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Response of Bell Pepper (*Capsicum annuum*) to Foliar Feeding with Micronutrients and Shoot Pruning

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Authors' contributions

This work was carried out in collaboration between all authors. Author SA designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors MS, ACR and AA wrote the protocol and managed the analyses of the study. Author AA managed the literature searches. Author MHK supervised the study. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: An experiment was conducted during the period from October 2012 to April 2013 at Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to evaluate the response of bell pepper with foliar feeding with micronutrients and shoot pruning.
Methods: The experiment consisted of two levels shoot pruning *viz*., P_0: no shoot pruning & P_1: shoot pruning and six levels of foliar applications of micronutrients as; 1. M_0: control (water); 2. M_1: boron (B) @ 100 ppm as H_3BO_3; 3. M_2: zinc (Zn) @ 100 ppm as $ZnSO_4$; 4. M_3: copper (Cu) @ 100 ppm as $CuSO_4$; 5. M_4: manganese (Mn) @ 100 ppm as $MnSO_4$ and 6. M_5: mixed micronutrients @

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100 ppm each (B, Zn, Cu and Mn). The two factor experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.
Results: In case of shoot pruning, the greatest number of marketable fruits per plant (8.70), maximum fruit setting (39.32%) and highest yield (26.60 t/ha) was obtained from shoot pruning and whereas for micronutrients, the greatest number of marketable fruits per plant (9.57), maximum fruit setting (40.53%) and highest yield (29.98 t/ha) elicited by mixed micronutrients with 100 ppm.
Conclusion: Application of shoot pruning with mixed micronutrient with 100 ppm elicited (30.43 t/ha) the highest yield compared to other treatment and seems to be the best combination for bell pepper production.

Keywords: Pruning; mixed micronutrients; foliar feeding; yield; bell pepper.

1. INTRODUCTION

Bell pepper or Capsicum (*Capsicum annuum*) is a flowering plant under the genus Capsicum and belongs to the family Solanaceae. Tropical South America, especially Brazil is thought to be the original home of pepper [1]. It is now widely cultivated in Central and South America, Peru, Bolivia, Costa Rica, Mexico and in almost all the European countries, Honkong and India. Small scale cultivation is found in peri-urban areas primarily for the supply to some city markets in Bangladesh [2]. A 100 g of edible portion of pepper provides 24 Kcal of energy, 1.3 g of protein, 4.3 g of carbohydrates and 0.3 g of fat [3]. Also, it is one of the valuable medicinal plants in pharmaceutical industries, owing to high amounts of health promoting substances, particularly antioxidant, capsaicin and capsantin [4]. Capsicum is considered a minor vegetable crop in Bangladesh. Pepper plants have a branching habit; therefore, fruit development is controlled by restricting the branching pattern to 1, 2, 3 and 4 main branches.

The reasons for pruning bell pepper under greenhouse conditions is to train plant to grow upright in order to facilitate light penetration all over the leaf canopy, improve fruit set and obtain early fruit ripening and high yield of large sized fruits [3,5]. Pruning methods vary with different branching habits of *Capsicum* cvs. and under different plant densities [6,7]. Due to the heavy vegetative growth and fruit load on the colored pepper plants [8], shoot pruning is an important factor in proper utilization of production area [7]. Several studies have reported an increase in fruit yield of sweet pepper with increase in shoot number under soilless media in protected agriculture [5,9]. However, there is little information on the effect of shoot pruning on bell pepper in a soil culture. Foliar feeding is a relatively new technique of feeding plants by applying liquid fertilizer directly to their leaves [10]. Foliar application of micronutrients produced the highest number of fruits per plant, dry fruit yield, net income and benefit cost ratio. Increasing frequency of zinc spraying from three to four times does not increase the number of chilli fruits per plant [11]. It was realized that productivity of crop was being adversely affected in different areas due to deficiencies of micronutrients [12]. The deficiency of micronutrients increased remarkably due to intensive cropping, loss of top soil by erosion, loss of micronutrients by leaching, liming of soil and lower availability and use of farm yard manure [13]. Micronutrients are usually required in minute quantities; nevertheless they are vital to the growth of plant. Improvement in growth characters as a result of application of micronutrients may be due to the enhanced photosynthetic and other metabolic activity which leads to an increase in various plant metabolites responsible for cell division and elongation [14]. Photosynthesis enhanced in presence of zinc and boron [15]. However, considering the above circumstances, the present study was undertaken: i. to find out the influence of shoot pruning and micro nutrients on the vegetative growth and reproductive growth of bell pepper and to incorporate the new methods in the production technology of bell pepper in Bangladesh.

