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ORIGINAL ARTICLE

EFFECT OF DIFFERENT LEVELS OF NANO-SILICON, BORON ON THE VEGETATIVE GROWTH AND YIELD OF CUCUMBER PLANT (*CUCUMIS SATIVUS* L.) OF PLASTIC HOUSE GROWN

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Abstract: The experiment was conducted at the agricultural research and experiment station, College of Agriculture, Al-Muthanna University, during the agricultural season 2018-2019, to study the effect of spraying different levels of silicon and boron nanoparticles on some vegetative growth characteristics and yield of cucumber (Maha cultivar). The study included nine treatments, silicon and boron were used at three levels: (Si_0 spraying with distilled water, Si_1 spraying with silicone at a concentration of 150 mg.L^{-1} and Si_2 spraying with silicone at a concentration of 300 mg.L^{-1}) and (B_0 spraying with distilled water, B_1 spraying with boron at a concentration of 20 mg.L^{-1} and B_2 spraying with boron at a concentration of 40 mg.L^{-1}), respectively. The experiment was conducted according to a Randomized Complete Block Design (R.C.B.D.) with three replicates. The results of the study showed that foliar spraying with silicon had a significant effect on most of the studied traits (plant height (cm), number of leaves.$plant^{-1}$, leaf area, number of fruits.$plant^{-1}$, fruit weight (g) and the total yield per plant (g)). The treatment Si_2 significantly outperformed the other treatments and gave the highest averages for the aforementioned traits. Whereas, the boron spray treatment had a significant effect on the characteristic of leaf area, fruit weight (g) and yield of plant (g), where treatment B_2 gave the highest mean of these traits but. The Si2B2 treatment was significantly superior in the characteristics of leaf area, number of fruits and yield of plant.

***Keywords*:** Nano-silicon, Boron, Vegetative growth, yield, Cucumber (*Cucumis sativus* L.).

Cite this article

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1. Introduction

Cucumber (*Cucumis sativus* L.) from Cucurbitaceae, it is one of the most important and widespread summer vegetable crops in the world. It grows naturally in tropical and semi-tropical regions. Its original home is India, from which it spread to China and Morocco. The nutritional value of cucumber fruits lies in the fact that they contain many nutrients and vitamins such as calcium, iron, phosphorous and potassium and water constitutes 97.95 percent of the weight of the fruit. Every 100 g of fruits contains 0.07 mg of protein, 24 mg calcium, 50-80 mg potassium, 14 mg calories, 20 IU Vitamin A, 0.075 mg vitamin B1 (riboflavin) and 0.3 mg Vitamin B2 (niacin). Cucumber fruits are consumed either fresh or pickled and have many medicinal uses. It is also useful in balancing high and low blood pressure. All soils contain many nutrients, but that does not mean that they are unlimited, because this store of nutrients is subject to depletion and depletion, the continuation of cultivation processes, air erosion, loss, washing and others [Dawd and Abdulla (2020)].

Most of the Iraqi soils are inclined to alkaline, makes some nutrients, including boron and silicon, unavailable. It is difficult to be absorbed by the roots of the plant. Foliar fertilization is the best and fastest way to address nutrient deficiencies, for example, a lack of boron leads to a disorder of the metabolic process, reducing the

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growth and development of the plant and the lack of yield. Whereas, silicon deficiency leads to deformation of plant growth and development as a result of environmental and biological stresses. Therefore, it increases the plant's resistance against these stresses and stimulates the antioxidant systems [Obaid and Hassan (2018)].

The study aims to use silicon and boron to improve the growth and development of cucumber plants, increased resistance to pathogens and environmental stresses, increasing production and improving its quality.

2. Materials and Methods

The experiment was conducted during the agricultural season 2018-2019 in an unheated greenhouse, at the agricultural research and experiment station, College of Agriculture, Al-Muthanna University. Cucumber seeds (Maha cultivar) were sown in cork dishes containing peat moss on 13/11/2018, then the soil of the plastic house was plowed and smoothed, random samples were taken from three sites with a depth of 0-30 cm. The samples were analyzed in the soil analyzes laboratory of the Soil and Water Resources Department, College of Agriculture, Al-Muthanna University and the results of the soil analyzes were as shown in Table 1.

It was conducted as a factorial experiment with two factors according to the Randomized Complete Block Design (R.C.B.D.) with three replicates.

