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Vegetative and Reproductive Response of Bitter Gourd to the Foliar Application of Boric Acid

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Abstract

Bitter gourd is the most valuable medicinal vegetable of family *Cucurbitaceae*. Bitter gourd is monoecious in nature, which has the ability to produce more staminate flowers than to pistillate flowers. The main reason for the reduction in yield of bitter gourd is due to less female flower production. Boron is the micronutrient, which plays an important role in plant development, membrane stability, cell wall structure, phenol and carbohydrate metabolism and sugar transportation. Boron has an important role in the cell differentiation, growth of cell wall, growth of shoot and it also enhances the number of flowers and ultimately fruit yield. Foliar application of boric acid at the concentration of 6 mM significantly increased the number of nodes for the appearance of male flowers, number of nodes for the appearance of female flowers, numbers of male and female flowers plant^{-1}, sex ratio M/F and plant height at flower bud initiation stage. The application of boric acid (6 mM) also increased the plant height, root weight, fruit numbers plant^{-1} at 1st and 2nd picking, fruit length plant^{-1}, fruit diameter plant^{-1}, fresh fruit weight and plant weight and yield at 2nd picking. These results suggest that the boric acid foliar application can be useful to improve female flowers and yield of the bitter guard.

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Introduction

Momordica charantia L. (bitter gourd) is an essential vegetable crop of tropical and subtropical areas and commonly cultivated in different countries of the world such as India, Pakistan, America, China, Bangladesh, Sri Lanka, Thailand, Japan, Indonesia, Philippines, Malaysia, Nepal, etc. [1]. Bitter gourd is getting popularity in global cuisine due to its high nutritional and medicinal importance. Bitter gourd has different medicinal properties such as antimutagenic, abortifacient, antilipolytic, cytotoxic, hypoglycemic, antiviral and analgesic [2]. Bitter gourd contains different nutrients in rich amount like vitamin A, vitamin C, carotenoids, essential amino acids, folic acid, moisture, lipids, fiber, protein, carbohydrate, calcium, potassium, iron, manganese, copper, phosphorus and the entire plant have many bioactive compounds [3]. Naturally, bitter gourd is a monoecious plant because it contains maximum number of staminate (male) flowers as compared to pistillate (female) flowers. This flowering response of bitter gourd is not beneficial and reasonable, due to this reason, it gives less fruit setting and fruit yield, that is a major drawback in bitter gourd. To get maximum fruit production from bitter gourd, there should be synchronized between male and female flower ratio [4]. Maleness and femaleness in bitter gourd can be influenced by different environmental factors such as temperature, photoperiod and by the application of different micro-nutrition or plant growth regulators [5]. In the bitter gourd, the average ratio of staminate to pistillate flowers in monoecious lines in the whole flowering period is normally 50:1 [6]. This sex ratio also differs considerably from 9:1 to 48:1 [7].

The boric acid is used as a source of boron, a micronutrient, which plays an important role in plant development, membrane stability, cell wall structure, phenol and carbohydrate metabolism and sugar transportation [8]. Boron also involves with the growth of cell wall, shoot growth, cell differentiation, and enhance the flowering number and fruit yield [9]. There is little understanding available about the foliar spray of boric acid on the bitter gourd. The objective of the present study is to evaluate the vegetative and reproductive response of bitter guard to the foliar application of boric acid.

