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Effect of Foliar Application of Salicylic acid (SA) along with Micronutrients (Boron & Zinc) on Growth and Yield of Parthenocarpic Cucumber (*Cucumis sativus* L.)

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ABSTRACT: Cucumber (*Cucumis sativus* L.) holds significant economic and nutritional importance. To augment its growth and yield, nutrients play a very vital role. The experiment encompassed the application of two different concentrations of SA, specifically 200 mg kg^{-1} and 400 mg kg^{-1}, alongside zinc at 25 mg kg^{-1} and boron at 50 mg kg^{-1}. The combination of SA at 400 mg kg^{-1} with boron at 50 mg kg^{-1} and zinc at 25 mg kg^{-1} demonstrated noteworthy results with respect to growth parameters namely, vine length (333.33 cm), node count of 45.46, and leaf area measuring 565.149 cm², at 60 days after sowing. Additionally, this combination yielded the highest fruit yield per vine (4.37 kg) and an overall total yield of 136.78 t ha^{-1}, suggesting potential synergistic effects. The study faced challenges in optimizing the nutrient application for enhanced cucumber growth and yield. Despite the complexities, the strategic combination of salicylic acid, boron and zinc showcased remarkable improvements. The response to foliar application of SA at 400 mg kg^{-1} with boron at 50 mg kg^{-1} and zinc at 25 mg kg^{-1} exhibited significant variations among treatments, offering promising avenues for the advancement of cucumber cultivation.

Keywords: Boron, Foliar spray, Parthenocarpic cucumber, Salicylic acid, Zinc.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a highly valuable vegetable crop that belongs to the family Cucurbitaceae. Cucumber is a rich source of vitamins, minerals, and antioxidants, making it an essential component of a healthy diet. The crop is widely cultivated throughout the world, and it is highly valued for its culinary and nutritional properties. It provides a cooling effect, prevents constipation, and is useful for curing jaundice (Bhagwat *et al.*, 2018). In India, cucumbers are cultivated over 109 thousand hectares with a production of 1696 thousand metric tons (NHB, 2018-19). The major cucumber-growing states are Haryana, Madhya Pradesh, Karnataka, Andhra Pradesh, Uttar Pradesh and Punjab. It is good for diabetic patients as it contains low sugars and helps in the burning of excess fat in the body. It is a day-neutral annual plant species; nevertheless, under protected conditions, these crops can be grown throughout the year. It is an annual monoecious, trailing, climbing, and herbaceous plant. The main stem is angular, with nodes at the point where leaves develop. Adverse environmental conditions hinder pollination, consequently impacting fruit production and productivity. In contrast, parthenocarpic vegetables do not require pollination and fertilization for fruit development (Riya Rani *et al.*, 2022). The Parthenocarpic cucumber produces female flowers which are yellow in colour and sets fruit without pollination (Guan *et al.*, 2019). Depending on the variety, the fruit is fleshy, smooth, or rough. The optimum daytime temperature required for the crop varies between 20° C-30° C and the pace of early growth increases as the temperature rises within this range. Cucumber production in India is mostly limited to open-field conditions. Low yield and poor quality in open fields are mostly caused by biotic and abiotic factors. Cucurbit crops cultivated under protected conditions for their fruits or seeds are becoming more ubiquitous because of year-round demand and the potential for profitable prices for growers (Nerson, 2008). A significant part of Salicylic acid's function in enhancing plant development is nutrient uptake as well as other processes like stem elongation, leaf emergence, and fatalities. (Rubio *et al.*, 2009). Salicylic acid also improves the antioxidant capacity of cucumber plants, enhancing their ability to tolerate environmental stress. SA stimulated various aspects of plant growth, root development, leaf expansion, and chlorophyll production, resulting in healthier and more vigorous cucumber plants. Boron is essential for growth, development, and a variety of other physiological processes such as Nitrogen metabolism, protein formation, cell division, and cell wall formation (Havlin *et al.,* 2017). Boron played a crucial role in proper fruit development, facilitating the movement of nutrients within the plant and leading to larger and well-shaped cucumbers. Zinc is also required by a variety of enzymes including dehydrogenase, aldolase, isomerases, proteinase, peptidase, and phosphohydrolase (Mousavi, 2011). Adequate zinc level promotes healthy root development, enabling efficient water and nutrient absorption from the soil.

