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Effect of silicon and humic substances on the productivity and absorption of minerals in cucumber

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ABSTRACT

Objective: To evaluate the effect of potassium silicate and humic substances in the mitigation of salt stress in cucumber grown in a greenhouse.

Design/Methodology/Approach: A completely randomized design with factorial arrangement was used. The first factor was the cucumber varieties (Var): Induran (I) and SV2516 (SV). The second factor was potassium silicate (Si), with doses of 0, 10, and 20 mL·L^{-1}. The third factor was humic substances (SH), with doses of 0, 10, and 20 kg/ha.

Results: The best interaction for the NFP and Y variables was SV*SH20. The N and Ca content in the fruit was I*SH10, while the K and P content was SV*Si20. Meanwhile, Mg, Fe, and Cu interactions stood out with SV*Si10, SV*Si20, and I*Si10, respectively. The best interaction in leaf mineral content was I*SH20 (N), SV*SH10 (P and K), and SV*Si20 (Cu).

Study Limitations/Implications: There was no significant difference in Ca, Mg, and Fe in leaf.

Findings/Conclusions: At least one of the interactions between cultivars and bio stimulant doses favored agronomic traits, quality, and mineral absorption in fruit.

Keywords: salt stress, humic substances, potassium silicate.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most popular vegetables cultivated all over the world (Singh *et al.*, 2017). There are several cultivars on the market that are mainly characterized by the different sizes, shapes, colors, flavors, and vegetative characteristics of their fruits. The most common types of cucumber are classified as: American, European, Middle Eastern, Dutch, and Oriental (López *et al.*, 2015). China, Iran, Russia, Turkey, USA, and Mexico are the main cucumber producers. Mexico ranks sixth worldwide, reaching a production of 956,005 tons. Approximately 20 thousand hectares are dedicated to this crop and generate exports of 693,611 t, with

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a value of around 483 million dollars (FAOSTAT, 2017). Kumar *et al.* (2017) mention that high levels of soil salinity can inhibit seedling germination and growth, as a result of the combined effect of high osmotic potential and specific ion toxicity. They also affect short- and long-term photosynthesis. In the short term, stomatal limitations can affect photosynthesis, leading to a decrease in carbon assimilation (Acosta *et al.*, 2017). Salt stress also causes excessive generation of reactive oxygen species (ROS), such as superoxide anions, hydrogen peroxide, and hydroxyl radicals (Zhang *et al.*, 2014). Biostimulants are increasingly integrated into production systems with the aim of modifying physiological processes in plants. This modification optimizes their productivity, offering a potentially novel approach to the regulation and modification of physiological processes in plants, in order to stimulate growth, mitigate stress-induced limitations, and increase yield (Yakhin *et al.*, 2017). The role and importance of humic substances (SH) in soils have been proven for a long time. Their multiple properties especially their capacity to "sequester" (adsorbent and chelate) organic and mineral compounds (pesticides and metals) allows them to play an essential role in the solubilization, bioavailability, degradability, transport, and exchange of these compounds in water and soil (Ouni *et al.*, 2014). This role results from the greater cation exchange capacity of the soil that contains SH and the increased availability of phosphorus that interferes with the precipitation of calcium phosphate (Du Jardin, 2015). Likewise, the beneficial properties of silicon are better documented in terms of its positive effects on tolerance to abiotic stress and pathogen resistance. It is mainly deposited at flow endpoints in cell walls and intercellular spaces. These silicon or phytolith depositions increase the mechanical resistance and erection of the leaves, which increases the interception of light and photosynthesis (Albrecht, 2019).

MATERIALS AND METHODS

This research project was carried out during the 2020 spring-summer in the Departamento de Horticultura at the Universidad Autónoma Agraria Antonio Narro, in the city of Saltillo, Coahuila, Mexico (1790 m.a.s.l., 25° 21" N 101° 01" W).

Crop management

Cucumber cultivars from two commercial American-type cucumber hybrids (Induran and SV2516) were planted in polystyrene trays with 72 square cavities. The cultivars were transplanted 20 days after planting, when the seedlings had two true leaves. The planting density was 2.7 plants/m^2. The two cucumber cultivars were staked to a single stem. Initial formative pruning and pruning were performed throughout the cycle, as axillary buds and tendrils grew.

The solution proposed by Steiner (1969) was chosen for the fertilization stage. The nutrient solution was supplied by fertigation and set at 1.8 dS m^{-1} and 6 pH at the beginning of the transplant. Two weeks after transplant, 25 mM sodium chloride was added to cause salt stress. No more sodium chloride was added after the E.C. reached 6 dS m^{-1} in the nutrient solution in the soil.

A foliar application of potassium silicate (Genhydro® Armor Si™) was applied every 7 days as a biostimulant throughout the cycle. Regarding humic substances, Cosmocel® H-85™ was drenched thrice (in the vegetative, flowering, and development stages).

This project used a completely randomized block design with factorial arrangement. Three factors were included in this arrangement: 1) the Induran (I) and SV2516 (SV) cucumber varieties (Var); 2) potassium silicate (Si) with 0, 10, and 20 $mL \cdot L^{-1}$ doses; and 3) humic substances (SH) with 0, 10, and 20 kg/ha doses (Table 2). There were three replicates and a total of 54 experimental units.