Materials and Methods

Seeds of a commercially cultivated variety of bitter gourd "Faisalabad long" were obtained from Vegetable Research Institute, AARI, Faisalabad. Seeding of bitter gourd was done on the raised bed. The size of the raised bed was 1.82 m wide and 6.07 m long. The plants were spaced 1 ft apart. Fertilizer was applied according to requirement after the soil nutrient analysis. Fertilizers urea, diammonium phosphate (DAP) and sulfate of potash (SOP) were applied @ 150, 125 and 125 kg per hectare, respectively. One-third amount of nitrogen (N), whereas the full amount of phosphorus (P) and potash (K) fertilizer was added at the sowing time, while the last dose of nitrogen was applied at flowering stage. Standard and proper measures were used for the plant protection in bitter gourd. The experiment was performed in a randomized complete block design (RCBD) and replicated three times with 15 plants in each replication. Boron was applied as boric acid (Jaffar Brothers (Pvt) Limited, Pakistan) by the foliar application method at two plant leaf stage and following treatments were used: T_0: (control = no application of boric acid; T_1: (boric acid 2 mM), T_2: (boric acid 4 mM) and T_3: (boric acid 6 mM).

Data were collected for different parameters such as plant height (cm) at flower bud initiation stage and at the second fruit harvest stage, days to first flowering, no. of node for appearance of male flowers per plant, no. of node for appearance of female flowers per plant, no. of male flowers per plant, no. of female flowers per plant, sex ratio M/F, root weight (g), no. of fruit per plant at 1st picking, no. of fruit per plant at 2nd picking, fruit length plant^{-1} (cm), fruit diameter plant^{-1} (mm), weight of root (g), fresh fruit weight (g), plant weight (g), and yield (g). The analysis of variance of the data for each attribute was computed using the STATISTIX 8.1 and HSD Tukey's range test was applied to find the means of different parameters that were significantly different from each other [10].

Results and Discussion

Plant height

The foliar application of boric acid at different levels, *i.e.*, 2 mM, 4 mM, and 6 mM, to bitter gourd variety "Faisalabad long" at two-leaf stage showed significant (P<0.05) results for plant height at flower bud initiation stage and at the second fruit harvest stage. At flower bud initiation stage, the plant height was increased with increasing concentration of boric acid. The maximum plant height of 85 cm was measured in plants treated with foliar application of boric acid at 6 mM, while in control, it was measured

Table 1 Effect of foliar application of different concentrations of boric acid on growth and yield parameters of the bitter guard. Different letters in a column show a significant difference at P=0.05 according to Tuckey's test.

Treatments	Plant height at the start of flowering plant^{-1} (cm)	Days to first flowering	No of nodes for appearance of male flowers plant^{-1}	No of nodes for appearance of female flowers plant^{-1}	No. of male flowers plant^{-1}	No. of female flowers plant^{-1}	Sex ratio M/F	Plant height plant^{-1} at 2nd harvest (cm)
Control	53c	49a	8b	10c	120b	17c	7.02a	240d
2 mM	76b	40b	11ab	14bc	130b	20c	6.63a	268c
4 mM	78b	39b	13ab	16b	140ab	29b	4.88b	315b
6 mM	85a	30c	14a	22a	157a	37a	4.29b	368a

about 53cm, showing a 60% increase in plant height over control (Table 1).

After the second fruit harvest, the plant height in 6 mM treatment was reached to 368 cm on an average, while it was 240 cm in control treatment, showing a 35% increase in plant height over control. Other researchers also showed similar results with the foliar application of boric acid. Moniruzzaman et al. [12] reported that boron increased the number of leaf plant^{-1}, plant spread, plant height, length and width of the leaf, head weight and yield plant^{-1} in broccoli [12] (Table 1). Similarly, Gawad et al. [13] showed that foliar spray of boric acid significantly increased the number of leaves, plant height, leaf area, haulm fresh and dry weight of eggplant. In general, foliar application of boric acid positively enhanced the vegetative growth of eggplant. Boron is an essential element to plant health, because of its role in forming and strengthening cell. [11].

Days to first flowering

The foliar application of boric acid showed a significant effect on the number of days to first flowering. The minimum days to first flowering were determined 30 days at the 6 mm application rate of boric acid, while maximum days (49) to first flowering were determined in control treatment, showed a 38 % decrease in days to first flowering by the application of boric acid (Table 1). Kazemi [14] reported that by the application boric acid mean duration of flowering and the number of achenes were increased which is not in agreement with our results. The different results might be because of a different variety or different soil and environmental conditions.