The first factor: foliar spraying with the nano-silicone element Sio2 at three levels:

Si_0: comparison treatment (spraying with distilled water).

Table 1: Some physical and chemical properties of the experiment soil.

Parameters	Unit	Value
clay	(%)	31
silt		19
sand		50
Texture	Sandy clay loam	
N	Ppm	1.40
P		47.00
K		172.00
EC	ds.M^{-1}	4.68
PH	-	7.60
TDS	Ppm	3.02
NacL	Ppm	6.1

Si_1: spraying with silicone, a concentration of 150 mg.L^{-1}.

Si_2: spraying with silicone, a concentration of 300 mg.L^{-1}.

The second factor: foliar spraying with boron B element at three levels:

B_0: comparison treatment (spraying with distilled water).

B_1: spraying with boron concentration of 20 mg.L^{-1}.

B_2: spraying with boron concentration of 40 mg.L^{-1}.

The experimental units amounted to 9 for each replicate.

The experimental unit included ten plants that were transferred and planted in the soil of the greenhouse on 17/12/2018 at a distance of 30 cm between plants and 80 cm between planting lines. The process of spraying plants with nanoscale silica was carried out ten days after they were transferred and grown in the greenhouse. It was sprayed with boron with the beginning of the flowering on December 30, 2018. All agricultural operations required to serve the crop were carried out.

2.1 Studied traits

Vegetative growth measurements

Five plants were taken randomly from each experimental unit and the following characteristics were measured:

Height of the plant (cm): It was measured with a metric tape measure from the level of the soil surface to the top of the stem main plant.

Number of total leaves (leaf.Plant^{-1}): The total number of leaves of the five selected plants was calculated and taken the average.

Leaf area (dm^2): The total area of the plant was calculated using a planometer, represented by three leaves from each plant, and the average was extracted and multiplied by the number of leaves.

Measurements of the yield and its components

Number of fruits.Plant^{-1} = Fruits number of the experimental unit / plants number in the experimental unit.

Fruit weight rate (g) = product of the experimental unit / Fruits number of the experimental unit.

The yield of plant (g): It represents the yield of the plants of the experimental unit and of all fairies divided by the number of experimental unit plants.

All experimental data were subjected to statistical analysis (ANOVA). The averages were compared using the least significant difference test (L.S.D.), to show the statistical differences between the transactions at the 5% probability level, according to the statistical system Genstat.

3. Results and Discussion

Vegetative growth

Table 2 shows a significant increase in most of the vegetative growth characteristics with the increase in the concentration of spraying with silicon, the Si_2 spraying treatment was superior in plant height and number of leaves and it gave the highest averages, which were 121.63 cm and 26.88 leaves. $Plant^{-1}$ sequentially. Whereas, it did not differ significantly in leaf area characteristic from Si_1 spraying treatment, but both were superior to Si_0 comparison treatment.

The reason for this may be due to the positive effects of silicon on the growth characteristics of plants treated with silicon. The mechanical strength provided by the silicon element enables the plant to be erect and to intercept the largest amount of light and receive it by the leaves, because silicon bonds with other biological compounds such as lectin, pectin and cellulose, which form cell walls, which pushes towards strengthening and arranging papers, make it erect, which leads to blocking the maximum amount of sunlight, thus increasing the activity and efficiency of photosynthesis others [Dawd and Abdulla (2020)], in addition, the silicon element helps in the growth of roots, increased penetration into the soil, increase the efficiency of absorption of macronutrients, such as K, P, S, Mg and Ca required for plant growth, in addition to increasing the resistance of plants against environmental and biological stresses [Garg and Bhandari (2015)].

Table 3 noted that increasing the concentration of spraying with the element boron had a significant effect on the characteristics of vegetative growth, where the spray treatment B_2 outperformed in giving the highest value on leaf area, amounted to 22.52 dm^2, with an increase of 24.90% compared to the comparison treatment, which gave the least paper area of 18.03 dm^2, did not differ significantly from the B_1 spray treatment in terms of plant height and number of leaves, but both of them were significantly superior to the comparison treatment B_0 in the above traits.

