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Effect of Boron Levels on Physiology and Quality Characters of Greenhouse Parthenocarpic Cucumber (*Cucumis sativus* L.)

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Abstract An experiment conducted to examine the effect of boron on physiology of plant, and quality attributes of parthenocarpic cucumber produced in greenhouse with the soil application of boron at the rate of 1.5 kg ha^{-1} along with foliar spray of 0.25% boric acidon 30 and 45 days after sowing (DAS). It was found to impart significant influence on forchlorophyll-A, chlorophyll-B, total chlorophyll, leaf area, IAA oxidase enzyme activity, ascorbic acid, flesh thickness and moisture content of the fruit. Whereas soil application of 1 kg ha^{-1} of boron with foliar spray of boric acid @ 0.25% on 30 and 45 DAS differed significantly for highest calcium content and shelf life of fruit. Plants sprayed with 0.25% of boric acid had found to be higher fruit firmness. Total soluble solids (TSS) of the fruit found to be higher in soil application of 1 kg ha^{-1} of boron along with the foliar spray of 0.50% boric acid on 30 and 45 DAS. The highest total dry matter content of the fruit significantly differed for 1.5 kg ha^{-1} boron with 0.5% boric acid spray on 30 and 45 DAS. However, in several treatment combinations, the application of boron at the rate of 1.5 kg ha^{-1} along with the foliar spray of 0.25% boric acid found to be optimum for production of best quality parthenocarpic fruits under tropical greenhouse condition.

Keywords Boron, Boric acid, Leaf area, IAA oxidase enzyme, Dry matter.

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Introduction

Cucumber (*Cucumis sativus* L.) is popular vegetable among Cucurbitaceae family. It is grown for its tender edible fruits in almost all parts of the world. In India, it is grown in 0.41 lakh hectares with an annual production of 6.41 lakh tonnes [1]. Boron is one among the seventeen essential element required for the comple-

Table 1. The initial physico-chemical soil characteristics and boron levels on chlorophyll content of greenhouse cucumber.

Parameter	Value		Chlorophyll-A (mg g^{-1})			Chlorophyll-B (mg g^{-1})			Total chlorophyll (mg g^{-1})		
Lime status	Calca-reous	Treat-ments	Season I	Season II	Mean	Season I	Season II	Mean	Season I	Season II	Mean
Soil texture	sandy loam	T_1	1.287	1.037	1.162	0.435	0.235	0.335	1.608	1.589	1.598
Soil type	Black	T_2	1.808	1.608	1.708	0.699	0.499	0.599	2.507	2.419	2.463
Organic carbon (%)	0.42	T_3	1.654	1.054	1.354	0.634	0.434	0.534	2.128	2.142	2.135
pH	7.95	T_4	1.457	1.058	1.258	0.541	0.341	0.441	1.872	1.869	1.871
Electrical conductivity (EC, dS m^{-1})	2	T_5	1.563	1.363	1.463	0.762	0.562	0.662	1.996	2.012	2.004
Available N (kg ha^{-1})	204	T_6	1.679	1.179	1.429	0.553	0.353	0.453	1.942	1.998	1.970
Available P (kg ha^{-1})	54	T_7	1.770	1.570	1.670	0.699	0.499	0.599	2.373	2.424	2.399
Available K (kg ha^{-1})	1046	T_8	2.082	1.883	1.982	0.826	0.626	0.726	2.678	2.616	2.647
Available B (ppm)	0.34	T_9	1.897	1.697	1.797	0.763	0.563	0.663	2.478	2.554	2.512
Available Ca (%)	0.28	SEm±	0.040	0.035	0.038	0.015	0.009	0.012	0.056	0.045	0.051
		CD (5%)	0.084	0.075	0.076	0.031	0.020	0.025	0.119	0.097	0.103

tion of plant growth. Since, it play an important role in many metabolic processes like cell wall strengthening and development, cell division, sugar transport, hormone development, flower production and retention, fruit and seed development [2]. Boron is considered to be an essential micro nutrient of crop plants, the active range of boron concentrations essential for the production of quality fruits and it has extremely narrow range of toxicity [3]. Cucumber is considered as high value with low volume vegetable crop, which is mainly grown under greenhouses for the production of best quality tender edible fruits which are of slicing quality. But, in most of the cases the quality fruits production is limited due the widespread deficiencies of boron in Indian soils. However, the application methods and requirement of boron still questionable in greenhouse cucumber production [4]. Hence, the this study has been initiated to reveal the effect of elemental boron and boric acid levels with soil and foliar application methods for production of export quality parthenocarpic cucumbers under greenhouse under Indian tropics.