Evaluation of yield variables

The following variables were evaluated: number of fruits per plant (NFP), fruit weight (FW/PF), fruit diameter (FD/DF), fruit length (FL/LF) and yield (Y/Rend). NFP was evaluated once the crop entered the fruit set and the development stages. In the case of FW, the fruits of a sample —taken by experimental unit and which had the characteristics required by the market— were weighed after they had been harvested. This process was carried out with a Steren® MED-080 scale, with a maximum weight of 5 kg. Regarding the FD, the maximum circumference of the fruit was evaluated with a Steren® digital vernier. The LF was measured from one end to the other using a Truper® FH-5M flexometer. Finally, regarding Y, the weight of all the fruits harvested from each treatment was measured per square meter.

Mineral evaluation

The macroelements and microelements evaluated in fruit and leaf were N, P, K, Ca, Mg, and Fe. Three repetitions were taken per experimental unit. A digestion, distillation, and titration process was carried out to analyze N, following the procedure described by Mckean (1993). First, a 0.050 g dry and ground vegetable sample was weighed; then it was placed in Kjeldahl micro digestors and 5 mL of digester solution were added; subsequently, the mix was taken to 400 °C to disintegrate the organic nitrogen. The sample was considered ready when it showed a transparent hue. The samples were subjected to 50% NaOH and the resulting distillate was poured into 30 mL of 2% H_3BO_3 until it increased to 60 mL. The result was titrated with 0.025 N H_2SO_4 until it turned pink. N was calculated using the following formula.

$$\%N = \frac{\left(ml\ acid\ titrant - ml\ blank\right) \times N\ of\ the\ acid \times 1.4007}{Sample\ weight\ in\ grams} \times 100$$

P, K, Ca, Mg, and Fe were subjected to acid or wet digestions. At this stage, a 0.5 g sample of dry and ground matter was weighed. The previously weighed sample was placed in a 100-mL beaker and 30 mL of HNO_3 with a purity of 96% was added. The results were then placed on a watch glass rack for digestion. Once the sample was transparent, it was measured in a 50-mL Erlenmeyer flask with deionized water. P was analyzed by colorimetry with the amino-naphthol-sulfonic acid (ANSA) method in a Thermo® Bio Matte 5 UV-VIS spectrophotometer (Terán, 2016).

$$mg / gr = \frac{Curve\ reading \times 10^{-3}}{Grams\ of\ the\ sample \times the\ dilution}$$

Meanwhile, K, Ca, Mg, and Fe were analyzed by atomic absorption spectrometry with a GBC Scientific Equipment® Xplorra. Ca and Mg digestions were diluted to of the initial concentration (Williams, 1972). To determine the mineral concentration, the absorbance of each mineral was taken and later supported with the following formula.

$$Element\ (\mu / g) = \frac{(c)(V)(d.f.)}{(W)}$$

Where: c=Concentration of the element that contains the sample used; V=Volume of the sample used; $d.f. = \frac{Volume\ of\ the\ diluted\ sample\ in\ mL}{Volume\ of\ the\ aliquot\ taken\ from\ the\ dilution\ in\ mL}$; and W=Weight of the sample in grams.

Statistical data analysis

The results obtained from the determination of each variable were subjected to an ANOVA and the means were compared using Duncan's test ($p \leq 0.05$), using the 2018 version of the Infostat statistical software.

RESULTS AND DISCUSSION

Agronomics

The Var*Si interaction had a statistically significant difference ($p \leq 0.05$) in FW, FD, FL, and Y. In the Var*SH interaction, a statistically significant difference ($p \leq 0.05$) was observed in the evaluated variables of NFP, FW, FD, FL, and Y. In relation to NFP, the SV*Si10 interaction recorded the best average: 30.9% more than I*Si10 (Figure 1A). However, SV*SH20 registered the maximum mean: 33% more than the SV*SH10 interaction (Figure 1B). Al-madhagi (2019) reported that 100-mg L^{-1} doses of humic acids increase the number and the average weight gain of cucumber fruits. Previous experiments indicated that SH treatments improved some fruit characteristics —for example, fruit number, fruit weight, and dry weight per fruit— of several crops, including cucumbers, tomatoes, onions, eggplants, and peppers (Shehata *et al*., 2016). The SV*Si10 interaction was the maximum mean for the FW analysis, with a value of 388.3 g. This results was 16% higher than I*Si0, which had a minimum value of 326.1 g (Figure 1C). SH did not behave in the same way as Si. The maximum value (403.2 g) was obtained by the SV*SH0 interaction, while the minimum value was recorded with the I*SH0 interaction (Figure 1D). Therefore, the SH did not infer on the FW variable. Regarding FD, the interaction with the highest mean was SV*Si0. This result was 5.5% higher than the I*Si20 interaction, which recorded the lowest value (Figure 1E). Meanwhile, in SH, the interaction with the highest value was SV*SH10. This result was 7.7% higher than the I*SH0 interaction that obtained the lowest value (Figure 1F). Therefore, it can be inferred that SH promoted FD in cucumber. Ekinci *et al.*, (2015) analyzed several types of biostimulants and determined that the application of different SH doses to cucumber plants obtained similar results regarding the diameter and length of the fruit. Regarding FL, the SV*Si0 interaction obtained the highest value, which was 7.5% higher than the result of the I*Si10 interaction with the lowest value (Figure 1G). Consequently, it can be inferred that the Si doses do not directly favor the increase of FL. Meanwhile, the SV*SH10 interaction showed the highest SH value: 6.1% higher than the I*SH10 interaction that obtained the lowest value (Figure 1H). These data are consistent with those previously published by Ameta *et al.* (2017), who applied 10kg/ha of humic acids to the soil + 0.1% humic acids and micronutrients to the leaves, obtaining cucumber crop with very similar fruit lengths. Regarding Y, the SV*Si10 interaction had the highest value, obtaining 33.1% more than the I*Si10 interaction (Figure 1I); therefore, the assumption is that the Si supply is not related to the increase in Y —which is attributed to the genetic aspects of the varieties used. The SV*SH20 interaction had the highest SH value: 32% higher than I*SH10, which was the interaction with the lowest value (Figure 1J). For their part, Abd Elkareem *et al.* (2017) obtained higher yields (15-20%) with the direct application of HS into the soil and Benyamin Esho and Saeed (2017) reported that the application of different HS doses to several pumpkin (*Cucurbita pepo* L.) varieties resulted in a higher yield.

