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Effect of Boron Application on Growth, Yield and Quality of Bitter Gourd

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Abstract

Boron is an essential plant nutrient which plays an integral role during cell division, sugar transportation, reproduction as well as in the physiological and biochemical events occurring in plants, especially related to the enhancement of quality of crops. Boron has also been found imperative for human health, as it is involved in mineral and hormonal metabolism, enzyme action and other important cell membrane functions. Therefore, keeping in view the importance of this micronutrient, this study was planned to assess the effects of boron on the yield and quality of bitter gourd. Three replicated field experiments were laid down in a randomized complete block design with six treatments. Control, recommended NPK, 0.5, 0.75, 1 and 1.25 kg boron/ha along with recommended NPK. The results showed that boron had a significant effect on bitter gourd fruit yield and the highest yield (14.1 t/ha) was obtained in the treatment where 1.25 kg/ha boron was applied while the low yield (5 t/ha) was obtained from control. The visual quality parameters (size, girth and weight) were significantly improved by boron application and it was increased with increasing boron levels. The highest boron concentration (30 ppm) in bitter gourd fruit was noted in the treatment where highest boron (1.25 kg boron/ha) was applied, whereas minimum boron concentration (7.8 ppm) was found in control, where no boron was applied. The results also revealed that boron has non-significant effects on the uptake of N and P, but had a significant effect on the uptake of K and Zn.

Introduction

Bitter gourd (*Momordica charantia*) belongs to the most prevalent cucurbitaceous vegetable. It is grown extensively throughout the world. In Pakistan, about 5000 hectares are under bitter gourd cultivation during the summer season, and its production is about 50,000 tons per annum. Bitter gourd is very nutritional which carries 17 calories/100 g and is very rich in phytonutrients like anti-oxidants, minerals, vitamins and dietary fiber. It also contains polypeptide-P (plant insulin) that lowers blood sugar levels [1].The fresh bitter gourd is an exceptional source of α-carotene, ß-carotene, lutein, zeaxanthin, vitamin-A and vitamin-C. These compounds act as defensive agents against reactive oxygen species (ROS) and oxygen-derived free radicals that play a role in various diseases. It is also a good source of B-complex vitamins and minerals as zinc, iron, manganese, potassium and magnesium. During the plant growth period, micronutrients play various roles in physiological and biochemical processes and among those nutrients, Boron (B) is a vital element involves in flowering and fruiting of the plant so its deficiency origins floral deformities inducing male bareness [2]. Boron deficiency also results in stunted growth because it is a part of structure [3]. Boron deficiency affects the growing points of roots and youngest leaves. The leaves fade and become craggy and curly. Boron scarcity affects the synthesis of protein and amino acid, mobility of macronutrients (nitrogen and phosphorus) and sugar [4]. Nucleic acid synthesis and calcium uptake also depend upon the availability of B [5].

In Pakistan, the climatic conditions are very blunt, i.e., high temperature and low rainfall in arid and semi-arid areas of wheat-cotton cropping system, so soil B makes complex with organic matter gradually [6, 7] and also adsorbs on clay surfaces [8, 9]. The reported data about Pakistan showed that 49% area of Punjab is B deficient [10, 11]. Another reason of B deficiency in Pakistan is high calcareousness of soils which eventually resulted in precipitation of B with $CaCO_3$ [12] and is quite unavailable for plant growth [13]. Boron availability decreases with the increasing pH, and most of the total soil B is unavailable to the plants [14, 15]. Boron is associated directly and indirectly with several plant functions, as it involves in the growth of cells in newly emerging shoots and roots while in some plants it is crucial for boll formation, flowering, pollination, seed development and sugar transport [16, 17]. Boron plays a supportive role in cell wall synthesis, lignification [18] and cell wall structure [19]. Boron deficiency plays a significant role in yield reduction of many vegetables, including bitter gourd due to premature flower, square or boll shedding. Bitter gourd is a very popular vegetable in Pakistan and its yield optimization is a major concern of local farmers. Information regarding boron effect on major crops is although available in Pakistan, but the vegetables response to boron under alkaline calcareous soils is not available. So keeping in view the importance of boron and bitter gourd, this study was planned to find the effect of B application on the growth, yield, and quality of bitter gourd.

Materials and Methods

Experiment site and design

This study was conducted for three consecutive years (2013-2015) at the Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute Faisalabad, Pakistan. The selected field was adequate in potassium while squat in available phosphorus, organic matter and 0.05 M HCl extractable B contents (Table 1).