2. MATERIALS AND METHODS

2.1 Experimental Location

The experiment was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experiment was carried out during *Rabi* season. The location of the study was situated in $23^{o}74^{/}$N latitude and $90^{0}35^{/}$E longitude [16]. The soil of the experimental area belongs to the Modhupur Tract [17] under AEZ No. 28.

2.2 Experimental Treatments and Design

The experiment consisted of two shoot pruning *viz*.P_0: no shoot pruning and P_1: shoot pruning and six levels of foliar applications of micronutrients as 1. M_0: control (water), 2. M_1: boron (B) @ 100 ppm as H_3BO_3, 3. M_2: zinc (Zn) @ 100 ppm as $ZnSO_4$, 4. M_3: copper (Cu) @ 100 ppm as $CuSO_4$, 5. M_4: manganese (Mn) @ 100 ppm as $MnSO_4$ and 6. M_5: mixed micronutrients @ 100 ppm each (B, Zn, Cu and Mn). Experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates. The fertilizers N, P, K and S in the form of urea, TSP, MoP and gypsum, respectively were applied by BARI [18]. Pruning operation was carried out at 21 days after transplanting (DAT). Pruning was done leaving four shoot per plant with a sharp knife and in the case of no pruning, normal plant growth was allowed and each spraying treatment of 100 ppm was sprayed on the foliage of the plants during vegetative stage, flower initiation stage and 2 times at blooming by a mini hand sprayer.

2.3 Data Collection

Harvesting of fruits was started at 80 DAT and continued up to final harvest based on the marketable sized of fruits. Harvesting was done by hand picking. The data collection based on characters assessing plant growth, yield and yield attributes, plant height, number of leaves/plant, days from transplanting to 1st flowering, fruit setting (%), days to 1st harvest, length of fruit, diameter of fruit, pericarp thickness, fruit yield/ha were recorded.

2.4 Statistical Analysis

The data obtained from different characters were statistically analyzed using MSTAT-C software. The mean values of all the characters were evaluated and analysis of variance was performing by the 'F' test. The significance of the difference among the treatments means were separated by using the Least Significant Difference (LSD) at 5% level of probability [19].

3. RESULTS

3.1 Plant Height

Shoot pruning and micronutrient on bell pepper elicited significant variation for plant height at final harvest. The tallest plants were obtained from the shoot pruning that received mixed micronutrients but not significantly different from the other shoot pruning treatments with micronutrients (Table 2). The treatment P_1M_5 produced significant results for plant height 63.19 compared to P_0M_0 that produced the shortest plants.

3.2 Number of Leaves/Plant

The maximum number of leaves per plant was recorded from P_1M_5 (143.53), whereas the minimum number of leaves/plant was observed from P_0M_0 (113.93) at final harvest (Table 2).

3.3 Days to 1st Flowering

Flowering of bell pepper starting 3 days earlier in pruned plants as compared to non pruning plants (Table 1). The first flowering was started 4 days earlier in combined micronutrients treatment compared to control treatment (Table 1). The plants grown under control treatment it takes about 14 days higher than that of shoot pruning with combined micronutrients (Table 2).

3.4 Fruit Setting

The maximum fruit setting (39.73%) was found from P_1, while the minimum (34.43%) was attained from P_0 (Table 1). The maximum fruit setting (40.53%) was found from M_5 which was statistically similar (39.31%) with M_2, while the minimum fruit setting (33.14%) was recorded from M_0 i.e. control condition (Table 1). The maximum fruit setting (41.56% and 41.34% were observed in P_1M_2 and P_1M_5, respectively while the minimum (30.38%) was found from P_0M_0 (Table 2).

3.5 Days to 1st Harvest

Minimum days from transplanting to 1st harvest (116.61) was attained from P_1, while the maximum days (120.72) was found from P_0 (Table 1). The minimum days from transplanting to 1st harvest (114.00) was found from M_5 which was statistically similar (115.00 days and 116.50 days) to M_2 and M_1, while the maximum days (125.17) was recorded from M_0 i.e. control condition (Table 1). The minimum days from transplanting to 1st harvest (107.33) was found from P_1M_5, while the maximum days (129.67) was recorded from P_0M_0 (Table 2).