Foliar nutrition increases the efficiency of applied nutrients, which they require for maximum growth and yield. It can also use the substance more quickly and accurately than soil applications. Chemical fertilizer and pesticide doses are rising steadily to achieve higher yields. Because of the negative effects of chemical fertilizers, it is critical to have alternatives for increasing yields that have no negative side effects. Like many other micronutrients Zinc and Boron are very important elements although required in very small quantities by plants for some specific and physiological functions performed by plants. Keeping the preceding emphasis in consideration, an experiment was carried out to know the effect of Salicylic acid (SA) along with Boron and Zinc on growth and yield of parthenocarpic cucumber.

MATERIAL AND METHODS

The experiment was conducted at the Department of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru, with the assistance of Centre for Advanced Agricultural Science and Technology (CAAST) Project. The soil of the experimental area was red sandy loam with consistent fertility and a pH range of 6.4 to 6. In this study, eight different treatment combinations were applied in addition to the standard recommended fertilizer doses (RDF) of 60:50:80 kg NPK ha^{-1}, and these treatments were replicated three times: T_1 [Control]; T_2 [B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})]; T_3 [SA_1 (200 mg kg^{-1}) + B (50 mg kg^{-1})]; T_4 [SA_1 (200 mg kg^{-1}) + Zn (25 mg kg^{-1})]; T_5 [SA_1 (200 mg kg^{-1}) + B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})]; T_6 [SA_2 (400 mg kg^{-1}) + B (50 mg kg^{-1})]; T_7 [SA_2 (400 mg kg^{-1}) + Zn (25 mg kg^{-1})] and T_8 [SA_2 (400 mg kg^{-1}) + B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})]. The experiment was laid out in a Randomized Block Design (RBD). In the month of April, 2022, the seeds were sown at a spacing of 60 cm × 40 cm. The sprays were taken up on the 25, 35 and 45 days after sowing. Foliar spray of boron, zinc, salicylic acid was prepared by using 'Boric Acid' (H_3BO_3), 'Zinc Sulphate' ($ZnSO_4$) and 'Salicylic Acid' ($C_7H_6O_3$) respectively. Randomly selected plants from each plot were observed and tagged, and growth parameters were recorded at 40 and 60 days after sowing. The measured variables included vine length (cm), the number of branches, nodes and leaves per vine. Leaf area (cm^2) calculations employed a linear expression involving leaf length and width, with a constant of 0.88 and a deduction of 4.27 (Blanco and Folegatti 2005). Additionally, five fruits at random from each replication were chosen for yield and quality parameter assessment. Fruit girth was measured by Vernier Calipers at the middle portion of fruit and TSS was measured using a handheld refractometer. Number of fruits per vine, fruit yield per vine (kg), and total yield (t/ha) were assessed yield parameters and fruits collected on the day of harvest were kept under ambient condition to study the shelf-life. Physiological loss in weight was calculated by taking difference between initial fruit weight and weight of the fruits after 12 days. The infestation of powdery mildew was evaluated and the per cent incidence was recorded under as per cent plant infected based on scoring system which were scored from 0 to 4 scale as given by Morishita*et al.,* 2003. Disease incidence (DI) was estimated using the following equation:

$$\mathrm{DI}\,(\%) = \left(\frac{n}{N}\right) \times 100$$

Where, n is the number of infected leaves in each treatment and N refers to the total number of leaves (healthy and infected).