Minerals

The Var*Si interaction had a highly statistically significant difference ($p \leq 0.01$) in the P and Mg variables and a statistically significant difference ($p \leq 0.05$) for N, K, Ca, Fe, and Cu. Regarding Var*SH, a statistically significant difference ($p \leq 0.05$) was observed in N, P, Ca, Mg, and Fe. Regarding the N variable in fruit, the SV*Si10 interaction was the maximum mean with a value of 20.2 $g \cdot kg^{-1}$. It was 34.1% higher than SV*Si10, which had a value of 13.33 $g \cdot kg^{-1}$ (Figure 2A). Meanwhile, I*SH10 obtained the maximum N mean, with a value of 22.56 $g \cdot kg^{-1}$. This result was 34.4 % higher than SV*SH0, which had a value of 14.78 $g \cdot kg^{-1}$ (Figure 2B). Leaves had the best interaction with I*Si20 and I*SH20 (Figure 3A and 3B). Yasir *et al.* (2016) have suggested that using organic fertilizers based on humic substances in the soil plus the application of amino acids into the leaves favor the absorption of N. Humic acids make nutrients available for absorption; therefore, they facilitate growth, the accumulation of carbohydrates, and the increase in the photosynthetic rate and chlorophyll production.

When analyzing the P variable in fruit, the SV*Si20 interaction recorded the maximum mean with a value of 6.7 $g \cdot kg^{-1}$. This result was 48.4% higher than SV*Si10, which had a value of 3.48 $g \cdot kg^{-1}$ (Figure 2C). For its part, SV*SH10 recorded the maximum mean with a value of 5.9 $g \cdot kg^{-1}$. This result was 27.9% higher than I*SH0, which registered a value of 4.25 $g \cdot kg^{-1}$ (Figure 2D). SV*Si20 and SV*SH10 recorded best absorption of P in the leaves (Figure 3C and 3D). El-Nemr *et al.* (2012) have reported that, compared with their