No. of nodes for the appearance of male flowers

The number of nodes of staminate flower per plant was significantly (P<0.05) increased by the foliar application of different levels of boric acid in bitter gourd. The highest number of nodes of male flower (14) was estimated when boric acid was applied at 6 mM in Faisalabad long cultivar of bitter gourd. While the lowest number of nodes of staminate flowers (8) was noted in control treatment, showing a 75 % increase in the number of nodes for the appearance of male flowers over control (Table 1). Foliar application of boric acid enhanced the vegetative growth of tomato because boron is involved in different physiological roles, such as metabolism of protein, synthesis of pectin, synthesis of (ATP), sugar translocation at the flowering development and fruiting stages [15]. In this study, boric acid increases the number of nodes and leaves at all tested concentrations. In another study, the application of gibberellins stimulates the male sex expression in cucurbits [16].

No. of nodes for the appearance of female flowers

Number of nodes for female flowers are a sign of total number of flowers on a vine in fruit set. Various levels of boric acid increased the number of nodes of female flowers per plant in a bitter gourd variety. All the treatments enhanced the number of nodes of the pistillate flower plant-^{1} in bitter gourd. It was recorded that the higher number of nodes of female flowers (22) were found at 6 mM level of boric acid while the lowest were found in control (10) treatment, showing a 120% increase in the number of nodes for the appearance of female flowers per plant as compared to control (Table 1). In another study, similar results were found, when boron induced the female flowers in cucurbits and the highest number of female flowers were observed at 4 ppm of boric acid [17]. Application of auxin is also helpful to increase the female sex expression in cucurbits [18].

No. of male flowers plant^{-1}

Faisalabad long variety of bitter gourd showed higher number of staminate flowers plant^{-1} when treated with the different concentration of boric acid.

Table 2 Effect of foliar application of different concentrations of boric acid on growth and yield parameters of the bitter guard. Different letters in a column show a significant difference at *P*=0.05 according to Tuckey's test.

Treatments	No. of fruits per plant at 1st picking	No. of fruits per plant at 2nd picking	Fruit length plant^{-1} (cm)	Fruit diameter plant^{-1} (mm)	Root weight (g)	Fresh fruit weight (g)	Plant weight (g)	Yield plant^{-1} (g)
Control	8b	7b	13d	31c	14d	39c	185d	970d
2 mM	12ab	10ab	25c	38b	22c	54b	297c	1293c
4 mM	14a	12a	36b	43b	38b	66a	391b	1475b
6 mM	17a	14a	42a	54a	42a	74a	484a	1930a

The application of 6 mM boric acid showed the highest number of staminate flowers plant^{-1} (157) compared to non-treated control (120), showing a 30% increase in the number of male flowers per plant compared to control (Table 1). In another study, boric acid increased the number of nodes and leaves at 2.5 ppm concentration of boron. In addition, the application of gibberellin also stimulated the male sex expression in cucurbits [16].

No. of female flowers plant^{-1}

Foliar spray of boric acid in bitter gourd significantly enhanced the total number of female flowers compared to control. The highest number of pistillate flowers plant^{-1} (37) were determined at 6 mM concentration, while minimum no. of pistillate flowers plant^{-1} (18) were measured in control, showing 117% increase in the number of female flowers per plant as compared to control (Table 1). In another study, boron gave better growth by enhancing the level of indole acetic acid (IAA) and IAA /cytokinin ratio in leaves and reduced the IAA oxidase inhibitors [19]. The application of IAA also maximized the pistillate flowers in cucurbit [20]. Boron applied at the concentration of 3 or 4 ppm provided the maximum number of female flowers per plant and fruits plant^{-1} in bitter gourd [21].