The leaf miner damage was rated using a scale of 1-9 as reported by Singh & Weigand (1994) with some modifications. The number of leaf miners per leaf (NLM) was counted from tagged plants from each plot. Damage was estimated as using the below formula (Toker *et al.*, 2010).

$$\mathrm{LMD}\,\% = \left(\frac{\text{Number of damaged leaves}}{\text{Total number of leaves}}\right) \times 100$$

The experimental data of different parameters are presented as the mean and standard error of the mean (SEM). Data analysis followed the methodology outlined by Panse and Sukhatme (1978), and statistical comparisons were facilitated using the OPSTAT software available at *http://www.hau.ernet.in*.

RESULTS AND DISCUSSION

Significant differences were observed among the various treatments on the growth, yield and quality attributes due to the foliar application of micronutrients and salicylic acid

Effect of salicylic acid, boron and zinc on growth of parthenocarpic cucumber. Treatment T_8 [SA_2 (400 mg kg^{-1}) + B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})] showed significant increase in vine length (184.66 cm & 333.33 cm), maximum number of nodes (25.46 & 45.46), maximum number of branches (8.40 & 15.47) and increased internodal length (8.60 cm & 8.80 cm) at 40 and 60 days after sowing, respectively and the mean data values are envisaged in Table 1. The effect of salicylic acid, which plays a crucial role in raising the levels of plant hormones auxins and cytokinins that might have aided in vegetative growth of the crop. Because of the combined application of salicylic acid, boron and zinc, it might have promoted cell division and multiplication, which increased other hormone production in plants that may have increased the number of nodes, internodal length and leaf area. The result of this study conforms with the research work of Meena *et al.* (2017) in cucumber, Nada and El-Hady (2019) in cucumber, Nasrabadi *et al.* (2015) in Iranian melons, Abd el-mageed *et al.* (2016) in squash, Ali *et al.* (2015) in tomato and Haleema *et al.* (2018) in tomato.

Correlation. The correlation coefficient was analysed among 6 characters for 8 treatments and their correlation with level of significance is given in Table 2. Correlation measures the degree and direction of interdependence between pair of variables. When observations recorded at 60 days after sowing, among the correlated characters, number of branches per vine showed significant positive correlation with total yield at 5% level of significance whereas, internodal length, vine length and number of nodes per vine was found significant at 1% level of significance. The nature and magnitude of association between yield and its components traits is necessary to understand the effectiveness of applied treatments. The application of SA, boron, and zinc has shown a positive correlation with growth attributes in cucumber crops. These chemicals influence various aspects of cucumber plant growth and development.

Effect of salicylic acid, boron and zinc on yield parameters of parthenocarpic cucumber. The mean data for the yield attributes as an effect of salicylic acid, boron and zinc are envisaged in Table 3. Among all the different treatments, T_8 [SA_2 (400 mg kg^{-1}) + B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})] found to be significant in recording maximum fruits per vine (29.26). Additionally, T_8 exhibited the utmost leaf area (565.149 cm^2), maximum average fruit weight (149.55 g) and highest fruit yield per vine (4.37 kg) inturn leading to maximum total yield of 136.78 tons per hectare. In contrast, T_1 [Control] displayed a lower leaf area, minimum number of fruits, lesser average weight of fruits, minimum fruit yield per vine and lowest total yield per hectare. Raskin (1992) confirmed that salicylic acid serves as an endogenous growth regulator for flowering and florigenic effects, salicylic acid and boron being involved in the reproductive phase of plants might have led to higher fruit setting and zinc might have helped in increasing the number of flowers due to an increase in RNA and DNA contents in reproductive tissue which may in turn enhance fruit yield. Many research scholars have proved that a multitude of effects, including yield increases, might have occurred in response to the application of exogenous salicylic acid, boron and zinc altogether that increased photosynthetic activity leading to a rise in the production and storage of carbohydrates. The favourable impact of these micronutrients on the retention of flowers and fruits might have helped in increasing fruit production and total yield. The recorded data corresponds with the findings of Yadav *et al*. (2020) in brinjal, Kadu *et al.* (2018) on watermelons and Sathiyamurthy *et al.* (2017) on tomatoes. In this current research, the benefit-cost ratio was worked out for all treatments on cucumber crops (Fig 1). The highest B: C ratio of 1.59 was observed in T_8 [SA_2 (400 mg kg^{-1}) + B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})] followed by 1.48 observed in T_5 [SA_1 (200 mg kg^{-1}) + B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})]. The least B: C ratio (1.25) was witnessed in control.