Materials and Methods

The experiment study conducted by the use of cucumber hybrid 'Silyon' (RijkZwaan Seeds Pvt. Ltd.) under polyhouse condition during *kharif* 2014 and *rabi* 2015 at department of Vegetable Crops, Horticulture College and Research Institute (HC & RI), Tamil Nadu Agricultural University, Coimbatore (TN) India. Geographically, it is locáted at 11°14´ North latitude, 77°10´ East longitude and altitude of 338 m above mean sea level (MSL). The initial characteristics of soil (Table 1) and treatment details are T_1-Control without boron application, T_2-Soil application of 1 kg ha^{-1} boron, T_3-Soil application of 1.5 kg ha^{-1} boron, T_4-Foliar spray of 0.25% boric acid at 30 and 45 Days after sowing (DAS), T_5-Foliar spray of 0.5% boric acid at 30 and 45 DAS, T_6-Soil application of 1 kg ha^{-1} boron with foliar spray of 0.25% boric acid at 30 and 45 DAS, T_7-Soil application of 1 kg ha^{-1} boron with foliar spray of 0.5% boric acid at 30 and 45 DAS, T_8-Soil application of 1.5 kg ha^{-1} boron with foliar spray of 0.25% boric acid at 30 and 45 DAS, and T_9-Soil

Table 2. Physiological and quality characters of greenhouse cucumber of greenhouse cucumber influenced by boron levels.

Treatments	Leaf area (cm^2)			IAA oxidase ($\mu g\ g^{-1}\ h^{-1}$)			Total dry matter ($g\ plant^{-1}$)			Ascorbic acid ($mg\ 100\ g^{-1}$)			TSS (°Brix)		
	Season I	Season II	Mean	Season I	Season II	Mean	Season I	Season II	Mean	Season I	Season II	Mean	Season I	Season II	Mean
T_1	430.40	414.39	422.39	15.14	14.14	14.64	21.34	19.51	20.43	6.83	6.03	6.43	2.10	1.90	2.00
T_2	458.78	458.78	458.78	15.63	14.83	15.23	23.76	24.28	24.02	7.39	6.59	6.99	2.80	2.60	2.70
T_3	472.93	466.76	469.85	16.80	16.00	16.40	26.40	25.65	26.02	7.85	7.05	7.45	2.41	2.20	2.30
T_4	470.86	457.46	464.16	16.30	15.50	15.90	22.12	21.49	21.80	7.45	6.65	7.05	2.30	2.10	2.20
T_5	489.96	473.30	481.63	16.90	16.50	16.70	28.90	28.94	28.92	8.13	7.33	7.73	2.20	1.92	2.06
T_6	532.76	525.02	528.89	19.03	18.63	18.83	28.93	30.00	29.47	7.67	6.87	7.27	3.04	2.78	2.91
T_7	520.86	522.97	521.92	18.94	18.44	18.69	31.91	30.90	31.90	7.99	7.59	7.79	3.10	2.90	3.00
T_8	536.97	532.86	534.92	22.54	21.74	22.14	33.45	31.20	32.32	8.49	8.19	8.39	2.80	2.60	2.70
T_9	533.89	527.57	530.73	20.32	19.92	20.21	34.45	31.92	33.18	8.37	7.97	8.19	2.70	2.40	2.55
SE±m	12.18	10.25	11.26	0.34	0.36	0.35	0.63	0.46	0.55	0.15	0.13	0.14	0.049	0.047	0.048
CD (5%)	25.83	21.73	22.63	0.72	0.77	0.71	1.34	0.97	1.11	0.33	0.37	0.29	0.102	0.100	0.096

application of 1.5 kg ha^{-1} boron with foliar spray of 0.5% boric acid at 30 and 45 DAS. The experiment was consisted of ninetreatments, which were replicated at thrice in a randomized block design (RBD) with an area dimension of 9 m^2 plot per treatment. Raised beds of 1 m width and 30 m length were prepared. The farm yard manures has been applied at the rate of 25 t/ha during land preparation and recommended dose of nutrients namely N: P: K were applied at the rate of 150:75:75 kg per hectare was applied to all treatment and treatments were induced subsequently. The IAA oxidase activity in the leaf sample was determined colorimetric method at 540 nm suggested by Parthasarathy et al. [5]. At harvest (100 DAS), eandomly selected five plants in each treatments were uprooted and separated into different parts and dried in hot air oven at temparature at 80°C for 72 h for recording total dry weight of plant. The experimental data of various quality and physiological characters were subjected to Fisher's mothod of analysis of variance (ANOVA) as per methods outlined by Panse and Sukhatme [6]. Critical difference (CD) calculated wherever the *F* test found significant. The analyzed data are presented with the level of significance at 5%.

Results and Discussion

The experimental data revealed that the treatment (T_8) soil application of 1.5 kg ha^{-1} boron with foliar spray of 0.25% boric acidon 30 and 45 DAS recorded highest content of chlorophyll-A, -B and total chlorophyll significantly (1.98, 0.72 and 2.64 mg g^{-1}) respectively (Table 1), which is followed by treatment T_9 and lowest recorded in the treatment T_1 (RDF of nutrients N: P: K) for both the seasons, the lowest chlorophyll content in treatment T_1 was due to no application of boron, and boron deficiency affects the chlorophyll development which leads to reduction in the photosynthetic oxygen evolution rate and efficiency of photosystem II [7], which is also confounded in bitter gourd [8]. The leaf area was highest (534.92 cm^2) in plants treated with soil application of 1.5 kg ha^{-1} boron with foliar spray of 0.25% boric acid on 30 and

Table 3. Effect of boron levels on quality attributes of greenhouse cucumber.