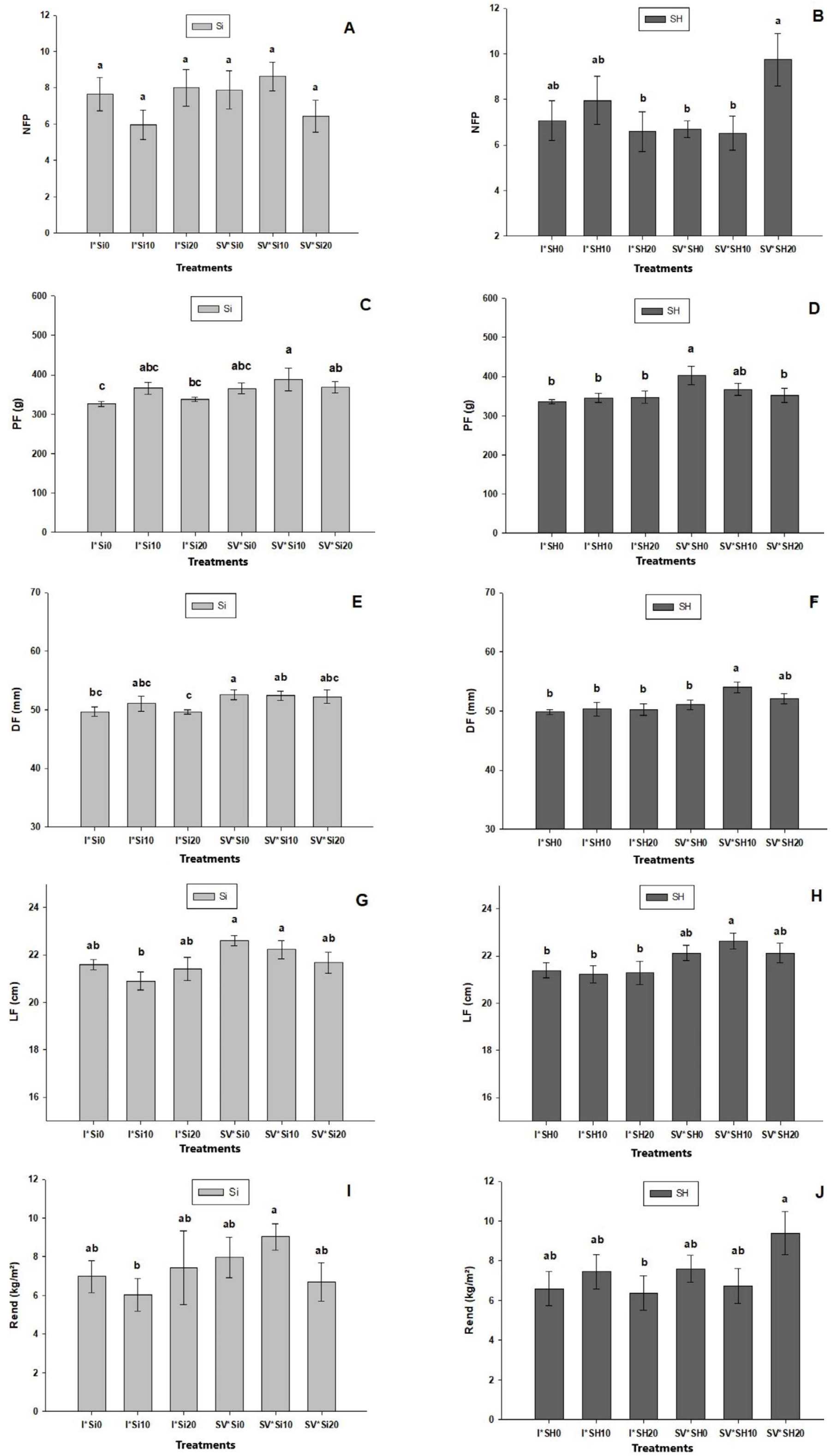

Figure 1. Tests of means. A and B (number of fruits); C and D (fruit weight); E and F (fruit diameter); G and H (fruit length); I and J (yield); Si=Silicon (0, 10, 20 mL L^{-1}); SH=humic substances (0, 10, 20 kg ha^{-1}); I=Induran; SV=SV2516. Different letters indicate significant differences between treatments, according to Duncan ($p \leq 0.05$), n=9 ± standard error.

controls, the application of humic acids increased the content of minerals such as N, P, and K in cucumber leaves, and found that the applications of these substances can stimulate the uptake of macro and microelements.

For the variable of K in fruit, the SV*Si20 interaction recorded the maximum mean, with a value of 28.3 $g \cdot kg^{-1}$. This result was 24.4% higher than SV*Si10, which registered a value of 21.39 $g \cdot kg^{-1}$ (Figure 2E). In contrast, the I*SH20 interaction obtained the maximum mean, with a value of 26.3 $g \cdot kg^{-1}$, which was 10.6% higher than the 23.5 $g \cdot kg^{-1}$ value of I*SH0 (Figure 2F). Regarding the K content in leaves, the SV*Si10 treatment had the highest value (Figure 3F). In many plant species, foliar application of silicic acid in the flag leaves of cereal crops increase N, P, and K absorption in grain (Soratto *et al.*, 2012). Another plausible explanation for SH activity is the hormone-like behaviour of their structures, which facilitates the nutrient translocation throughout the plant. Subsequently, the formation of complexes with metal ions increases their solubility and availability to plant roots (Khaled and Fawy, 2011). Regarding Ca in fruit, the I*Si20 interaction recorded the maximum mean with a value of 5.2 $g \cdot kg^{-1}$. This result was 53.8% higher than SV*Si20, which registered a value of 2.4 $g \cdot kg^{-1}$ (Figure 2G). The I*SH10 interaction obtained the maximum mean with a value of 5.7 $g\ kg^{-1}$. This result was 49.1% higher than I*SH0, which registered a value of 2.9 $g \cdot kg^{-1}$ (Figure 2H). In addition, Tripathi *et al.* (2014) recorded a significant decrease in the Ca an K concentrations in plants grown under a high NaCl treatment; however, their concentrations were raised to the required level by the addition of Si in both shoots and roots. In relation to Mg in fruit, the SV*Si10 interaction had the maximum mean with a value of 3.3 $g \cdot kg^{-1}$. This result was 36.3% higher than I*Si20, which registered a value of 2.1 $g \cdot kg^{-1}$ (Figure 2I). However, SV*SH0 had the maximum mean with a value of 3.5 $g \cdot kg^{-1}$. This result was 34.2% higher than I*SH20, which registered a value of 2.3 $g \cdot kg^{-1}$ (Figure 2J). Under salt stress (150 mM NaCl), Si (2 mM Na_2SiO_3) increased the K, Ca, and Mg content and decreased the Na and Cl content in tomato roots, stems, and leaves. This phenomenon was not mediated by a reduced translocation from root to stem or stem to leaf, but rather by a salt dilution effect triggered by improved growth —*i.e.*, higher shoot biomass accumulated under salt stress and Si application (Li *et al.*, 2015).

Regarding Fe in fruit, the SV*Si20 interaction had the maximum average with a value of 117.7 ppm. This result was 43.4% higher than SV*Si20, which registered a value of 66.6 ppm (Figure 4A). However, the I*SH0 interaction recorded the maximum average with a value of 116.2 ppm. This result was 56.1% higher than I*SH20, which registered a value of 65.3 ppm (Figure 4B). Studies prove the ability of Si to modulate the Fe absorption activity of cucumber at an early stage of stress, as result of the Fe deficiency, through the regulation of the gene expression levels of the proteins involved in this process (Pavlovic *et al.*, 2013). It has also been shown that Si application can facilitate Fe mobility and translocation from the xylem to the shoot, along with the accumulation of Fe-chelating compounds, such as citrate in xylem sap and leaf tissues (Bityutskii *et al.*, 2014). Regarding the means of Cu in fruit, the I*Si0 interaction had the maximum mean with a value of 11.9 ppm. This result was 42.8% higher than SV*Si20, which registered a value of 6.8 ppm (Figure 4C). However, the maximum mean value for I*SH10 was 11.3 ppm. This result was 30.9%