There was significant variation within the treatments for the incidence of powdery mildew disease and damage of leaf miner demonstrated in Fig. 2 & 3. Salicylic acid application played significant role in the signal transduction system in plants that contributed to local and systemic resistance to pathogens (Meena *et al*., 2001 in groundnut). Maximum powdery mildew infection and leaf miner damage observed in the control might be because of non application of salicylic acid which plays critical role in the transduction mechanism that leads to development of resistance in crop. SA is considered to be the most promising contender as an endogenous activator of pathogen resistance in tobacco and cucumber, whether through activation of PR-proteins or other yet-to-be-identified pathways (Raskin, 1992).

Effect of salicylic acid, boron and zinc on quality of parthenocarpic cucumber. An appraisal of data presented in Table 4 showed that, Total Soluble Solids, shelf life, PLW % of fruits has significantly impacted due to foliar application of salicylic acid, boron and zinc. The highest TSS (3.30 ºBrix), fruit length (19.03 cm) and fruit girth (4.33 cm) was found in T_8 [SA_2 (400 mg kg^{-1}) + B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})]. Different treatment of salicylic acid, boron and zinc influenced chlorophyll content and significantly maximum chlorophyll content (37.71 SPAD) was recorded in T_8. Fruits harvested in T_8 [SA_2 (400 mg kg^{-1}) + B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})] have shown higher shelf life (8.43 days) and lowest PLW of 26.34 %. The SA treatment probably controlled how the stomata closed and changed the composition and amount of wax in the fruit, which decreased the transpiration and respiration rates in the cucumber and that might have decreased weight loss in the treated fruits. Zinc maintains the permeability of membranes, and boron improves the mobility of calcium to the fruits, which may have decelerated the rate of weight loss during storage. Therefore, the combination effect of salicylic acid, boron and zinc helped in retaining quality attributes of cucumber fruits. The results are in agreement Preciado-Rangel *et al.* (2019) in cucumber, Nada and El-Hady (2019) in cucumber, Bommesh *et al*. (2016) in cucumber, Yadav *et al*. (2022) in pointed gourd, Yadav *et al*. (2020) in bittergourd and Yadav *et al*. (2019) in bottle gourd.

Table 1: Effect of treatments on growth attributes of parthenocarpic cucumber.

Treatment	Vine length (cm)		Number of branches per vine		Number of nodes per vine		Internodal Length (cm)	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
T_1	100.66	197.46	4.86	9.10	17.00	29.60	7.26	7.46
T_2	149.33	276.66	7.96	14.73	22.53	40.23	8.46	8.63
T_3	130.33	237.73	7.33	13.76	20.86	36.73	8.03	8.21
T_4	129.66	233.66	7.26	13.13	21.66	38.80	8.06	8.23
T_5	181.33	306.66	8.30	15.03	23.73	42.93	8.53	8.70
T_6	123.33	256.00	7.36	14.40	20.73	36.40	8.16	8.33
T_7	155.33	260.33	7.26	14.20	21.80	37.46	8.13	8.20
T_8	184.66	333.33	8.40	15.47	25.46	45.46	8.60	8.80
F test	*	*	*	*	*	*	*	*
S. E. m±	14.24	21.26	0.41	0.66	1.23	2.33	0.18	0.24
C. D at 5 %	43.63	65.13	1.25	2.04	3.77	7.13	0.56	0.74

*Significant at 5% level

Table 2: Correlation among different characters influenced by salicylic acid, boron and zinc in parthenocarpic cucumber

60 DAS	Total yield	Internodal Length	Vine length	Number of nodes per vine	Number of branches per vine
Total yield	-				
Internodal Length	0.857**	-			
Vine length	0.979**	0.920**	-		
Number of nodes per vine	0.896**	0.959**	0.938**	-	
Number of branches per vine	0.774*	0.949**	0.841**	0.877**	-

* and ** significant at P = 0.05 and 0.01 respectively

Table 3: Effect of treatments on yield attributes of cucumber.

