

Mineral Content and Yield of *Cucumis sativus* L. under Substrate Mixtures and Different Salinity Levels of the Nutrient Solution

González-Balcazar, Antonio¹; Angulo-Castro, Azareel¹; Rubio-Aragón, Walter A.²; Elenes-Sánchez, Jesús H.¹; Armenta-Ayala, José O.¹; Cázarez Flores, Luz Ll.¹; Mendoza Medrano, Daniel¹; Castro-Rubio, Heidi M.^{1*}

¹ Universidad Autónoma de Sinaloa. Facultad de Agronomía, Carretera Culiacán-Eldorado km 17.5, Apartado Postal 25. Culiacán, Sinaloa, México, C. P. 80000.

² Universidad Autónoma de Sinaloa. Facultad de Ciencias Económicas, Administrativas y Tecnológicas, Carretera a Angostura Km. 0.5, Colonia Morelos, Guamúchil, Salvador Alvarado, Sinaloa, México. C.P. 81400.

* Correspondence: heidi.castro@uas.edu.mx

ABSTRACT

Objective: To evaluate the effects of Steiner nutrient solution salinity and coconut fiber/compost mixtures on the yield, commercial quality, and mineral content (K^+ , Ca^{2+} , and Mg^{2+}) of leaves and fruits of *Cucumis sativus* L.

Design/methodology/approach: The study was conducted under greenhouse conditions in Culiacán, Sinaloa, using a completely randomized design with a 3×3 factorial arrangement. The evaluated factors were Steiner solution salinity (1.0, 1.5, and 2.0 $mS\ cm^{-1}$) and coconut fiber/compost ratios (100/0, 75/25, and 50/50% v/v). The number of fruits per commercial category and the mineral concentration in foliar tissue and fruits were determined 78 days after transplanting by atomic absorption spectrophotometry.

Results: Increasing electrical conductivity (EC) to 2.0 $mS\ cm^{-1}$ significantly enhanced total yield and the “Super Select” category, with values 40% higher than those recorded at 1.0 $mS\ cm^{-1}$. Fruit mineral nutrition reached its highest levels at 2.0 $mS\ cm^{-1}$, particularly in interaction with 50% compost, which resulted in the greatest concentrations of K, Ca, and Mg. In contrast, foliar Ca and K stabilized at 1.5 $mS\ cm^{-1}$, whereas foliar Mg declined.

Study limitations/implications: The results are specific to the Zeus F1 hybrid and to the climatic conditions of the Culiacán Valley. Findings/conclusions: A Steiner solution at 2.0 $mS\ cm^{-1}$ optimized fruit yield and mineral quality. The combination of coconut fiber with 50% compost and an EC of 2.0 $mS\ cm^{-1}$ is recommended to maximize the commercial competitiveness of cucumber production without compromising nutritional balance.

Keywords: Fruit quality, electrical conductivity, hydroponics.

Citation: González-Balcazar, A., Angulo-Castro, A., Rubio-Aragón, W. A., Elenes-Sánchez, J. H., Armenta-Ayala, J. O., Cázarez-Flores, L. Ll., Mendoza-Medrano, D. & Castro-Rubio, H. M., (2026). Mineral Content and Yield of *Cucumis sativus* L. under Substrate Mixtures and Different Salinity Levels of the Nutrient Solution. *Agro Productividad*. <https://doi.org/10.32854/nbjef88>

Academic Editor: Jorge Cadena Iñiguez

Associate Editor: Dra. Lucero del Mar Ruiz Posadas

Guest Editor: Juan Francisco Aguirre Medina

Received: December 26, 2025.

Accepted: March 17, 2026.

Published on-line: May 25, 2026.

Agro Productividad, 19(3). March. 2026. pp: 19-28.

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0 International license.



INTRODUCTION

Cucumber (*Cucumis sativus* L.) cultivation under protected systems has experienced substantial growth due to the increasing demand for intensive and sustainable production (Abad & Puchades, 2002). In Mexico, the state of Sinaloa ranks as the leading exporter of this vegetable crop, contributing a substantial share of the supply to the United

States market during the autumn-winter production cycle (SADER, 2022). To maintain competitiveness in international markets, it is essential to optimize fruit yield and quality through the study of nutrient solution concentrations and substrate mixtures. In this regard, Sonneveld and Voogt (2009) indicate that electrical conductivity (EC) is the principal variable for regulating the balance between vegetative and reproductive growth. Inadequate concentrations generate either deficiencies or toxicities; low EC limits mineral availability, whereas excessive levels induce osmotic stress, thereby reducing water potential and fruit cell expansion (Adams, 2002; Savvas and Gruda, 2018).