Treatments	Fish thickness (cm)			Fruit firmness (kg cm^{-1})			Calcium content of fruit (mg 100g^{-1})			Shelf life (days)		
	Season I	Season II	Mean	Season I	Season II	Mean	Season I	Season II	Mean	Season I	Season II	Mean
T_1	3.25	3.21	3.23	2.26	2.26	2.26	8.62	8.57	8.59	6.54	6.52	6.53
T_2	3.35	3.42	3.39	3.58	3.55	3.56	9.36	9.33	9.34	8.35	8.28	8.32
T_3	3.65	3.68	3.67	3.21	3.31	3.26	8.04	8.38	8.20	8.72	8.59	8.65
T_4	3.45	3.51	3.48	3.62	3.71	3.67	7.43	7.37	7.40	8.02	7.79	7.91
T_5	3.73	3.82	3.77	3.32	3.31	3.32	10.08	10.27	10.18	9.26	9.25	9.25
T_6	3.82	3.75	3.78	3.01	3.06	3.04	10.87	10.75	10.81	9.43	9.56	9.49
T_7	3.85	3.92	3.89	3.14	3.06	3.10	7.02	6.86	6.94	8.94	8.95	8.94
T_8	4.21	4.37	4.29	3.12	3.08	3.10	6.43	6.57	6.50	8.43	8.12	8.27
T_9	4.15	4.29	4.22	3.05	3.04	3.05	6.36	6.22	6.29	8.01	8.03	8.02
SE±m	0.080	0.068	0.080	0.063	0.078	0.071	0.17	0.15	0.15	0.184	0.199	0.191
CD (5%)	0.190	0.144	0.160	0.134	0.165	0.143	0.35	0.32	0.32	0.391	0.421	0.385

45 DAS (T_8), the treatment T_8 found to be at par with T_9 treatment for both the seasons. It might be due to improvement of nutrients by cucumber plants in enhancement of vegetative growth in terms of leaf area. It might be due to the synergistic effect of boron application through soil and foliar spray, this phenomenon is accorded with cucumber [9] and watermelon [10]. The IAA oxidase enzyme activity found to significant in the treatment T_8 (22.14 µg g^{-1} h^{-1}), and it is followed by treatment T_9 and the least significant enzyme activity observed in control treatment (T_1) in both the seasons, it could be due to boron deficit in the treatment plants, which in turn leads to insufficient production of IAA synthesis for encouraging IAA oxidative metabolism, results are found to be similar as reported earlier by Xiang et al. [11]. However, soil application of 1.5 kg ha^{-1} boron with foliar spray of 0.5% boric acidon 30 and 45 DAS (T_9) recorded highest dry matter (33.18 g plant^{-1}) followed by treatment T_8 (Table 2) in both the seasons. It could be due to more number of leaves, it could lead to the more photosynthetic and other metabolic activities in these boron treatments, leads to increase in various plant metabolites responsible for cell division and cell elongation [12, 13].

The significantly highest ascorbic acid (8.39 mg 100^{-1}) was observed in treatment T_8 followed by treatment T_9 and lowest was observed in control treatment (T_1) in both the seasons. This might be due to increase in carbohydrate metabolism in plants where the boron application has been succeeded; these results are accorded with the findings in watermelon [10]. The significantly highest total soluble solids (TSS) was recorded (3°Brix) with the soil application of 1 kg ha^{-1} boron with foliar spray of 0.5% boric acidon 30 and 45 DAS (T_7), which was followed by treatment T_6 (Table 2) for both the seasons. This might be due to increased translocation of sugars and growth modifying substances in plants, these results are as par with the findings of muskmelon [14].

The significantly highest calcium content of fruit (10.81 mg 100 g^{-1}) recorded in the treatment T_6-soil application of 1 kg ha^{-1} boron with foliar spray of 0.25% boric acid on 30 and 45 DAS, which was fol-

lowed by the treatment T_5 for both the seasons, this might be due to the antagonistic effect of calcium with boron interaction could affects the uptake of calcium, it is accorded with cucumber [15]. Firmness of fruit shows significant effect with boron foliar spray of 0.25% boric acid on 30 and 45 DAS (T_4) (3.67 kg cm^{-2}) in both the seasons, it is on par with treatment T_2. It might be due to lower level of calcium accumulation with increased boron concentration in the treatment and its accordance findings of Subbiah [16]. The highest fiesh thickness (4.29 cm) was observed in the treatment T_8 followed by the treatment T_9 and lowest was observed in the control treatment T_1 for both the seasons. This might be due to increased volume of fruit filled with water in the form of edible pulp, similar findings were revealed in water melon [10]. The treatment T_6 recorded highest shelf life of fruits (9.49 days), which is on par with the treatment T_5 and least was observed in control with 6.53 days during both the seasons (Table 3), it might be due to thickening of cell wall with boron application which assists in extended shelf life of fruits cell and cell wall metabolism by maintaining the calcium-pectin association [17].

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