Treatment	Leaf area (cm^2)	Chlorophyll content (SPAD)	Number of fruits per vine	Average Fruit weight (g)	Fruit yield per vine (kg)	Total yield (t/ha)
T_1	422.239	32.11	24.00	130.73	3.14	98.09
T_2	542.914	35.67	26.26	138.96	3.65	114.23
T_3	481.930	36.93	25.20	135.33	3.41	106.87
T_4	474.463	36.07	25.13	134.16	3.37	105.37
T_5	550.245	37.40	27.88	141.86	3.95	123.49
T_6	494.467	34.27	25.86	140.65	3.63	113.64
T_7	492.368	33.80	26.00	137.23	3.57	111.59
T_8	565.149	37.71	29.26	149.55	4.37	136.78
F test	*	*	*	*	*	*
S. E. m±	28.01	0.81	0.94	2.71	0.14	4.51
C. D at 5 %	85.80	2.50	2.88	8.31	0.44	13.82

*Significant at 5% level

Table 4: Effect of treatments on quality attributes of parthenocarpic cucumber.

Treatment	Fruit length (cm)	Fruit girth (cm)	Shelf life (days)	PLW %	TSS (ºBrix)
T_1	14.40	3.40	6.10	31.37	2.96
T_2	17.93	3.60	7.29	29.75	3.13
T_3	17.66	3.63	7.53	27.64	3.03
T_4	17.33	3.66	7.61	27.48	3.00
T_5	18.66	4.16	7.79	26.67	3.17
T_6	17.66	3.86	7.87	26.62	3.07
T_7	17.50	3.83	7.84	26.76	3.01
T_8	19.03	4.33	8.43	26.34	3.30
F test	*	*	*	*	*
S. E. m±	0.73	0.10	0.22	0.36	0.05
C. D at 5 %	2.24	0.32	0.68	1.13	0.17

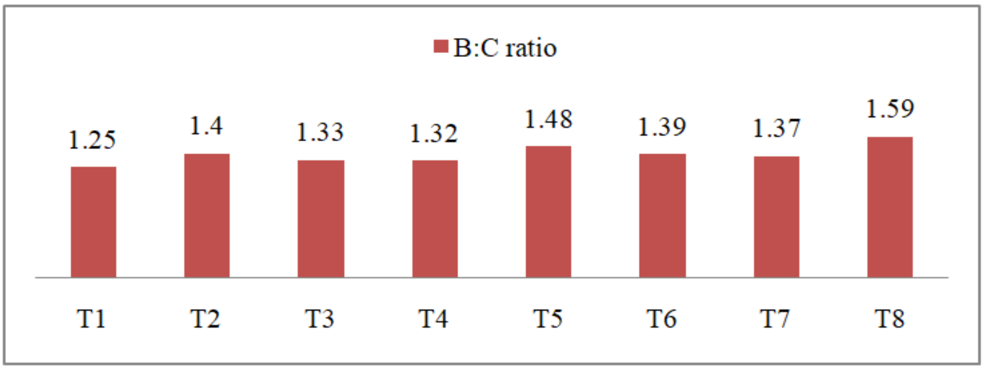

Fig. 1. Benefit-Cost ratio.

