatment T_9 (25.12), T_{12} (24.90) and T_{11} (24.13) and differed significantly with rest of the treatments. In contrast absolute control recorded significantly ($p < 0.05$) lowest number of pods plant^{-1} (15.32) being on par with treatment T_2 (16.87).

Improved vegetative growth such as number of branches $plant^{-1}$ provided more sites for translocation of photosynthates and ultimately resulted in higher number of pods $plant^{-1}$ by Praveena *et al.* [8] Padbhushan and Kumar [9] reported that boron helps in the flower and pollen seed formation. Similar results were observed by Dixit and Elamathi [10] Meena *et al.* [11] Devi *et al.* [12] Pandey and Gupta [13] Singh and Srivastava *et al.* Maqbool *et al.* [14].

3.1.2 Number of seeds pod^{-1}

The data presented in Table 2 revealed that, the mean number of seeds pod^{-1} differs significantly ($p < 0.05$) due to effect of soil and foliar application of boron. However, treatment receiving soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1 % along with RDF (T_{10}) shows significantly ($p < 0.05$) highest number of pods pod^{-1} (14.48) and was on par with treatment T_9 (13.91) and T_{12} (13.23) and differed significantly with rest of the treatments. While significantly lower number of pods pod^{-1} (8.67) was recorded in absolute control and being on par with T_2 (9.30), T_5 (9.65) and T_6 (9.84) and differed significantly ($p < 0.05$) with rest of the treatments.

The boron application enhanced the flower count which makes stigma receptive and sticky, thereby causing pollen seed fertile and enhanced pollination leads to increased seeds pod^{-1} by Kaisher et al. [15]. Padbhushan and Kumar [9] reported that improvement in number of seeds pod^{-1} may be due to the increase in germination percentage of seed inside the pod. Meena *et al.* [11] stated that boron fertilization also increased the pollen producing capacity, anthesis and pollen seed viability increased number of seeds per pod in soy bean. Similar results were confirmed by Dixit and Elamathi [10] Singh *et al.* [1] and Maqbool *et al.* [14] in green gram.

3.1.3 Test weight of 100 seeds (g)

The result distinctly indicated that, the mean test weight of 100 seeds differs significantly ($p < 0.05$) due to effect of soil and foliar application of boron (Table 3). Significantly, maximum test weight of 100 seeds was recorded in treatment T_{10} (5.12 g) (T_2 +soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1 %) and was on par with T_9 (5.07 g) and T_{12} (4.93 g) and differed significantly with rest of the treatments. Absolute control recorded significantly lower test weight of 100 seeds (3.70 g). Combination of soil and foliar application of boron shows superior effect then soil/foliar application of boron alone.

Increase in test weight of 100 seeds in green gram may be due to the involvement of boron in physiological and biochemical processes like membrane permeability, sugar translocation, leaf photosynthates migration from source to sink etc. Padbhushan and Kumar [9] noticed that role of boron on pollen production capacity of anther, fertilization, viability of pollen seeds, pollen tube growth and pollen germination enhanced test weight of 100 seeds in green gram. Kaisher *et al.* [15] concluded that enhanced pod setting and reduced the sterility of flower, thereby increase in test weight of green gram. The results are in harmony with those reported by Devi *et al.* [12] in soy bean, Singh and Srivastava *et al.* [1] and Maqbool *et al.* [14] in green gram.

Table 1. Treatment details of the experiment

T_1	Absolute Control
T_2	RDF (FYM 7.50 t ha^{-1} + NPK 12.5: 25: 25 kg ha^{-1} + $ZnSO_4$ 10 kg ha^{-1})
T_3	T_2 + soil application of boron 2.50 kg ha^{-1}
T_4	T_2 + soil application of boron 5.00 kg ha^{-1}
T_5	T_2 + soil application of boron 7.50 kg ha^{-1}
T_6	T_2 + foliar application of boron 0.05 %
T_7	T_2 + foliar application of boron 0.1 %
T_8	T_2 + foliar application of boron 0.2 %
T_9	T_2 + soil application of boron 2.50 kg ha^{-1} + foliar application of boron 0.05 %
T_{10}	T_2 + soil application of boron 2.50 kg ha^{-1} + foliar application of boron 0.1 %
T_{11}	T_2 + soil application of boron 5.00 kg ha^{-1} + foliar application of boron 0.05 %
T_{12}	T_2+ soil application of boron 5.00 kg ha^{-1} + foliar application of boron 0.1 %

Table 2. Effect of soil and foliar application of boron on number of pods plant^{-1}, number of seeds pod^{-1} and test weight of 100 seeds (g), number of nodules plant^{-1}, seed yield and haulm yield of green gram