3.6 Length of Fruit

The maximum length of fruit (7.81 cm) was recorded from P_1, while the minimum length (7.22 cm) was found from P_0 (Table 1). The data

revealed that pruning influenced length of fruit of bell pepper. The maximum length of fruit (8.55 cm) was found from M_5 which was statistically similar to M_2 (8.18 cm) and closely followed by M_1 (7.62 cm), where the minimum length (6.12 cm) was observed from M_0 (Table 1). The maximum length of fruit (8.80 cm) was found from P_1M_5, while the minimum length (6.02 cm) was observed from P_0M_0 (Table 2).

3.7 Diameter of Fruit

The maximum diameter of fruit (5.24 cm) was recorded from P_1, while the minimum diameter (5.04 cm) was obtained from P_0 (Table 1). The maximum diameter of fruit (5.66 cm) was found from M_5 which was statistically similar (5.47 cm) to M_2 and closely followed (5.26 cm) by M_1, while the minimum diameter (4.22 cm) was recorded from M_0 i.e. control condition (Table 1). The maximum diameter of fruit (5.60 cm) was recorded from P_1M_5, while the minimum diameter (4.03 cm) was observed from P_0M_0 (Table 2).

3.8 Pericarp Thickness

The maximum pericarp thickness (6.50 mm) was observed from P_1, while the minimum pericarp thickness (6.12 mm) was found from P_0 (Table 1). The maximum pericarp thickness (6.99 mm) was found from M_5 which was statistically similar (6.76 mm and 6.60 mm) with M_2 and M_1, while the minimum thickness (5.03 mm) was attained from M_0 i.e. control condition (Table 1). The maximum pericarp thickness (7.20 mm) was recorded from P_1M_5, while the minimum thickness (4.77 mm) was observed from P_0M_0 (Table 3).

3.9 Individual Fruit Mass

The highest weight of individual fruit (61.03 g) was observed from P_1, while the lowest weight (59.40 g) from P_0 (Table 1). The highest mss of individual fruit (62.68 g) was recorded from M_5 which was statistically similar (61.99 g and 60.67 g) to M_2 and M_1, while the lowest mass (57.61 g) was found from M_0 i.e. control condition (Table 1). The highest mass of individual fruit (62.96 g) was attained from P_1M_5, while the lowest mass (55.89 g) was observed from P_0M_0 (Table 3).

3.10 Yield/Hectare

Eleven percent more yield was found from when the plants were shoot pruned (Table 1). Compared to control treatment fertilizer 40% highest yield was found from M_5 (Table 1). Treatment combination of shoot pruning with combined micronutrients gave the 44% more fruits compared to control treatment (Table 3).

4. DISCUSSION

Shoot pruning of bell pepper may be the increases for the longest plat height as a result of increase the activity of apical dominance that are influenced by plant growth regulators especially auxin that helps intermodal elongation. Baki [20] found that pruning showed a significant effect on plant height and unpruned plants exhibited highest plant height. Ambroszczyk et al. [21] reported that pruning strongly affected the effectiveness of crop growth. Datir et al. [22] reported that micronutrients like iron, zinc, copper and manganese were organically chelated with seed amino acids and the application of amino acid-micronutrient chelate at the concentration of 1.5 and 2.0% resulted in maximum plant height. Significant variation was observed due to the interaction effect of shoot pruning and foliar application of micronutrients in terms of plant height of bell pepper at final harvest. Shetty and Manohar [23] reported that capsicum plants responded significantly to the pruning and pruned plants produced maximum number of leaves per plant than unprunned plants. Dongre et al. [24] also reported the reduction of shoot from pepper plant also reduces the days for flowers initiations when the plant was cultivated with micronutrients. Capsicum plants responded significantly to the pruning in respect of fruit setting [23]. He also reported that, pruning increases the percent of fruit setting.