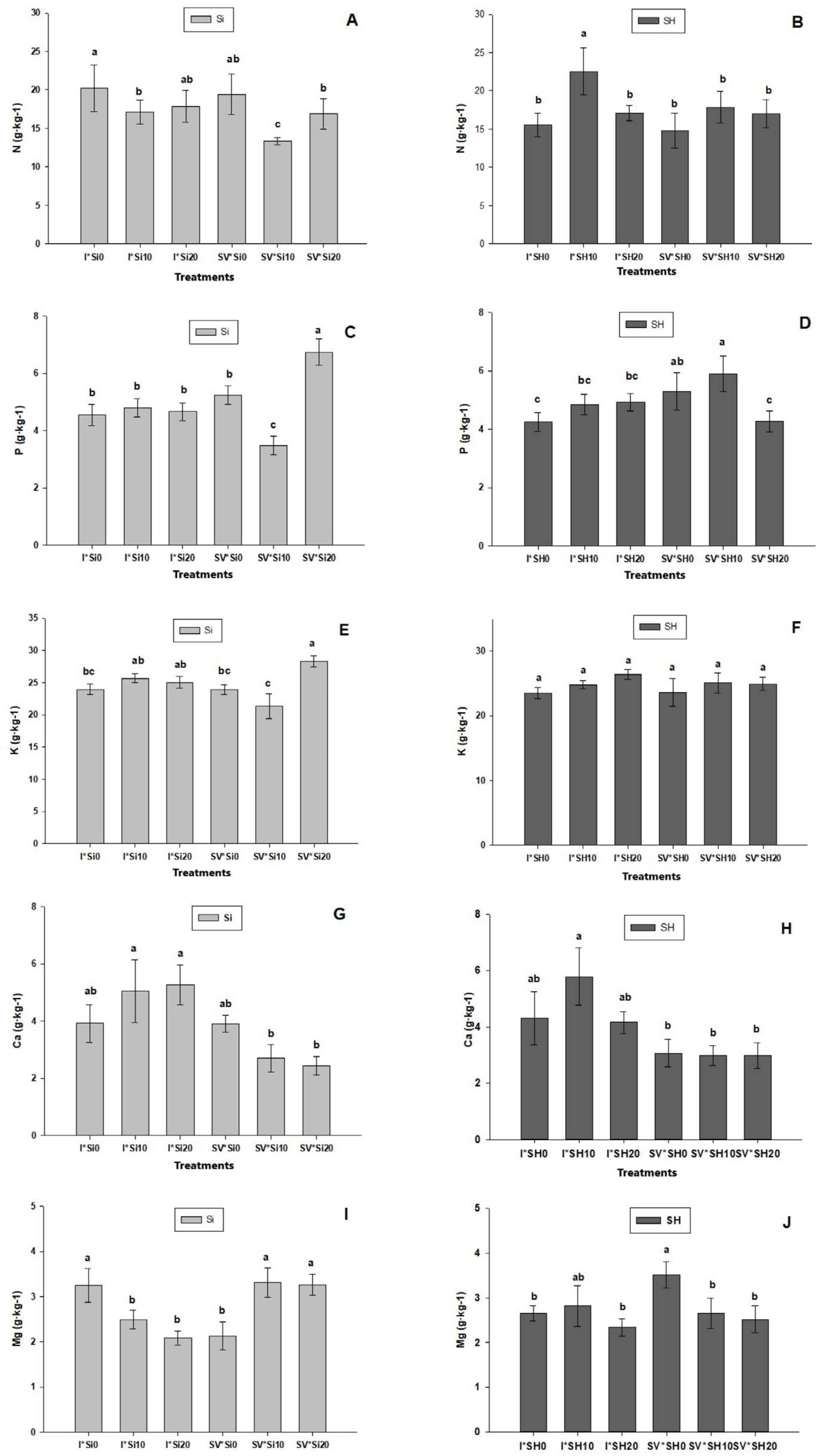

Figure 2. Tests of means on macrominerals in fruit. A and B (Nitrogen); C and D (Potassium); E and F (Phosphorus); G and H (Calcium); I and J (Magnesium); Si=Silicon (0, 10, 20 mL L^{-1}); SH=humic substances (0, 10, 20 kg ha^{-1}); I=Induran; SV=SV2516. Different letters indicate significant differences between treatments, according to Duncan (p≤0.05), n=9 ± standard error.