Within this framework of precision nutrition, the use of Steiner's Universal Solution (1984) has been fundamental in intensive horticulture. This formulation is based on the concept of "ionic balance," in which the mutual relationship among anions (NO_3^- , H_2PO_4^- , SO_4^{2-}) and cations (K^+ , Ca^{2+} , and Mg^{2+}) remains constant regardless of the total solution concentration. Steiner proposed that the effectiveness of a nutrient solution lies not only in the quantity of nutrients supplied, but also in their balanced proportion, which enables the plant to absorb elements according to its physiological demand without generating excessive antagonisms in the rhizosphere. Nevertheless, the performance of this solution may be conditioned by the applied EC and the type of substrate used. Several studies indicate that, although Steiner proportions are considered optimal, total ionic strength must be adjusted to compensate for the potential adsorption of nutrients by active organic substrates such as compost (Hartz *et al.*, 1996). The substrate plays a crucial role in physical support, root aeration, and the dynamics of water and solute retention (Raviv *et al.*, 2002). Coconut fiber, owing to its high porosity and physical stability, promotes vigorous root development and minimizes the incidence of pathogens (Abad *et al.*, 2005). However, the incorporation of compost has emerged as a valuable strategy to enhance the biological and chemical fertility of the growing medium by providing gradually released nutrients and stimulating beneficial microbial activity (Hartz *et al.*, 1996; Lazcano and Domínguez, 2011). The cations K^+ , Ca^{2+} , and Mg^{2+} are critical within this balance: potassium regulates turgor and fruit filling, calcium is essential for cell wall integrity, and magnesium, as the central atom of chlorophyll, is indispensable for carbon fixation (Marschner, 2012; Barker and Pilbeam, 2015). Evaluating the interaction between different Steiner solution levels and coconut fiber/compost mixtures is essential to determine whether ionic balance remains efficient under the climatic and management conditions of the Culiacán Valley. Therefore, the aim of this study was to evaluate the impact of three nutrient solution concentrations and three substrate ratios on the growth, yield, and mineral profile of slicer-type cucumber under greenhouse conditions.

MATERIALS AND METHODS

The present study was conducted under greenhouse conditions at the experimental field of the Faculty of Agronomy of the Autonomous University of Sinaloa, located at kilometer 17.5 of the Culiacán-Mazatlán highway. Slicer-type cucumber cv. Zeus F1 (Fitó[®], Mexico), characterized by indeterminate growth, was used in the experiment. Two-colored plastic bags with a volume of 15 L were placed at a spacing of 1.8 m between rows and 40 cm between bags, and were mounted on a plastic structure to allow nutrient

solution drainage. The substrate consisted of coconut fiber (coconut chips and natural coconut mix 70/30, COCOMIX[®]) combined with compost (compost produced from 100% natural feedlot cattle manure) according to each corresponding treatment. The irrigation system consisted of half-horsepower pumps, and water was conveyed through 16-mm plastic tubing. Water application was carried out two stakes inserted into the substrate, connected to a dripper with a discharge rate of 2 L h⁻¹ by means of microtubing. One cucumber plant was established per container, trained vertically with raffia to a single stem, and supplied with the nutrient solution corresponding to each treatment. Crop nutrition was provided through Steiner's Universal Solution (1984), with concentrations adjusted to obtain the three salinity levels evaluated (1.0 mS cm⁻¹, 1.5 mS cm⁻¹, and 2.0 mS cm⁻¹), while maintaining constant ionic relationships in accordance with the original formulation.

Nine treatments were evaluated (Table 1), resulting from the combination of three salinity levels of Steiner solution (1.0 mS cm⁻¹, 1.5 mS cm⁻¹, and 2.0 mS cm⁻¹) and three coconut fiber/compost ratios: 100/0, 75/25, and 50/50 (volume/volume).