The reason for this increase may be attributed to the essential and important role of the boron element in the physiological processes of plants, its deficiency affects the metabolism, growth and development of plants. Boron contributes to the structural and functional construction of cell wall and membranes, the flow of electrons across membranes through the formation of the enzyme ATPase such as K, Ca, H, Po4 and Rb ions [Ahmed *et al.* (2011)]. The contribution of boron to increasing root growth by increasing the activity of root cell division and elongation, as well as increasing the division and elongation of the developing apex cells

Table 2: Effect of the foliar application of different levels of Silicon on the Vegetative growth of Cucumber plant.

Silicon (Si)	Vegetative growth		
	plant length (cm)	leaves numbers per $plant^{-1}$	leaves area per plant ($dm^2.Plant^{-1}$)
Si_0	99.97	22.20	17.19
Si_0	113.08	22.81	21.11
Si_2	121.63	26.88	22.10
$L.S.D._{0.05}$	7.835	3.375	2.396

Table 3: Effect of the foliar application of different levels of Boron on the Vegetative growth of Cucumber plant.

Boron (B)	Vegetative growth		
	plant length (cm)	leaves numbers per $plant^{-1}$	leaves area per plant ($dm^2.Plant^{-1}$)
B_0	102.73	20.22	18.03
B_0	113.46	24.35	19.86
B_2	118.48	27.31	22.52
$L.S.D._{0.05}$	7.835	3.375	2.396

through its positive role in auxin, especially IAA enzyme, leads to an increase in plant height. Spraying with boron increases the chlorophyll content in the leaves, stimulating the activity of thylakoid membranes in electron transport, thus increasing the activity of photosynthesis, this finding is in agreement with the findings of Bommesh *et al*. (2017), on increasing the vegetative growth characteristics of cucumber plants treated with boron as a spray on the vegetative total.

Table 4 show that there are significant effects of the bilateral interaction between the levels of spraying with silicon and boron in the characteristic of leaf area. The binary interaction treatment Si_2B_2 gave the highest value in this trait, which amounted to 27.04 dm^2 compared with the binary comparison treatment Si_0B_0, which recorded the lowest value of 14.64 dm^2 with a significant increase of 84.70%, can be explained on the basis of the important and positive role of silicon and boron in improving the efficiency of the photosynthesis process and stimulating tabular vegetative growth (2) and (3), while there were no significant effects of the two interaction levels of the study coefficients in the characteristics of plant height and number of leaves.

The yield and its components

Table 5 noted that the levels of foliar spraying with silicon have risen to the level of significance in the character of the yield and its components. The Si_2 spraying treatment was significantly superior to the rest of the other treatments in the number of fruits.$Plant^{-1}$, the weight of the fruit (g) and the yield of one plant (g) and it gave the highest values of 16.90 fruits.$Plant^{-1}$, 78.52 g and 1334.20 g, respectively, in comparison with the control treatment Si_0, which recorded the lowest values for these traits amounted to 12.51 fruits.$Plant^{-1}$, 67.36 g and 850.29 g, respectively, with increases of 35.10, 16.57 and 56.91%, respectively.

This can be explained on the basis that silicon sprayed on the plant, increases chlorophyll content in leaves, increasing the activity of the photosynthesis process, positively reflected on stimulating plant growth and development and increasing processed carbohydrates and thus increasing the yield. Or perhaps this is due to the important role of silicon in increasing the activity of the metabolic and physiological processes of the plant and encouraging the processes of absorption and transport of nutrients, in addition to what was previously mentioned about increasing the leaf area of a plant (Table 2), thus increasing the manufacture of carbohydrates and their transfer from the source (leaves) to the places of consumption (fruits and flowers). Consequently, the number of fruits increased

Table 4: Effect of the interaction of different levels of Silicon, Boron on the Vegetative growth of Cucumber plant.

Silicon(Si)	Boron(B)	Vegetative growth		
		plant length (cm)	leaves numbers per $plant^{-1}$	leaves area per plant (dm^2. $Plant^{-1}$)
Si_0	B_0	91.56	18.04	14.64
	B_1	106.23	22.68	18.09
	B_2	102.11	25.88	18.85
Si_1	B_0	102.79	20.23	19.22
	B_1	113.95	23.83	22.44
	B_2	122.50	24.36	21.66
Si_2	B_0	113.85	22.39	20.22
	B_1	120.20	26.54	19.03
	B_2	130.83	31.70	27.04
$L.S.D._{0.05}$		N.S	N.S	4.150

Table 5: Effect of the foliar application of different levels of Silicon on yield of Cucumber plant.