When pepper plants pruned it was found that early yield as well as 1st harvest period longer significantly [25]. Fruit length was greatest in plants which had one stem [26]. Pepper plants pruned to one branch resulted in a significant increase in fruit size [25]. Dongre et al. [24] also reported similar findings. Fruits diameter were greatest in plants with one stem [26]. Laxman and Mukherjee [27] also reported similar findings. Dongre et al. [24] also reported similar findings that fruit quality as well as thickness of fruits was increased when pepper plants were pruned. Capsicum plants responded significantly to the thus leads to increase of mass of individual plant [23]. Individual fruit mass was 59.02 g for plants pruned once and 47.21 g for those which were not pruned [28]. Dasgan and Abak [6] found that fruit yield per hectare was not significantly influenced by the number of shoots per plant.

Table 1. Main effect of shoot pruning and foliar application of micronutrients on yield contributing characters of bell pepper

Treatments	Days to 1st flowering	Fruit Setting (%)	Days to 1st harvest	Length of fruit (cm)	Diameter of fruit (cm)	Pericarp thickness (mm)	Individual fruit mass (g)	Yield per hectare (ton)
Shoot pruning								
P_0	56.61 a	34.43 b	120.72 a	7.22 b	5.04 a	6.12 b	59.40 b	23.58 b
P_1	53.11 b	39.73 a	116.61 b	7.81 a	5.24 a	6.50 a	61.03 a	26.60 a
$LSD_{(0.05)}$	2.233	1.315	3.931	0.355	-	0.240	1.571	0.750
Level of significance	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Foliar application of micronutrients								
M_0	58.67 a	33.14 d	125.17 a	6.12 d	4.22 d	5.03 c	57.61 c	17.77 e
M_1	54.00 b	37.34 bc	116.50 b	7.62 bc	5.26 bc	6.60 ab	60.67 ab	25.77 c
M_2	53.17 b	39.31 ab	115.00 b	8.18 ab	5.47 ab	6.76 a	61.99 ab	28.41 b
M_3	55.50 b	36.18 c	120.00 ab	7.36 c	5.15 bc	6.30 b	59.10 bc	24.44 d
M_4	55.50 b	35.99 c	121.33 ab	7.27 c	5.08 c	6.18 b	59.25 bc	24.18 d
M_5	52.33 b	40.53 a	114.00 b	8.55 a	5.66 a	6.99 a	62.68 a	29.98 a
$LSD_{(0.05)}$	3.868	2.277	6.809	0.614	0.334	0.415	2.721	1.300
Level of significance	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CV(%)	5.89	5.13	4.79	6.82	5.43	5.49	4.77	4.33

In a column means having similar letter(s) are statistically similar and those having different letter(s) differ significantly at 0.05 level of probability

1. P_0: No shoot pruning, 2. P_1: Shoot pruning and 1. M_0: Control (no micronutrients), 2. M_1: Boron (B) @ 100 ppm, 3. M_2: Zinc (Zn) @ 100 ppm, 4. M_3: Cupper (Cu) @ 100 ppm, 5. M_4: Manganese (Mn) @ 100 ppm, 6. M_5: Mixed micronutrients @ 100 ppm each (B, Zn, Cu and Mn)

Table 2. Interaction effect of shoot pruning and foliar application of micronutrients on plant height of bell pepper

Treatments	Plant height at Final harvest (cm)	Number of leaves at Final harvest	Days from transplanting to 1st flowering	Fruit Setting (%)	Days from transplanting to 1st harvest	Length of fruit (cm)	Diameter of fruit (cm)
P_0M_0	50.80 d	113.93 c	60.00 a	30.38 f	129.67 a	6.02 e	4.03 f
P_0M_1	56.18 c	123.47 b	55.00 ab	33.99 def	115.00 bcd	6.93 de	5.11 bcd
P_0M_2	58.32 abc	125.87 b	59.67 a	37.06 bcd	122.67 ab	8.45 ab	5.66 a
P_0M_3	58.00 abc	123.27 b	56.33 ab	31.87 f	117.00 bcd	6.76 ef	4.68 de
P_0M_4	60.26 abc	127.33 b	55.33 ab	33.57 ef	121.67 ab	6.84 def	5.04 cd
P_0M_5	60.26 abc	128.73 b	53.33 b	39.72 ab	118.33 bc	8.29 ab	5.72 a
P_1M_0	56.50 bc	125.07 b	57.33 ab	35.90 cde	120.67 ab	6.21 ef	4.41 ef
P_1M_1	61.21 abc	142.27 a	53.00 b	40.70 a	118.00 bc	8.30 ab	5.41 abc
P_1M_2	61.84 ab	140.47 a	51.33 bc	41.56 a	109.67 cd	7.92 bc	5.29 abc
P_1M_3	59.18 abc	127.07 b	54.67 ab	40.49 a	123.00 ab	7.95 abc	5.62 ab
P_1M_4	57.79 bc	127.67 b	55.67 ab	38.41 abc	121.00 ab	7.69 bcd	5.12 bcd
P_1M_5	63.19 a	143.53 a	46.67 c	41.34 a	107.33 d	8.80 a	5.60 ab
$LSD_{(0.05)}$	5.214	8.767	5.470	3.220	9.630	0.868	0.473
Level of significance	0.05	0.05	0.05	0.05	0.05	0.05	0.05
CV(%)	5.25	4.01	5.89	5.13	4.79	6.82	5.43