The experimental design was a completely randomized design with a 3×3 factorial arrangement and six replicates, each replicate consisting of one plant. Factor 1 was nutrient solution salinity (EC, mS cm⁻¹), and Factor 2 was the coconut fiber/compost ratio (% v/v). Six irrigation pulses were applied daily to the substrate from 08:00 to 16:00 h; the volume of water applied per pot was calculated based on the drainage percentage. Fruits were harvested and evaluated by size, and the number of fruits per plant and fruit length (cm) were recorded. Fruits were classified according to export standards as follows: Small (15.24 to 17.78 cm), Select (17.78 to 20.32 cm), Super Select (20.32 to 22.86 cm), and Large (22.86 to 25.40 cm).

Nutrient variables

The mineral composition (K, Ca, and Mg) of cucumber leaves and fruits was evaluated 78 days after transplanting. Leaves and fruits were dried in a forced-air oven (9053L, Ecoshel, USA) at 70 °C for 72 h. Subsequently, the samples were ground in an electric mill (MOGRA1, Surtek, Mexico). The resulting material was subjected to dry digestion in a

Table 1. Description of the treatments considered in the experiment.

Treatment	Nutrient solution salinity (EC mS cm ⁻¹)	Coconut fiber/compost ratio (% v/v)
1	1.0	100/0
2	1.0	75/25
3	1.0	50/50
4	1.5	100/0
5	1.5	75/25
6	1.5	50/50
7	2.0	100/0
8	2.0	75/25
9	2.0	50/50

muffle furnace (DTT 434, Caisa, Mexico) at 550 °C for 5 h. Two milliliters of hydrochloric acid were added to the extract, and the mixture was heated until the liquid evaporated. Distilled water was then added, and the solution was filtered through filter paper. The filtrate was diluted to 100 mL in a volumetric flask.

These filtrates were used to determine potassium (K), calcium (Ca), and magnesium (Mg) concentrations by atomic absorption spectrophotometry (AAAnalyst 200, PerkinElmer, USA), following the methodology described by Rodríguez and Rodríguez (2015). Analysis of variance for the studied variables was performed by evaluating the main factors of the factorial design, namely nutrient solution concentration (EC, mS cm^{-1}) and coconut fiber/compost ratio (% v/v), as well as their interaction. Prior to the analysis, data normality was verified using the Shapiro-Wilk test, and homogeneity of variances was also assessed. Mean comparisons were performed using Tukey's test ($\alpha=0.05$). Statistical analyses were conducted using SAS (Statistical Analysis System, 2002).

RESULTS AND DISCUSSION

The total number of fruits per plant showed a positive response as nutrient solution salinity increased to 2.0 mS cm^{-1} . Plants treated with the Steiner solution at 2.0 mS cm^{-1} produced a statistically higher number of fruits than those treated with the 1.0 mS cm^{-1} nutrient solution (Table 2). A similar response was observed in the number of fruits classified as Super Select, with a significant increase of 40% in plants supplied with the 2.0 mS cm^{-1} nutrient solution compared with those receiving the 1.0 mS cm^{-1} treatment (Table 2). The number of fruits classified as Select was significantly higher when the 1.0 mS cm^{-1} nutrient solution was applied compared with plants treated with the 1.5 mS cm^{-1} solution (Table 2).

The coconut fiber/compost ratio factor did not exert a statistically significant effect on the number of fruits by size category. However, the 75/25 mixture showed a tendency to produce a slightly higher total number of fruits, suggesting that the moderate incorporation of compost may improve the physical and chemical properties of the substrate by increasing moisture retention and nutrient availability (Abad *et al.*, 2005).

It was observed that increasing EC reduced fruit production in the "Select" category, while increasing production in the "Super Select" category. This finding is consistent with previous studies indicating that higher EC enhances fruit quality by favoring larger fruit sizes, although it may reduce the number of medium-sized fruits (Sonneveld and Voogt, 2009). Although the increase in EC did not significantly affect the production of large fruits, it did show a positive trend in total fruit production. This result is in agreement with previous reports indicating that a moderately high EC (2.0 mS cm^{-1}) can improve the yield of horticultural crops without adversely affecting fruit quality (Sonneveld and Voogt, 2009). The greater nutrient availability at higher EC levels may have promoted increased flowering and fruit set, as noted by Savvas and Gruda (2018), who reported significant improvements in yield and fruit quality in vegetable crops such as tomato and cucumber through the precise control of EC in soilless cultivation systems. The interaction analysis revealed statistically significant differences in the Select size category and in total fruit number. Regarding overall yield, treatment $2.0 \times 50/50$ achieved the

Table 2. Effect of nutrient solution salinity levels and coconut fiber/compost ratio on cucumber fruit size and number.