Sex ratio Male/Female flowers

The sex ratio is directly linked to total number of staminate and pistillate flowers, which is indirectly related to yield of bitter gourd. All the treatments of boric acid applied exogenously significantly reduced the sex expression than the control in the variety "Faisalabad long" of bitter gourd. The minimum sex ratio was determined at 6 mM boric acid treatment and maximum sex ratio was determined in control. However, the results were not significantly different between control and 2 mM boric acid treatment (Table 1). The male: female ratio and the flowering arrangement are influenced by different external factors and internal levels of ethylene, auxins, ascorbic acid and gibberellins and the set of ontogenies [22]. Application of different chemicals at 2 or 4 leaf stage plays important role in the suppression or promotion of male and female sex [23]. In cucurbits, sex expression was modified by the genetic composition of the plant and it can be changed by the foliar spray of IAA [24]

No. of fruits per plant at 1st and 2nd picking

The application of boric acid showed significant increase in the number of fruit plant^{-1} at first and second picking in bitter guard compared to control treatment; however, all boric acid treatments showed statistically nonsignificant differences among each other at both picking times (Table 2). Similar results were reported by other researchers of the effect of boric acid foliar application on number of fruits per plant [15, 25]. Boron plays important role in cell integrity, sugar transport, RNA metabolism and increased the respiration rate, uptake of certain nutrients and metabolic activities [26]. In another study, higher number of fruits per plant at different levels of foliar application of boron were found in tomato [27].

Fruit length and diameter plant^{-1}

The application of boric acid significantly increased the fruit length and diameter per plant. The maximum fruit length of 42 cm and maximum fruit diameter of 54 mm were determined when 6 mM boric acid was applied to bitter guard plants while the minimum fruit length of 13 cm and fruit diameter of 31 mm were found in control treatment (Table 2). The increase in fruit length and diameter might be attributed to the boron ability to activate cell division and cell elongation along with an increase in metabolic activity [26]. Similar results were reported by Rafeii et al. [28], when strawberry gave the maximum length of fruit, yield and weight of primary and secondary fruits with the application of boron. In another report, the application of boric acid showed an increase in fruit diameter and fruit length

in green chilies [29].

Root weight

Boric acid gave significant results with the maximum fresh root weight (42g) at the 6 mm application rate of the bitter gourd plant (Table 2). Similar results were reported when foliar spray of boric acid increased fresh tomato weight, root dry weight, better fruit set, yield, fruit shelf life and fruit firmness [30].

Fresh fruit weight

The results indicated that when the boric acid was applied on the bitter gourd, the maximum fresh fruit weight was gained at 6 mM level (74g) and least (39g) value was obtained for the control treatment (Table 2). Similar results were reported when a foliar spray of boric acid increased fresh tomato weight, root dry weight, better fruit set, yield, fruit shelf life and fruit firmness [30].

Plant weight

Maximum bitter guard plant weight (484g) was found in 6 mM boric acid treatment, while it was least (185g) in the control treatment (Table 2). A previous research also reported similar results when the fresh and dry weights of plants significantly increased in bitter gourd by the application of 2.5 ppm concentration of boron [17].

Yield plant^{-1}

Different parameters depend on the yield, such as no. of nodes, no. of female flowers and male flowers etc. Foliar spray of boric acid on bitter gourd enhanced the yield per plant. Highest yield (1930g) was recorded when 6 mM boric acid was used while the least yield was determined in the control treatment (Table 2). In addition to the other factors, the yield of bitter gourd was enhanced might be because of higher rate of photosynthesis and sugar synthesis, which also increased the chlorophyll formation and enzyme activity increasing the translocation of photosynthates to growing fruits that finally leads to the maximum production of dry matter and therefore more yield [31]. Boron is also involved in the development of cell wall, cell differentiation, shoot growth and increases flowering and fruit yield. In a report, the foliar spray of boric acid (100 ppm) in bitter gourd increased the fruit yield [9]. In another report, the foliar application of boron considerably increased the total potato yield, dry shoot yield and average weight of potatoes [25].

Conflict of interest

The authors declare that they have no conflict of interest.

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