Table 1 Physico-chemical properties of the experimental field.

Characteristics	Unit	Value
Sand	%	50.5
Silt	%	20
Clay	%	29.5
Textural Class	-	Sandy clay loam
Saturation percentage	%	9.13
pH		7.70
ECe	dS/m	2.82
K	mg/kg	142.6
P	mg/kg	6.10
B	mg/kg	0.40 (<0.5 deficient)
Zn	mg/kg	1.48
Organic matter	%	0.71

ECe = electrical conductivity of saturated soil extract

The soil texture was sandy clay loam. The study was set up as a randomized complete block design (RCBD) with six treatments and three replications. Recommended doses of nitrogen, phosphorus, and potassium (100 kg N + 100 kg P_2O_5 + 60 kg K_2O) were applied in five experimental plots. Treatments used were as follows: T1, Control; T2, recommended dose of chemical fertilizers (NPK); T3, 0.5 kg B/ha + NPK; T4, 0.75 kg B/ha +NPK; T5, 1.0 kg B/ha + NPK' and T6, 1.25 kg B/ha + NPK. Urea, single superphosphate, sulfate of potash and H_3BO_3 were used as the sources of N, P, K and B, respectively. All P, K, and B were applied at the time of sowing as basal dose while N was applied in two splits (half at sowing and half with first irrigation). Bitter gourd seeds (cv. Faisalabad long) were sown on 2.5 feet wide beds at 1.5 feet plant-plant distance in the spring. All the cultural practices were carried when and where required throughout the growth period.

Soil and plant analysis

Pre-sowing soil samples from the site were taken following zigzag manner at two depths (0-15 and 15-30 cm). Composite samples of each depth were made by mixing different samples in order to inspect the initial fertility status of the whole field. The collected soil samples were air-dried, ground and sieved through a 2 mm stainless steel sieve for physicochemical characteristics. Soil particle distribution was measured by the hydrometer method [20]. Soil pH was recorded by pH meter (Jenway- 3510) with glass electrodes using buffer of pH 4.0 and 9.0 as standards [21].The electrical conductivity of soil saturated extract was measured by EC meter (Jenway-4510) while vacuum pump was used for the extraction of soil paste extract. Organic carbon (OC) content of the soil was determined by the method described by Ryan et al. [22]. Soil B was estimated by dilute hydrochloric acid method [23, 24]. Available phosphorus was determined by Olsen's method [25] and extractable potassium was estimated by ammonium acetate (1 N of pH 7.0) extraction method [26] (Table 1).

Total eleven pickings of bitter gourd fruit were taken within two months (Jun-July) and yield data of whole plot was calculated. Fruits sampling was done after the last picking. Samples were processed and placed in an oven at 70^{o}C for 24 hrs and then ground. Boron in bitter gourd fruits samples was measured by colorimetry using Azomethine-H after dry ashing [24]. Total N was determined by Kjeldahl method [25]. Plant P was estimated by yellow color method on a spectrophotometer (U-2020) after wet digestion [27]. Plant K was analyzed with a flame photometer (Jenway PFP7). Available Zn was extracted by DTPA [28] and determined by atomic absorption. The uptake of nutrients by bitter gourd was determined on dry weight basis using the following relationship [29].

Nutrient uptake (kg/ha) = nutrient concentration (%) in plant (dry matter) × dry yield / 100

Statistical analysis

The collected data were analyzed by using Fisher's analysis of variance technique. LSD at 5% probability was used to compare the treatment means [30].

Results and Discussion

Quality and yield of bitter gourd

Bitter gourd is a popular summer vegetable in Pakistan. It is not only a nutritious plant, but also provides medicinal activities against various diseases. Boron can affect the function or composition of the brain, the skeletal and the immune systems [31]. The soil was supplemented with B to determine the optimum level of B for the optimum yield and quality of bitter gourd. The results of three year study (Fig.1) revealed that the highest fruit yield (14.1 t/ha) was obtained during the second year (2014) and the lowest yield (5 t/ha) was obtained in the third year (2015) which might be due to the B toxicity. When the treatments were compared with each other, the results clearly indicated that different levels of B exhibited a significant effect on yield over control and the highest yield (14.1 t/ha) was noted in the T6. This trend was same in all three years. This increase in bitter gourd fruit yield clearly indicated that B has residual effects which significantly increased the yield during the second year. These findings are fully supported by the results of other researchers [7, 8]. The highest fruit yield (12.0, 14.1 and 12.8 t/ha) was obtained in all three years at the B-level of 1.25 kg/ha. During third year (2015), the control treatment gave minimum bitter gourd yield (5.0 t/ha), while in the first and second year, yield was 6.9 and 6.2 t/ha respectively.