Factor	Small	Select	Siper Select	Big	Total
	Number of fruits				
Salinity levels (EC mS cm ⁻¹)					
1.0	0.38 a	1.22 a	1.83 b	4.88 a	8.33 b
1.5	0.55 a	0.38 b	2.16 ab	6.11 a	9.22 ab
2.0	0.16 a	0.72 ab	3.05 a	5.61 a	9.55 a
Coconut fiber/compost ratio (% v/v)					
100/0	0.38 a	0.88 a	2.44 a	5.27 a	9.00 a
75/25	0.50 a	0.72 a	2.16 a	5.83 a	9.22 a
50/50	0.22 a	0.72 a	2.44 a	5.50 a	8.88 a
Interaction (C.E mS cm ⁻¹ × % v/v)					
1.0 × 100/0	0.66 a	0.66 abc	2.00 a	5.33 a	8.66 ab
1.0 × 75/25	0.50 a	1.33 ab	1.50 a	5.66 a	9.00 ab
1.0 × 50/50	0.00 a	1.66 a	2.00 a	3.66 a	7.33 b
1.5 × 100/0	0.50 a	0.50 abc	2.16 a	5.66 a	8.83 ab
1.5 × 75/25	0.50 a	0.66 abc	2.50 a	6.33 a	10.00 ab
1.5 × 50/50	0.66 a	0.00 c	1.83 a	6.33 a	8.83 ab
2.0 × 100/0	0.00 a	1.50 a	3.16 a	4.83 a	9.50 ab
2.0 × 75/25	0.05 a	0.16 bc	2.50 a	5.50 a	8.66 ab
2.0 × 50/50	0.00 a	0.50 abc	3.50 a	6.50 a	10.50 a

Small (15.24 to 17.78 cm), Select (17.78 to 20.32 cm), Super Select (20.32 to 22.86 cm), and Large (22.86 to 25.40 cm). Means followed by different letters within the same column indicate statistically significant differences (Tukey, $p \leq 0.05$).

highest productivity. This value represented a 43.2% increase compared with treatment 1.0×50/50, which recorded the lowest performance and was the only treatment to show a statistically significant reduction in total production. In the Select category, the interaction also generated critical differences. Treatment 1.0×50/50 produced the highest number of fruits within this grade. In contrast, treatment 1.5×50/50 showed a complete absence of fruits in this range, marking an absolute statistical difference. Under an EC of 2.0 mS cm⁻¹, an 89.3% reduction in this grade was observed when the substrate changed from pure coconut fiber to the 75/25 mixture. No significant differences were detected for this interaction in the Small, Super Select, and Large categories. The superior response of treatment 2.0×50/50 suggests that soilless cultivation technologies should adjust nutrient solution concentration according to the physical and chemical properties of the substrate in order to maximize yield (Savvas and Gruda, 2018). According to Sonneveld and Voogt (2009), nutrient solution concentration must be tailored to substrate physical properties to prevent ion depletion in the root zone.

The decline in yield observed in treatment 1.0×50/50 indicates that a low EC is insufficient to compensate for potential ion retention or leaching in mixtures containing a

higher proportion of alternative material. Marschner (2012) states that nutrient availability is the main limiting factor during the cell expansion and organ-filling stages, which is consistent with the appearance of statistical differences only in the larger fruit categories (Large). On the other hand, the statistical similarity between the 1.5 and 2.0 mS cm⁻¹ treatments across most substrate proportions reflects a mechanism of ionic adaptation. As indicated by Urrestarazu (2013), once an optimal conductivity threshold is reached, additional increases do not always translate into a proportional rise in biomass due to the saturation of membrane transporters in the roots. In this study, the 1.5 to 2.0 mS cm⁻¹ range proved adequate for maximizing the production of Select- and Large-grade fruits.

The mineral nutrition analysis revealed that increasing the electrical conductivity of the nutrient solution progressively promoted cation accumulation in the fruit. The 2.0 mS cm⁻¹ level ranked as the highest treatment, showing a statistically significant difference compared with the lower doses, particularly in potassium (K) concentration, where the most pronounced quantitative increase of the entire experiment was observed (Table 3). With regard to calcium (Ca) and magnesium (Mg), both elements reached their highest concentrations under the 2.0 mS cm⁻¹ treatment, establishing a statistically significant difference relative to the 1.0 and 1.5 mS cm⁻¹ levels.