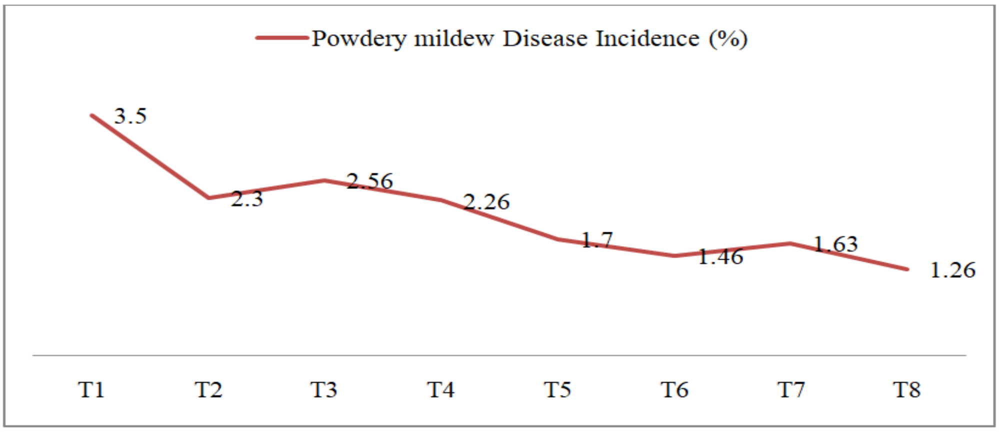

Fig. 2. Powdery mildew incidence.

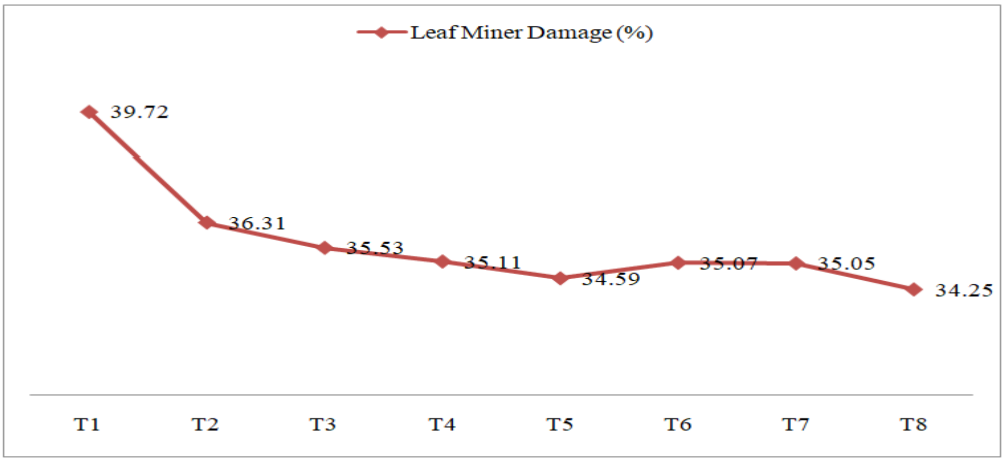

Fig. 3. Leaf miner damage.

CONCLUSIONS

The continual availability of salicylic acid, boron and zinc to the crop has influenced the growth and performance of the crop due to the effect of salicylic acid, which plays a crucial role in raising the levels of plant hormones auxins and cytokinins that might have aided in vegetative growth and yield of the crop. Boron plays a role in the growth and development of new cells at the meristematic region which may have influenced the growth of vine. Zinc applied as a foliar spray has improved the availability and uptake of mineral nutrients in the root region of the plant and that might have had an impact on the growth and development of the plant. The observed outcomes consistently highlight the positive effects of treatment T_8 [SA_2 (400 mg kg^{-1}) + B (50 mg kg^{-1}) + Zn (25 mg kg^{-1})] on various facets of crop development. Enhanced growth parameters, increased yield, and improved quality metrics collectively contribute to positioning T8 as a valuable component in the optimization of cucumber crop production.

FUTURE SCOPE

The foliar application of salicylic acid, boron, and zinc is a viable strategy for enhancing cucumber plant growth and yield. The use of these nutrients as foliar sprays can help reduce the use of chemical fertilizers, resulting in sustainable cucumber production systems.

Further research is needed to optimize the application rate, timing, and frequency of these nutrients to maximize their benefits.

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Conflict of Interest. None.

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