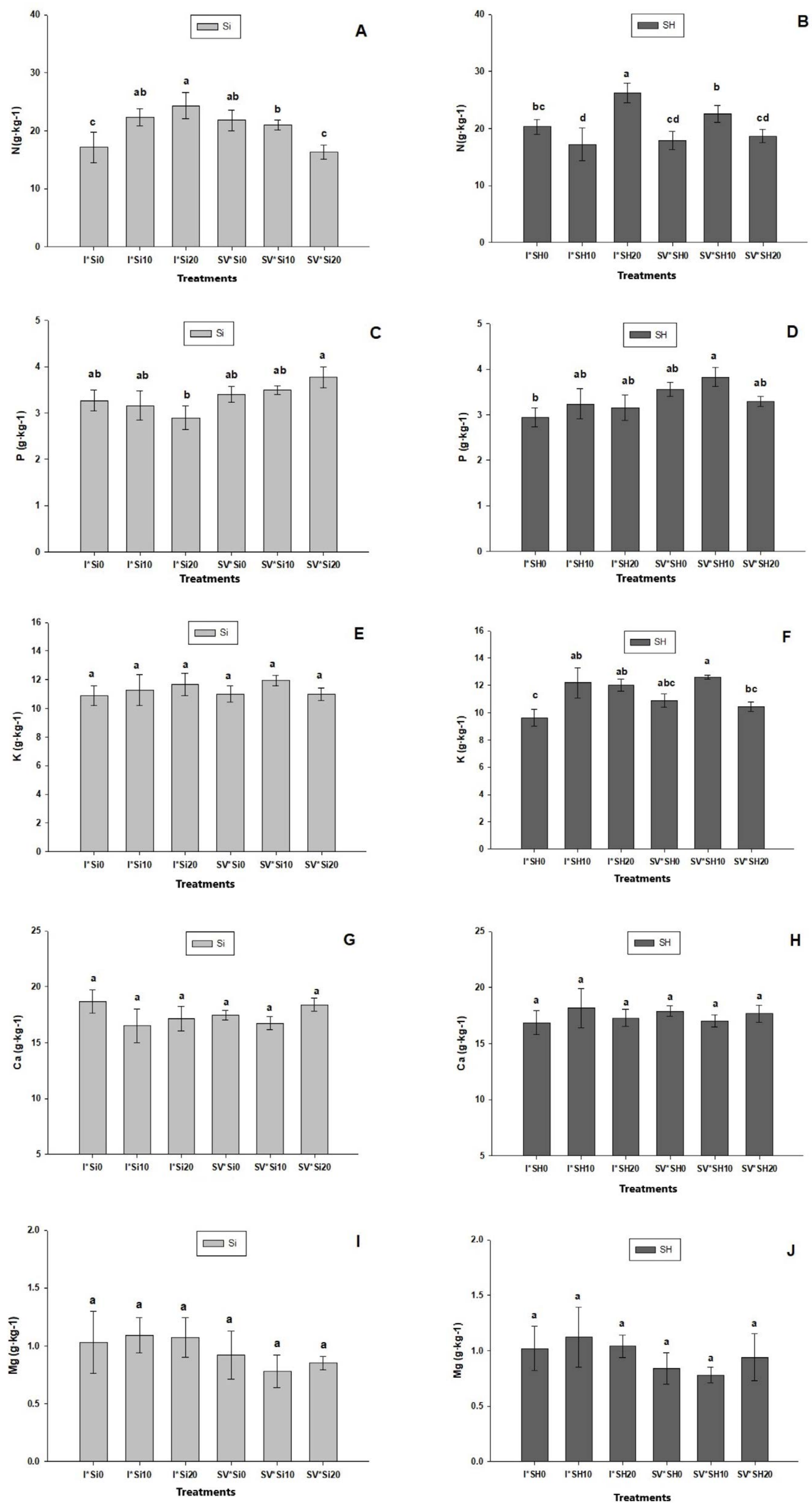

Figure 3. Tests of means on macrominerals in leaf. A and B (Nitrogen); C and D (Potassium); E and F (Phosphorus); G and H (Calcium); I and J (Magnesium); Si=Silicon (0, 10, 20 mL L^{-1}); SH=humic substances (0, 10, 20 kg ha^{-1}); I=Induran; SV=SV2516. Different letters indicate significant differences between treatments, according to Duncan ($p \leq 0.05$), n=9 ± standard error.

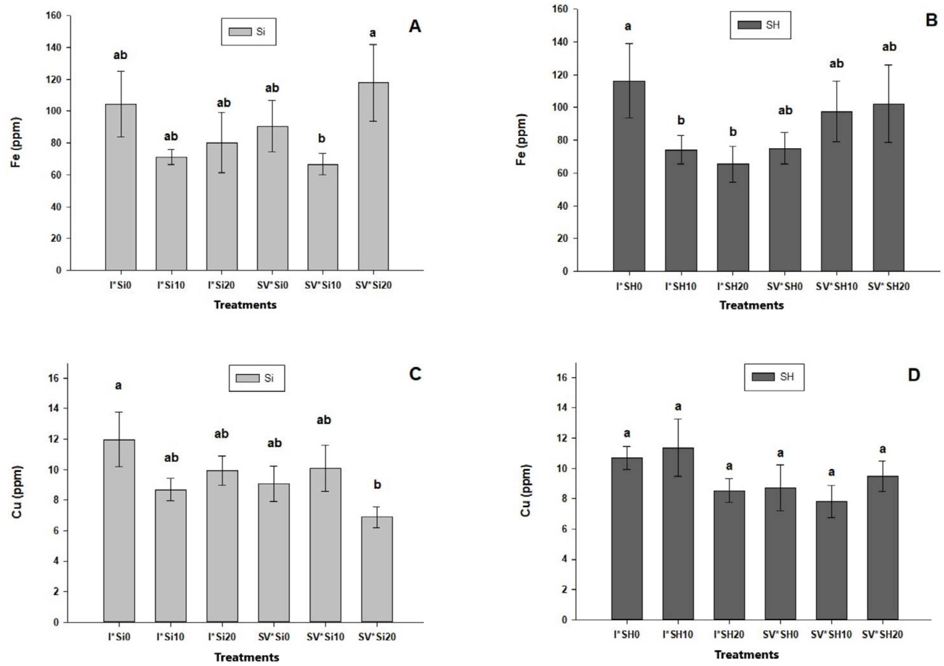

Figure 4. Tests of means on microminerals in fruit. A and B (Iron); C and D (Copper); Si=Silicon (0, 10, 20 mL L^{-1}); SH=humic substances (0, 10, 20 kg ha^{-1}); I=Induran; SV=SV2516. Different letters indicate significant differences between treatments, according to Duncan ($p \leq 0.05$), n=9 ± standard error.