The results revealed that the application of B increased the yield and in T3 where 0.5kg/ha B was applied, yield was increased about 1 t/ha than recommended fertilizer in the first year and about 2 t/ha in the second and third year. T4 and T5 were at par with each other. So as the applied B concentration was increased, yield was also increased.

This increase in yield maybe because of decrease in flower shedding (Table 2), the effect on the pollen germination and integrity of male flowers by the B application [32]. It was observed that B application decreased the flower shedding up to 52.8% in the treatment where maximum B (1.25 kg ha^{-1}) was applied. These results agree with the findings of Muazzam et al. [33]. It was also found that B at the rate of 0.5 kg and 0.75 kg ha^{-1} was at par with each other. The data also revealed that recommended fertilizer also helped in flowering and decreased in flower shedding by 17.3%. Boron reduces fruit drop, surges the fruit set and mends fruit quality as reported in numerous crops [34]. Data in Table 3 shows that maximum fruit length (22.8 cm), girth (19.5 cm) and weight (215 g) was observed in T6 where maximum B was applied followed by T5 and T4.

Table 2 Effect of different levels of boron on flower shedding of bitter gourd.

Treatment	Number of flower sheds per plot	Decrease in flower shedding (%)
T1	41.3 A	-
T2	34.1 B	-17.3
T3	27.3 C	-33.9
T4	27.3 C	-33.5
T5	22.0 D	-46.8
T6	19.5 D	-52.8
LSD	4.5	

Different letters show significant differences at P<0.05.T1 = Control; T2 = NPK; T3 = 0.5 kg B/ha + NPK; T4 = 0.75 kg B/ha + NPK; T5 = 1.0 kg B/ha + NPK' and T6 = 1.25 kg B/ha + NPK; LSD = least significant difference.

Table 3 Effect of different levels of boron on the quality of bitter gourd**.**

Treatment	Fruit Length (cm)	Girth (cm)	Weight (g)
T1	13.6 D	15.5 BC	94.0 E
T2	14.9 C	15.5 BC	125.8 D
T3	15.5 C	15.7 BC	125.0 D
T4	20.3 B	15.7 BC	160.7 C
T5	20.8 B	17.5 AB	178.2 B
T6	22.8 A	19.5 A	215.0 A
LSD	0.44	0.81	6.7

Different letters show significant differences at P<0.05.T1 = Control; T2 = NPK; T3 = 0.5 kg B/ha + NPK; T4 = 0.75 kg B/ha + NPK; T5 = 1.0 kg B/ha + NPK' and T6 = 1.25 kg B/ha + NPK; LSD = least significant difference.

The treatment where 0.5 kg/ha B was applied was at par with the treatment where only recommended fertilizer was added. Minimum fruit weight (94 g) and minimum length (5.3 in) was observed in control. The results agree with the findings of Goldbach [35], that in the absence of B, fruit that matures may be small in size, bronzed, and /or deformed. With the application of B (0.5 kg/ha), the length was increased by 3.4%. While in T6 the increase in length, girth, and weight was 52.5%, 25.8% and 70.9% compared to control, respectively.

Boron and zinc concentration in bitter gourd fruit

Boron flows from soil solution to plant tissue through concentration gradient called passive transport [36]. The B concentration in bitter gourd fruit was directly affected by applied B (Fig. 2) and the maximum concentration (30 ppm) was found in T6 (1.25 kg B/ha), while minimum concentration (7.8 ppm) was shown by control. Similar results were found by Tariq et al. [37], that plant B concentration increases in a linear fashion with the increase in B concentration applied to soil. It was also noted that the application of recommended fertilizer also helped in the utilization of B and its concentration in T2 (NPK) was double than control. Zn concentration in bitter gourd fruit was fascinatingly increased by the application of B to a certain level then its concentration was decreased. Minimum Zn concentration (25.1 ppm) was found in control while maximum Zn concentration (47 ppm) was found in T4 where 0.75kg/ha B was applied. After that, Zn concentration was lowered as the B availability was increased in T5 and T6. The results indicated that up to a certain level of B in soil, Zn and B showed a synergistic relation. Similarly, Grewal et al. [38] found that Zn uptake was increased by the application of sufficient B provided with that the Zn supply is ample.