Regarding the physical support, the use of pure coconut fiber (100/0) enabled greater calcium (Ca), potassium (K), and magnesium (Mg) uptake compared with the mixtures

Table 3. Effect of nutrient solution salinity and coconut fiber/compost ratio on Ca, K and Mg content in cucumber fruits.

Factor	Ca	K	Mg
	%		
Nutrient solution salinity (EC mS cm ⁻¹)			
1.0	0.75 b	2.97 b	0.21 b
1.5	0.71 c	2.80 c	0.19 c
2.0	0.85 a	4.71 a	0.23 a
Coconut fiber/compost ratio (% v/v)			
100/0	0.84 a	3.89 a	0.23 a
75/25	0.69 c	3.21 c	0.19 c
50/50	0.77 b	3.37 b	0.22 b
Interaction C.E × % v/v			
1.0 × 100/0	0.93 b	3.40 e	0.25 b
1.0 × 75/25	0.74 e	3.24 f	0.20 e
1.0 × 50/50	0.57 i	2.26 i	0.19 g
1.5 × 100/0	0.80 c	3.59 d	0.21 d
1.5 × 75/25	0.63 h	2.27 h	0.17 i
1.5 × 50/50	0.70 g	2.53 g	0.20 f
2.0 × 100/0	0.79 d	4.69 b	0.22 c
2.0 × 75/25	0.72 f	4.12 c	0.19 h
2.0 × 50/50	1.03 a	5.31 a	0.27 a

Means with different letters in the same column show statistical difference (Tukey, $p \leq 0.05$).

containing compost. Notably, the 75/25 mixture led to a significant decline in fruit mineral quality, differing negatively from both the pure coconut fiber substrate and the 50/50 mixture. This finding suggests a discontinuity in ionic availability when low proportions of organic material are incorporated. The interaction between factors produced statistically significant differences across all minerals and treatments, demonstrating that mineral uptake depends not on a single factor, but rather on their combined effect.

Treatment 2.0×50/50 emerged as the most efficient combination, reaching the maximum accumulation levels for the three evaluated elements. In contrast, treatment 1.0×50/50 represented the point of greatest mineral deficiency, particularly for calcium and potassium. This divergence confirms that, in substrates containing a high proportion of compost (50%), the nutritional performance of the fruit is highly sensitive to nutrient solution concentration, exhibiting an exponential ionic response as salinity increases. The statistical superiority observed at 2.0 mS cm⁻¹ can be attributed to the greater availability of solutes in the rhizosphere. Sonneveld and Voogt (2009) argue that nutrient uptake in hydroponic systems is optimized when the osmotic pressure of the solution facilitates mass flow toward the root. In the present study, the marked increase in potassium under the highest EC treatment is consistent with the findings of Fageria (2001), who identified K as a key driver of cell turgor and the transport of photoassimilates toward the fruit. The interaction analysis revealed that calcium was the element most strongly affected by the combination of factors. The reduction in Ca under treatment 1.0×50/50 suggests a retention phenomenon associated with organic matter. According to Abad *et al.* (2002), compost possesses a high cation exchange capacity (CEC), which may act as a cation sink when the nutrient solution is dilute (1.0 mS cm⁻¹). However, when these exchange sites are saturated at an EC of 2.0 mS cm⁻¹, calcium remains available in the circulating solution, thereby allowing its translocation to the fruit. Mengel and Kirkby (2001) confirm that Ca mobility depends strictly on water flow, which in this study was enhanced under balanced nutritional conditions. Although magnesium showed statistically significant differences, its variability was lower, indicating greater metabolic stability in cucumber. Nevertheless, the reduction observed in the 75/25 mixture may indicate an imbalance in the K/Mg ratio within the root zone. Barker and Pilbeam (2015) warn that an excess of potassium may suppress magnesium uptake; however, under the 2.0×50/50 interaction, a balance was achieved that maximized both elements, suggesting that 50% compost acts as an efficient chemical buffer when fertilization is high. With regard to mineral content in cucumber leaves, the analysis of salinity levels revealed a pattern distinct from that observed in the fruits. The 1.5 mS cm⁻¹ level promoted the greatest foliar accumulation of calcium and potassium, establishing a statistically significant difference relative to the lower level (1.0) (Table 4). However, increasing EC to 2.0 mS cm⁻¹ did not produce a further increase; instead, the values tended to stabilize or decline slightly, remaining within ranges of statistical similarity to the other levels.