Sl. No.	Treatments	Number of pods plant^{-1}	Number of seeds pod^{-1}	Test weight of 100 seeds (g)	Number of nodules plant^{-1}	Seed yield (q ha^{-1})	Haulm yield (t ha^{-1})
T_1	Absolute Control	15.32	8.67	3.70	14.75	5.99	1.22
T_2	RDF (FYM 7.50 t ha^{-1} + NPK 12.5: 25: 12.5 kg ha^{-1} + $ZnSO_4$ 10 kg ha^{-1})	16.87	9.30	3.92	16.94	8.34	1.70
T_3	T_2 + soil application of borax at 2.50 kg ha^{-1}	23.26	10.45	4.36	18.43	9.18	1.91
T_4	T_2 + soil application of borax at 5.00 kg ha^{-1}	22.89	10.17	4.13	18.96	8.97	1.86
T_5	T_2 + soil application of borax at 7.50 kg ha^{-1}	19.72	9.65	4.03	17.59	8.84	1.80
T_6	T_2 + foliar application of boric acid at 0.05 %	21.89	9.84	4.32	17.35	9.05	1.85
T_7	T_2 + foliar application of boric acid at 0.1 %	23.82	11.76	4.78	18.84	9.23	2.01
T_8	T_2 + foliar application of boric acid at 0.2 %	23.44	10.83	5.11	18.23	9.17	1.99
T_9	T_2 + soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.05 %	25.12	13.91	5.07	19.09	9.94	2.12
T_{10}	T_2 + soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1 %	25.74	14.48	5.12	19.55	10.19	2.17
T_{11}	T_2 + soil application of borax at 5.00 kg ha^{-1} + foliar application of boric acid at 0.05 %	24.13	12.80	4.86	19.86	9.41	2.08
T_{12}	T_2+ soil application of borax at 5.00 kg ha^{-1} + foliar application of boric acid at 0.1 %	24.90	13.23	4.93	20.12	9.61	2.13
S.Em±		**0.65**	**0.50**	**0.08**	**0.56**	**0.31**	**0.06**
CD 5%		**1.91**	**1.49**	**0.21**	**1.63**	**0.92**	**0.17**

Table 3. The effect of soil and foliar application of boron on economics of green gram

Sl. No.	Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T_1	Absolute Control	16750	40732	23982	1.43
T_2	RDF (FYM 7.50 t ha^{-1} + NPK 12.5: 25: 12.5 kg ha^{-1} + $ZnSO_4$ 10 kg ha^{-1})	21870	56712	34842	1.59
T_3	T_2 + soil application of borax at 2.50 kg ha^{-1}	22880	62424	39544	1.73
T_4	T_2 + soil application of borax at 5.00 kg ha^{-1}	23890	60996	37106	1.55
T_5	T_2 + soil application of borax at 7.50 kg ha^{-1}	24900	60112	35212	1.41
T_6	T_2 + foliar application of boric acid at 0.05 %	22120	61540	39420	1.78
T_7	T_2 + foliar application of boric acid at 0.1 %	22370	62764	40394	1.81
T_8	T_2 + foliar application of boric acid at 0.2 %	22620	62356	39736	1.76
T_9	T_2 + soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.05 %	23130	67592	44462	1.92
T_{10}	T_2 + soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1 %	23380	69292	45912	1.96
T_{11}	T_2 + soil application of borax at 5.00 kg ha^{-1} + foliar application of boric acid at 0.05 %	24140	63988	39848	1.65
T_{12}	T_2+ soil application of borax at 5.00 kg ha^{-1} + foliar application of boric acid at 0.1 %	24390	65348	40958	1.68

** cost of green gram- Rs. 6800 per quintal*

3.1.4 Number of nodules plant^{-1}

A perusal of the data (Table 2) indicated that effect of soil and foliar application of boron differs significantly ($p < 0.05$) on the number of nodules plant^{-1} of green gram. Application of RDF + soil application of borax 5.00 kg ha^{-1} + foliar application of boric acid 0.1 % (T_{12}) recorded significantly maximum number of nodules plant^{-1} (20.12) and was found on par with T_{12} (20.12) and was on par with treatment T_{11} (19.86), T_{10} (19.55), T_9 (19.09), T_4 (18.96) and T_7 (18.84) and differed significantly with rest of the treatments. While significantly minimum number of nodules plant^{-1} (14.75) was recorded in absolute control.

Bellaloui et al. [16] results showed that inoculated pea seedlings grown in the absence of boron (B-minus plants) yielded root nodules that were smaller than seedlings grown in presence of boron (B-plus plants). In addition, most nodules developed in the absence of boron still appeared white when examined 3 to 4 weeks after inoculation, whereas seedlings grown in the presence of boron already had pink nodules. The number of nodules in B-minus nodules (3.87 ± 0.23 μg B g^{-1} dry weight, compared to 43.53 ± 3.45 μg B g^{-1} dry weight for nodules derived from peas grown in the presence of boron.