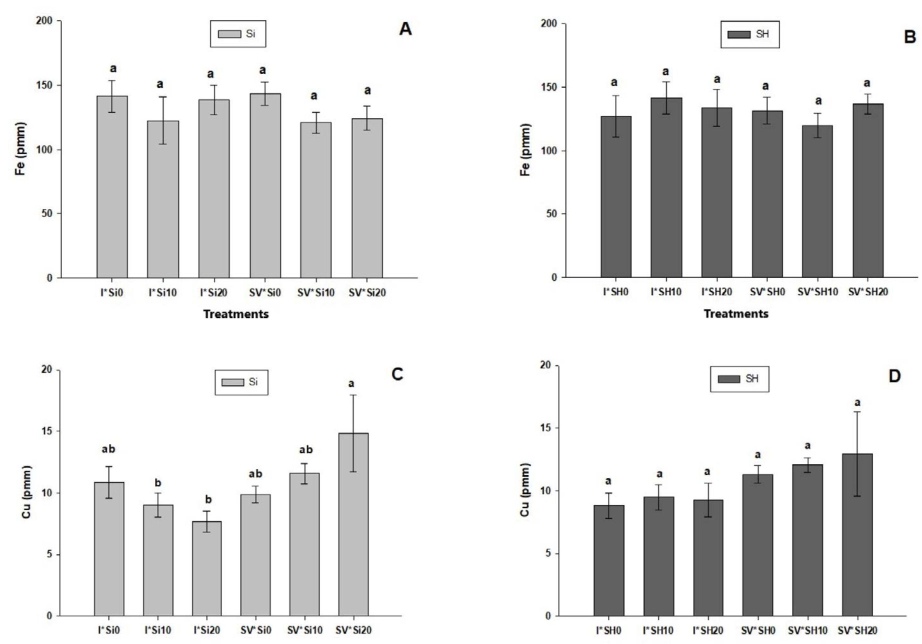

Figure 5. Tests of means on microminerals in leaf. A and B (Iron); C and D (Copper); Si=Silicon (0, 10, 20 mL L^{-1}); SH=humic substances (0, 10, 20 kg ha^{-1}); I=Induran; SV=SV2516. Different letters indicate significant differences between treatments, according to Duncan ($p \leq 0.05$), n=9 ± standard error.

higher than SV*SH10, which registered a value of 7.8 ppm (Figure D). The SV*Si20 interaction recorded the highest Cu content in leaves (Figure 5C). Cu absorption rates in alkaline soils are low. This is a consequence of the production of insoluble Cu complexes through the sequestration of oxides and hydroxides. An alternative to the low Cu activity in the soil is the use of SH to release carboxylic acid and favor its absorption (Turhan and Kuşçu, 2020). Protein hydrolysates (polypeptides, oligopeptides, and amino acids) and the components of SH have an impact on plant nutrition through the formation of complexes and chelates between peptides/amino acids and soil micronutrients (*i.e.*, Cu, Fe, Mn, and Zn). Consequently, they contribute to the availability of nutrients and its acquisition by the root system (De Pascale *et al.*, 2017).

CONCLUSIONS

The use of silicon and humic substances in different doses —along with the interaction of commercially available cucumber cultivars with improved resistance to different types of abiotic stress— can increase the productivity, quality, and absorption of nutrients and improve agronomic traits such as NFP, FW, FD, FL, and Y. Regarding mineral assimilation, it favors N, P, K, Ca, Fe, and Cu content and the N, P, K and, Cu content in the fruit and the leaves, respectively. Further research that involves various sources of silicon and humic substances, as well as their application techniques, their quantity, and their frequencies in cucumber cultivars is required to increase the mitigation of the stress caused by abiotic factors in regions of economic interest.

REFERENCES

Abd Elkareem, N. S., Moursy, M. A. M., Mostafa, M. M., & Elbably, W. Applying (2017). Deficit Irrigation and Natural Fertilization for Cucumber Yield Enhancement under Greenhouse.

Acosta-Motos, J. R., Ortuño, M. F., Bernal-Vicente, A., Diaz-Vivancos, P., Sanchez-Blanco, M. J., & Hernandez, J. A. (2017). Plant responses to salt stress: adaptive mechanisms. *Agronomy, 7*(1), 18.

Albrecht, U. (2019). [HS1330] Plant Biostimulants: Definition and Overview of Categories and Effects. *EDIS*, 2019(3).

Al-madhagi, I. (2019). Effect of humic acid and yeast on the yield of greenhouse cucumber. *Journal of Horticulture and Postharvest Research, 2*(1), 67-82.

Ameta, K. D., Sharma, S. K., Dubey, R. B., & Kaushik, R. A. (2017). Effect of Humic Acid and Micro Nutrients on Growth and Yield of Poly House Grown Cucumber (*Cucumis sativus* L.). Chemical Science Review and Letters.

Benyamin Esho, K., & Saeed, S. H. (2017). Effect of humic acid on growth and yield of three cultivars of summer squash (*Cucurbita pepo* L.). *Egypt. J. Exp. Biol. (Bot.), 13*(2), 167-171.