In the case of magnesium (Mg), an inversely proportional response to salinity was observed. The 1.0 mS cm⁻¹ level produced the highest foliar concentration, differing significantly from the higher levels, which caused a marked decline in the accumulation of this mineral in the vegetative tissue.

Table 4. Effect of nutrient solution salinity and coconut fiber/compost ratio on Ca, K and Mg content in cucumber leaves.

Factor	Ca	K	Mg
	%		
Nutrient solution salinity (EC mS cm ⁻¹)			
1.0	8.89 b	2.19 b	0.83 a
1.5	9.70 a	2.49 a	0.58 b
2.0	9.39 ab	2.28 ab	0.57 c
Coconut fiber/compost ratio (% v/v)			
100/0	9.36 a	2.41 a	0.69 a
75/25	9.19 a	2.33 a	0.65 c
50/50	9.44 a	2.23 a	0.65 b
Interaction C.E × % v/v			
1.0 × 100/0	8.76 a	2.18 ab	0.85 b
1.0 × 75/25	8.51 a	2.13 ab	0.78 c
1.0 × 50/50	9.41 a	2.28 ab	0.87 a
1.5 × 100/0	9.88 a	2.58 a	0.62 d
1.5 × 75/25	9.71 a	2.57 a	0.59 f
1.5 × 50/50	9.51 a	2.31 ab	0.54 i
2.0 × 100/0	9.43 a	2.46 ab	0.61 e
2.0 × 75/25	9.34 a	2.30 ab	0.57 g
2.0 × 50/50	9.40 a	2.08 b	0.55 h

Means with different letters in the same column show statistical difference (Tukey, $p \leq 0.05$).

With respect to the substrate, no statistically significant differences were detected in calcium and potassium content. However, magnesium exhibited particular sensitivity, as pure coconut fiber (100/0) allowed the greatest foliar retention, whereas the mixtures containing compost (75/25 and 50/50) significantly reduced its presence. The interaction showed a heterogeneous response. For calcium and potassium, most combinations remained within statistical homogeneity, except for treatment 2.0×50/50, which presented the lowest foliar potassium value and differed statistically from treatments 1.5×100/0 and 1.5×75/25. In the case of magnesium, all treatments showed statistically significant differences from one another. Treatment 1.0×50/50 achieved the highest foliar accumulation of Mg, whereas treatment 1.5×50/50 recorded the lowest value, revealing a complex fluctuation dependent on nutrient solution concentration in the organic medium. Unlike the fruit, in which the 2.0 mS cm⁻¹ level was superior, in the leaves the 1.5 mS cm⁻¹ level appears to represent the saturation or equilibrium point for Ca and K. According to Sonneveld and Voogt (2009), leaves function as organs of massive calcium accumulation due to their high transpiration rate. The statistical stability observed between 1.5 and 2.0 mS cm⁻¹ suggests that the plant reaches a transport limit toward the aerial part, redirecting excess ions toward the reproductive organs (fruits). This would explain why, in the previous tables, the fruit did show increases at 2.0 mS cm⁻¹. The behavior of magnesium constitutes a classic

example of ionic antagonism. The significant decline in Mg as EC increased from 1.0 to 1.5 mS cm⁻¹ is attributable to direct competition with potassium and calcium for root absorption sites. Marschner (2012) and Fageria (2001) indicate that an excess of K⁺ and Ca²⁺ in the nutrient solution strongly inhibits Mg²⁺ uptake. Since K and Ca increased significantly at the 1.5 level, foliar magnesium was displaced, confirming the need to monitor cation balance in order to prevent chlorosis induced by magnesium deficiency under high fertilization conditions. The absence of significant differences in Ca and K among substrates indicates that the evaluated mixtures provided similar aeration and moisture conditions, which did not restrict transport to the leaves. However, the variability of Mg in the interaction suggests that compost alters the availability of this mineral in a nonlinear manner. Urrestarazu (2013) and Abad *et al.* (2002) mention that composts may release their own magnesium, although its availability is conditioned by pH and by the concentration of the circulating solution. The maximum value obtained in treatment 1.0×50/50 for foliar Mg suggests that, under low salinity, compost provides additional magnesium that the plant is able to translocate efficiently before antagonism with other nutrients occurs.