In a column means having similar letter(s) are statistically similar and those having different letter(s) differ significantly as per 0.05 level of probability

1. P_0: No shoot pruning, 2. P_1: Shoot pruning and 1. M_0: Control (no micronutrients), 2. M_1: Boron (B) @ 100 ppm, 3. M_2: Zinc (Zn) @ 100 ppm, 4. M_3: Cupper (Cu) @ 100 ppm, 5. M_4: Manganese (Mn) @ 100 ppm, 6. M_5: Mixed micronutrients @ 100 ppm each (B, Zn, Cu and Mn)

Table 3. Interaction effect of shoot pruning and foliar application of micronutrients on yield character of bell pepper

Treatments	Pericarp thickness (mm)	Individual fruit weight (g)	Yield per hectare (ton)
P_0M_0	4.77 f	55.89 ef	16.77g
P_0M_1	6.23 cde	58.37 cdef	22.37 e
P_0M_2	6.97 ab	62.63 a	28.39bc
P_0M_3	5.92 cde	58.47 cdef	21.99 e
P_0M_4	6.05 cde	58.65 bcde	22.44 e
P_0M_5	6.77 abc	62.40 ab	29.54ab
P_1M_0	5.29 f	59.33 abcdef	18.77f
P_1M_1	6.97 ab	62.96 a	29.18ab
P_1M_2	6.56 bcd	61.35 abc	28.43bc
P_1M_3	6.67 abc	59.74 abcd	26.88 cd
P_1M_4	6.31 cd	59.85 abcd	25.92 d
P_1M_5	7.20a	62.96 a	30.43 a
$LSD_{(0.05)}$	0.587	3.848	1.838
Level of significance	0.05	0.05	0.05
CV(%)	5.49	4.77	4.33

In a column means having similar letter(s) are statistically similar and those having different letter(s) differ significantly at 0.05 level of probability

1. P_0: No shoot pruning, 2. P_1: Shoot pruning and 1. M_0: Control (no micronutrients), 2. M_1: Boron (B) @ 100 ppm, 3. M_2: Zinc (Zn) @ 100 ppm, 4. M_3: Cupper (Cu) @ 100 ppm, 5. M_4: Manganese (Mn) @ 100 ppm, 6. M_5: Mixed micronutrients @ 100 ppm each (B, Zn, Cu and Mn)

Fruit yield can be increased by managing shoot pruning and 4 plant m^{-2} pruned to four stems increased marketable and extra-large fruit yield in a short harvest period of a summer greenhouse sweet pepper crop [29]. Capsicum plants responded significantly to the pruning in respect of yield per hectare [23]. Pepper plants pruned to one branch resulted in a significant increase in fruit yield [25]. Laxman and Mukherjee [27] also reported similar findings from their earlier experiments.

5. CONCLUSION

Considering the findings of the experiment, it may be concluded that shoot pruning was found best for capsicum production. At the same time, foliar application of mixed micronutrients @ 100 ppm each (B, Zn, Cu and Mn as H_3BO_3, $ZnSO_4$, $CuSO_4$ and $MnSO_4$) was recorded best in this regard. It was also noted that the treatment combination, shoot pruning plus mixed micronutrients @ 100 ppm each: B, Zn, Cu and Mn showed best potentiality on the growth and yield of capsicum.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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