Silicon (Si)	Yield		
	Fruits number per $plant^{-1}$	Fruit weight (g)	Fruits yield per $plant^{-1}$ (g)
Si_0	12.51	67.36	850.29
Si_0	14.54	69.94	1018.06
Si_2	16.90	78.52	1334.20
$L.S.D._{0.05}$	1.473	8.026	119.382

and their weight increased, which led to an increase in the yield of one plant, the high content of silicon in the cucumber plant, associated with an increase in yield by improving plant resistance to pathogens, tolerating environmental stresses such as drought by reducing transpiration. This result is consistent with the findings of Jarosz (2013) who indicated that silicon has a positive effect on the cucumber yield.

Table 6 indicates the increase in the level of spraying with boron B_2 to the significant level in the characteristics of the weight of the fruit (g) and the yield of one plant (g), gave the highest values for these two traits, which were 79.84 g and 1300.91 g, respectively. Whereas, the comparison treatment B_0 gave the lowest values of the two characteristics above, which were 65.12 g and 828.33 g, with an increase of 22.60% and 57.10%, respectively. Treatment B_2 did not differ from treatment B_1 in the characteristic of the number of fruits, but both of them outperformed the comparison treatment B_0, as they recorded two values for the number of fruits, amounting to 16.23 fruits. Plant^{-1} and 15.08 fruit.Plant^{-1} in a row, while the control treatment B_0 recorded the lowest value in this trait, which amounted to 12.64 fruits.Plant^{-1}.

The reason for this increase may be due to the active role of boron in increasing the chlorophyll content in the leaves, increased activity of thylakoid membranes in electron transport, increasing the efficiency of the activity of the photosynthesis process, which led to an increase in the yield [Wang *et al*. (2015)]. Or, boron may play an essential role in nitrogen and carbohydrate metabolism, transport of sugars, proteins, enzymes, DNA, RNA, ascorbic acid and phenols. Boron may lead to an increase in crop productivity by controlling the pollination process due to its effect on the growth and elongation of the pollen tube and increase the vitality of pollen grains. In addition to controlling the transfer of carbohydrates to the active sites in the plant such as flowers and fruits, as well as its effect on the movement and transmission of hormones within plant tissues and thus regulating plant physiological processes [Epstein and Bloom (2003), Haque *et al*. (2011), Abdur and Ihsanulha (2012)]. This finding agreed with the findings of Bommesh *et al*. (2017).

Table 7 shows a significant effect of the binary interaction between silicon and boron on the two characteristics of the number of fruits.Plant^{-1}, the yield of one plant (g). The treatment of Si_2B_2 binary interaction significantly outperformed and the two highest values were recorded, amounting to 20.17 fruits. Plant^{-1} and 1710.55 g, respectively. Whereas, the comparison overlap treatment, Si_0B_0, gave the two

Table 6: Effect of the foliar application of different levels of Boron on yield of Cucumber plant.

Boron (B)	Vegetative growth		
	Fruits number per plant^{-1}	**Fruit weight (g)**	**Fruits yield per plant^{-1} (g)**
B_0	12.64	65.12	828.33
B_0	15.08	70.86	1073.31
B_2	16.23	79.84	1300.91
L.S.D.$_{0.05}$	1.473	8.026	119.382

Table 7: Effect of the interaction of different levels of Silicon, Boron on yield of Cucumber plant.

Silicon(Si)	Boron(B)	Yeild		
		Fruits number per plant^{-1}	**Fruit weight (g)**	**Fruits yield per plant^{-1} (g)**
Si_0	B_0	10.54	57.04	602.91
	B_1	13.71	70.00	961.40
	B_2	13.29	75.05	986.56
Si_1	B_0	14.05	64.81	904.01
	B_1	14.35	65.83	944.56
	B_2	15.23	79.17	1205.61
Si_2	B_0	13.33	73.52	978.07
	B_1	17.19	76.74	1313.98
	B_2	20.17	85.30	1710.55
L.S.D.$_{0.05}$		2.551	N.S	206.776

lowest values for these two traits, which amounted to 10.52 fruits.Plant^{-1} and 602.91 g, respectively. The second interaction of the levels of the study factors did not show a significant effect on the characteristic of the weight of the fruit.

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