CONCLUSIONS

Cucumber productivity and mineral content depend on the interaction between nutrient solution salinity and substrate nature. A Steiner solution salinity of 2.0 mS cm⁻¹ maximized total yield and the production of Super Select fruits, surpassing the 1.0 mS cm⁻¹ level by 14.6%. In coconut fiber mixtures containing 50% compost, the use of an EC of 2.0 mS cm⁻¹ proved essential to increase ionic availability in the circulating solution, thereby promoting greater accumulation of Ca, K, and Mg in the fruit compared with lower salinity levels. In contrast to the fruit, foliar tissue reached mineral equilibrium at 1.5 mS cm⁻¹, beyond which ionic antagonism intensified and reduced foliar magnesium concentration. The use of a nutrient solution with a salinity of 2.0 mS cm⁻¹ in substrates composed of coconut fiber mixed with 50% compost is therefore recommended to optimize nutrient translocation toward the reproductive organs and ensure the commercial quality of the crop.

REFERENCES

- Abad, M., & Puchades, R. (Eds.). (2002). *Compostaje de residuos orgánicos generados en la Hoya de Buñol (Valencia) con fines hortícolas*. Asociación para la Promoción Socio-Económica Interior Hoya de Buñol.
- Abad, M., Fornes, F., Carrión, C., & Noguera, V. (2005). Physical properties of various coconut coir dusts compared to peat. *HortScience*, *40*(7), 2138-2144. <https://doi.org/10.21273/HORTSCI.40.7.2138>
- Adams, P. (2002). Nutritional control in hydroponics. En D. Savvas & H. Passam (Eds.), *Hydroponic Production of Vegetables and Ornamentals* (pp. 211-261). Embryo Publications.
- Barker, A. V., & Pilbeam, D. J. (2015). *Handbook of Plant Nutrition* (2nd ed.). CRC Press. <https://doi.org/10.1201/b18458>
- Fageria, N. K. (2001). Nutrient interactions in crop plants. *Journal of Plant Nutrition*, *24*(8), 1269-1290. <https://doi.org/10.1081/PLN-100106981>
- Hartz, T. K., Costa, F. J., & Schrader, W. L. (1996). Compost use in containerized plant production. *HortScience*, *31*(3), 382-385. <https://doi.org/10.21273/HORTSCI.31.3.382>
- Hartz, T. K., Mitchell, J. P., & Giannini, C. (1996). Nitrogen and carbon mineralization dynamics of manures and composts. *HortScience*, *31*(6), 965-968. <https://doi.org/10.21273/HORTSCI.31.6.965>

- Lazcano, C., & Domínguez, J. (2011). The use of vermicompost in horticulture. En A. Karasut (Ed.), *Applied Environmental Biology* (pp. 230-254). Nova Science Publishers.
- Marschner, H. (2012). *Marschner's Mineral Nutrition of Higher Plants* (3rd ed.). Academic Press. <https://doi.org/10.1016/C2009-0-63043-9>
- Mengel, K., & Kirkby, E. A. (2001). *Principles of Plant Nutrition* (5th ed.). Springer Science & Business Media. <https://doi.org/10.1007/978-94-010-0556-2>
- Raviv, M., Lieth, J. H., & Bar-Tal, A. (2002). *Soilless culture: Theory and practice*. Elsevier. <https://doi.org/10.1016/B978-0-444-52975-6.X5000-6>
- Rodríguez, H., & Rodríguez, J. (2015). *Métodos de análisis de suelos y plantas: Criterios de interpretación*. Editorial Trillas.
- SAS Institute Inc. (2002). *SAS/STAT User's guide* (Version 9.4). SAS Institute.
- Savvas, D., & Gruda, N. (2018). Application of soilless culture technologies in the modern greenhouse industry – A review. *European Journal of Horticultural Science*, 83(5), 280-293. <https://doi.org/10.17660/eJHS.2018/83.5.2>
- Secretaría de Agricultura y Desarrollo Rural (SADER). (2022). *Expectativas Agroalimentarias 2022*. Servicio de Información Agroalimentaria y Pesquera.
- Sonneveld, C., & Voogt, W. (2009). *Plant nutrition of greenhouse crops*. Springer. <https://doi.org/10.1007/978-90-481-2532-6>
- Steiner, A. A. (1984). The universal nutrient solution. *Proceedings of the 6th International Congress on Soilless Culture* (pp. 633–650). ISOSC.
- Urrestarazu, M. (2013). *Manual de cultivo sin suelo*. Mundi-Prensa Libros.