3.1.5 Seed yield (q ha^{-1})

The data in Table 2 showed that soil and foliar application of boron differs significantly on seed yield of green gram. Combination of soil and foliar application shows superior effect as compared to foliar/soil sole application. However, significantly ($p < 0.05$) higher seed yield were recorded in treatment T_{10} (10.19 q ha^{-1}) which receive soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1 % along with RDF and being on par with treatment T_9 (19.86), T_{12} (19.55) and T_{11} (19.09) and differed significantly with rest of the treatments. Absolute control (T_1) recorded significantly ($p < 0.05$) lowest seed yield (5.99 q ha^{-1}) and being on par with T_2 (8.34 q ha^{-1}) which receives RDF.

Foliar applied boron shows better seed yield as compared to soil application, because boron availability is more during reproductive stage and foliar application helps immediate supplementation of boron to green gram by Padbhushan and Kumar [9]. Kaisher *et al.* [15] reported that boron improves growth parameter which ultimately enhanced photosynthesis activity, protein and carbohydrate metabolism, higher uptake of nutrients and translocation of these compounds from source to sink. Also, boron improves pollen germination, pollen tube growth; make stigma receptive helps in better yield parameters so increase in seed yield. The result is supported by Patra and Battacharya [17] Quddus *et al.* [18] Singh and Srivastava [1] Alam and Islam [19] and Maqbool *et al.* [14] in green gram.

3.1.6 Haulm yield (t ha^{-1})

Haulm yield affected significantly due to the effect of soil and foliar application of boron on green gram (Table 2). Application of RDF + soil application of borax at 2.50 t ha^{-1} + foliar application of boric acid at 0.1 % (T_{10}) recorded significantly maximum ($p < 0.05$) haulm yield (2.17 t ha^{-1}) and was on par with treatment T_9 (19.86), T_{12} (19.55) and T_{11} (19.09) and differed significantly with rest of the treatments. Absolute control (T_1) recorded lowest haulm yield (1.62 t ha^{-1}).

Dixit and Elamathi (2007) witnessed that foliar application of boron (0.2 %) in green gram increased haulm yield (30.0 q ha^{-1}) when foliar application of DAP 2 %+ NAA 40 ppm + B 0.2 % + Mo 0.05 % at 30 DAS over the control. These results are also confirmed Meena et al. [11] Choudhary et al. [20] Mishra et al. [21] and Praveena et al. [8] in terms of haulm yield.

3.2 Effect of Soil and Foliar Application of Boron on Economics of Green Gram

The economics of crop in terms of cost of cultivation, gross returns, net return and benefit cost ratio are presented in Table 3. Higher gross returns (69,292 Rs. ha^{-1}), net return (45,912 Rs. ha^{-1}) and benefit cost ratio (1.96) was found in T_{10} which receive soil application of borax at 2.50 kg ha^{-1} + foliar application of boric acid at 0.1 per cent along with RDF. This may be due to the better utilization of native and soil nutrients, higher seed and biomass yield. However, minimum gross returns (40,732 Rs. ha^{-1}) and net returns (23,982 Rs. ha^{-1}) were recorded in absolute control but minimum B:C ratio (1.41) was recorded in treatment T_5 (T_2 + soil application of borax at 7.50 kg ha^{-1}).

Devi et al. [11] stated that application boron could enhance the yield attributes such as increasing pods on lateral branches, seed number, and overall seed yield of soybean. Maximum benefit cost ratio was obtained by increasing the yield with the application of boron at 1.5 kg per ha.

4. CONCLUSION

In the present study it was observed that, the number of pods plant^{-1}, number of seeds pod^{-1}, test weight of 100 seeds (g), seed yield, haulm yield and B:C ratio were found significantly higher in treatment (T_{10}) receiving RDF + soil application of borax at 2.50 t ha^{-1} + foliar application of boric acid at 0.1 % (T_{10}) but number of nodules plant^{-1} was significantly ($p < 0.05$) higher in treatment receiving RDF + soil application of borax at 5.00 t ha^{-1} + foliar application of boric acid at 0.1 % (T_{12}). The lesser yield and economics in unfertilized control plots suggest that application of RDF along with zinc and boron alleviate the yield of green gram crop. However, considering majority of yield and economic factors from current study it is concluded that treatment (T_{10}) T_2 + soil application of borax at 2.50 t ha^{-1} + foliar application of boric acid at 0.1 % (T_{10}) was proved to be better in yield attributes of green gram.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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