Macronutrients concentration (N, P, K) in bitter gourd fruit

Data regarding the effect of B on the concentration of N, P, and K (Fig. 2) showed that B increased the concentration of N and P in bitter gourd fruit non-significantly. Minimum N (3.1 %) and P concentration (0.4 %) was found in control while maximum N (4.4 %) was found in T6 and maximum P (0.45%) was obtained in T5. On the other hand, the concentration of K in bitter gourd fruit was increased significantly with the increase in B concentration in soil. Boron and K are synergistic having coinciding roles to play in plant physiology. It has been shown that an optimal level of B

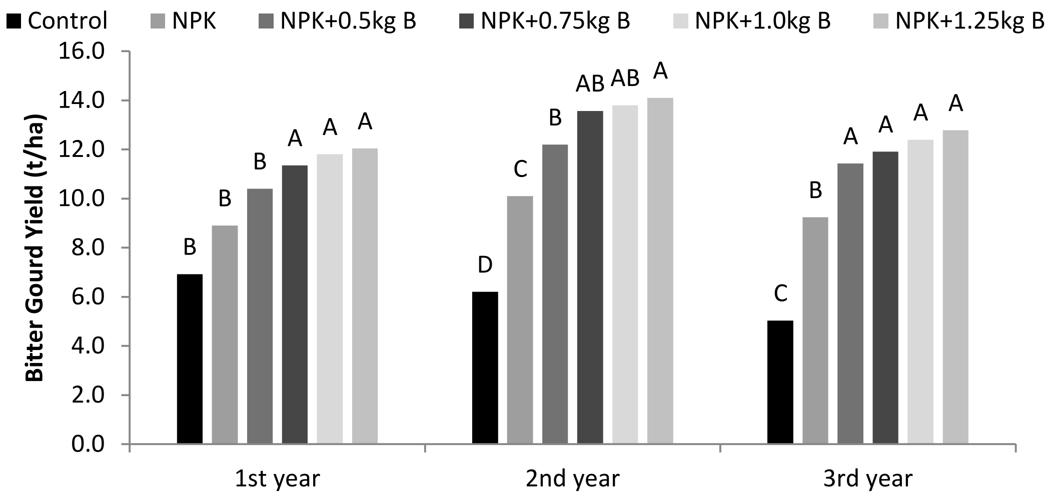

Fig. 1 Effect of different levels of boron (B) on the yield of bitter gourd. Different letters show significant differences at P<0.05

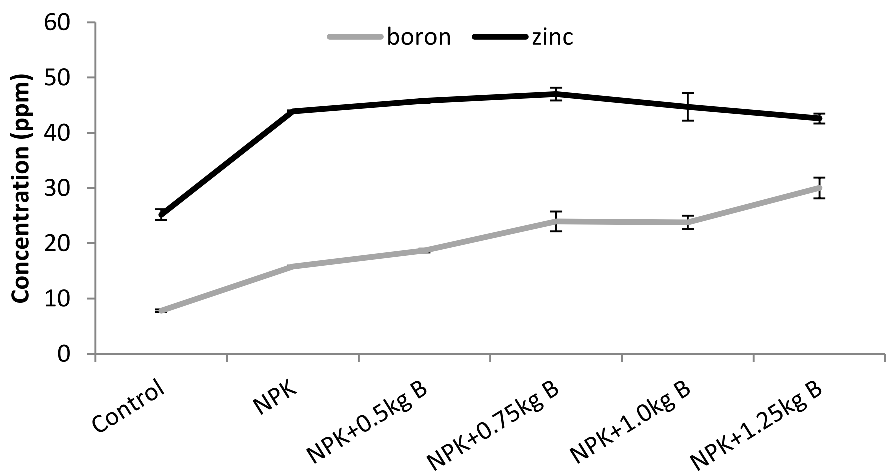

Fig. 2 Effect of different levels of boron (B) on the concentration of B and Zn in bitter gourd fruit at the end of the third year.