Bityutskii, N., Pavlovic, J., Yakkonen, K., Maksimović, V., & Nikolic, M. (2014). Contrasting effect of silicon on iron, zinc and manganese status and accumulation of metal-mobilizing compounds in micronutrient-deficient cucumber. *Plant physiology and Biochemistry*, 74, 205-211.

De Pascale, S., Rouphael, Y., & Colla, G. (2017). Plant biostimulants: innovative tool for enhancing plant nutrition in organic farming. *Eur. J. Hortic. Sci, 82*(6), 277-285.

Du Jardin, P. (2015). Plant biostimulants: definition, concept, main categories and regulation. *Scientia Horticulturae*, 196, 3-14.

Ekinci, M., ESRİNGÜ, A., Dursun, A., Yildirim, E., Turan, M., KARAMAN, M. R., & Arjumend, T. (2015). Growth, yield, and calcium and boron uptake of tomato (*Lycopersicon esculentum* L.) and cucumber (*Cucumis sativus* L.) asaffected by calcium and boron humate application in greenhouse conditions. *Turkish Journal of Agriculture and Forestry, 39*(5), 613-632.

El-Nemr, M. A., El-Desuki, M., El-Bassiony, A. M., & Fawzy, Z. F. (2012). Response of growth and yield of cucumber plants (*Cucumis sativus* L.) to different foliar applications of humic acid and bio-stimulators. *Australian Journal of Basic and Applied Sciences, 6*(3), 630-637.

FAOSTAT. (2017). Food and Agriculture Organization of the United Nations. Disponible en http://www.fao.org/faostat/en/#data/QC.2017. [Consulta: 20 de marzo de 2019].

Khaled, H., & Fawy, H. A. (2011). Effect of different levels of humic acids on the nutrient content, plant growth, and soil properties under conditions of salinity. *Soil and Water Research, 6*(1), 21-29.

Kumar, K., Amaresan, N., & Madhuri, K. (2017). Alleviation of the adverse effect of salinity stress by inoculation of plant growth promoting rhizobacteria isolated from hot humid tropical climate. *Ecological Engineering*, 102, 361-366.

Li, H., Zhu, Y., Hu, Y., Han, W., & Gong, H. (2015). Beneficial effects of silicon in alleviating salinity stress of tomato seedlings grown under sand culture. *Acta physiologiae plantarum, 37*(4), 71.

López-Elías, J., Ortega, S. G., López, M. A. H., León, J. J., Puente, E. O. R., & Amador, B. M. (2015). Producción de pepino (Cucumis sativus L.) en función de la densidad de plantación en condiciones de invernadero. *European Scientific Journal, 11*(24).

Mckean, S. J. (1993). Manual de análisis de suelos y tejido vegetal: una guía teórica y práctica de metodologías. Ciat.

Ouni, Y., Ghnaya, T., Montemurro, F., Abdelly, C., & Lakhdar, A. (2014). The role of humic substances in mitigating the harmful effects of soil salinity and improve plant productivity. *International Journal of Plant Production, 8*(3), 353-374.

Pavlovic, J., Samardzic, J., Maksimović, V., Timotijevic, G., Stevic, N., Laursen, K. H., & Nikolic, M. (2013). Silicon alleviates iron deficiency in cucumber by promoting mobilization of iron in the root apoplast. *New Phytologist, 198*(4), 1096-1107.

Shehata, S. A., Hassan, H. A., Tawfik, A. A., & Farag, M. F. (2016). Improving the productivity and quality of the cucumber crop grown under greenhouse conditions using some stimulants and spraying amino acids. *Journal of Plant Production, 7*(4), 385-392.

Singh, M. C., Singh, J. P., Pandey, S. K., Mahay, D., & Srivastava, V. (2017). Factors Affecting the Performance of Greenhouse Cucumber Cultivation: A Review. *Int. J. Curr. Microbiol. App. Sci, 6*(10), 2304-2323.

Steiner, G. A. (1969). Top management planning.

Terán Ruiz, C. F. (2016). Comparación de los métodos de digestión seca y digestión ácida por microondas para el análisis de fósforo en brócoli y acelga por espectrofotometría ultravioleta-visible (Bachelor's thesis, PUCE).

Tripathi, D. K., Singh, V. P., Gangwar, S., Prasad, S. M., Maurya, J. N., & Chauhan, D. K. (2014). Role of silicon in enrichment of plant nutrients and protection from biotic and abiotic stresses. In Improvement of crops in the era of climatic changes (pp. 39-56). Springer, New York, NY.

Turhan, A., & KUŞÇU, H. (2020). The Influence of Irrigation Water Salinity and Humic Acid on Nutrient Contents of Onion (Allium cepa L.). *Journal of Agricultural Sciences, 26*(2), 147-153.

Williams, T. R. (1972). Analytical methods for atomic absorption spectrophotometry (Perkin-Elmer Corp.).

Yakhin, O. I., Lubyanov, A. A., Yakhin, I. A., & Brown, P. H. (2017). Biostimulants in plant science: a global perspective. *Frontiers in plant science*, 7, 2049.

Yasir, N. F., Seheib, M. W., & Hasan, O. A. K. (2016). Effect of adding different organic fertilizers in the absorption of some of nutrient elements from soil in properties of plant growth and yield of cucumber plant. *Global J. Agric. Res, 4*(6), 13-19.

Zhang, L., Ma, H., Chen, T., Pen, J., Yu, S., & Zhao, X. (2014). Morphological and physiological responses of cotton (*Gossypium hirsutum* L.) plants to salinity. *PLoS One, 9*(11), e112807.