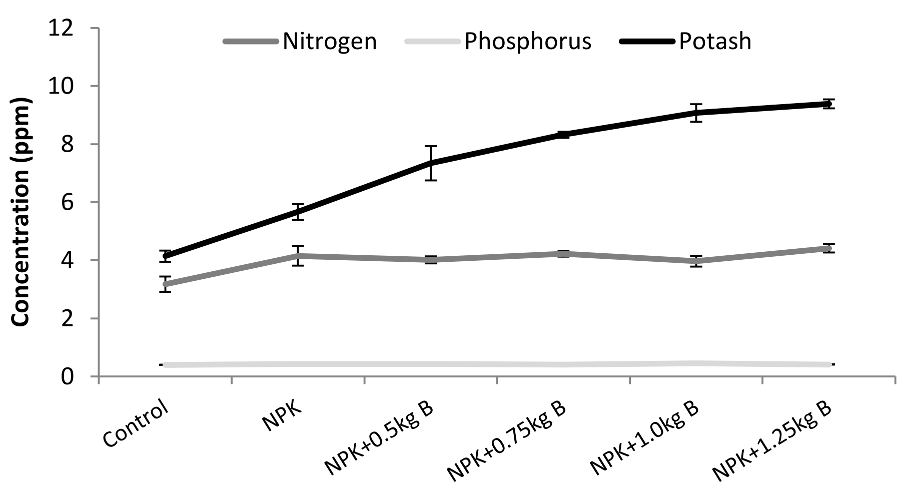

Fig. 3 Effect of different levels of boron (B) on the N, P and K concentration in bitter gourd fruit at the end of the third year.

Table 4 Fruit yield and uptake of nitrogen, potassium, phosphorus, boron and zinc in bitter gourd fruits.

Treatments	Yield* kg/ha	% increase over NPK	N uptake kg/ha	P uptake kg/ha	K uptake kg/ha	B uptake g/ha	Zn uptake g/ha
T1	5074 E	-	161.2C	20.4E	210.3 E	39.6D	127.7 D
T2	8065 D	-	334.9 B	34.5D	456.9 D	127.1C	354.0 C
T3	8957 C	11	359.3 B	38.3C	657.3 C	167.3C	409.8 B
T4	10307 B	28	435.3 A	42.4 B	858.0B	247.0B	484.4 A
T5	11205 A	39	444.4 A	50.6A	1016.9A	266.4AB	500.5A
T6	10063 B	25	443.8 A	41.8B	944.4A	302.2A	428.6 B
LSD	823.91		39.9	2.5	78.5	41.0	41.7

*Fruit yield on dry weight basis; Different letters show significant differences at $P<0.05$. T1 = Control; T2 = NPK; T3 = 0.5 kg B/ha + NPK; T4 = 0.75 kg B/ha + NPK; T5 = 1.0 kg B/ha + NPK' and T6 = 1.25 kg B/ha + NPK; LSD = least significant difference.

increases K permeability of the cell membrane [39]. Data showed that the minimum K concentration (4.1 %) was found in T1 (control) and in T2 (NPK), K concentration was 5.7%. Kumar et al. [40] and Hosseini et al. [41] also found the same synergistic relationship of K and B. Potassium plays a crucial photosynthesis and plant cell elongation [39], so role in osmoregulation, and also involves in more than 60 enzyme reaction. It has a key role in an increase in the concentration of K contributed towards the increase of bitter gourd yield.

Nutrient uptake by bitter gourd fruit

The plant's chemical composition varies with the availability of nutrients in the soil solution. Selective uptake, transportation, amassing and release of nutrients are the major factors affecting the nutrient concentration in plant tissues. Nutrient uptake by bitter gourd fruit (Table 4) on dry weight basis showed that in control, 5074 kg bitter gourd took up the 161 kg N, 20.5 kg P, 210.8 kg K, 39.6 g B, and 127.7 g zinc. With the application of recommended NPK fertilizers (no B), the B uptake was increased three folds (129.5 g/ha) and Zn uptake was increased two folds (362.1 g), while in T6, where maximum B was added, maximum N, K, and B were recovered from bitter gourd fruits, while maximum P and Zn were found in T5 treatment and the yield was also maximum in the T5 treatment.

Conclusions

The study concludes that B has pronounced effect on the lowering of flower shedding of bitter gourd thus increases the yield. Quality parameters (weight, girth, and length) of bitter gourd fruit were also improved with B application. Nutrients concentration in bitter gourd was also affected by boron. N and P concentration was increased non-significantly while K concentration in bitter gourd fruit was increased significantly. The concentration of Zn was increased up to a certain level of B (1 kg/ha) and then decreased. Nutrients uptake and yield was maximum in the treatment where maximum B was added. So it can be concluded that for better quality and quantity of bitter gourd, 0.75-1.0 kg/ha B should be applied.

Conflict of interest

The authors declared that they have no conflict of interest.

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