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SHORT COMMUNICATION

Organic nutrient solutions in production and antioxidant capacity of cucumber fruits

Guadalupe Santiago-López[1], Pablo Preciado-Rangel[1]*, Esteban Sánchez-Chavez[2], Juan Ramón Esparza-Rivera[3], Manuel Fortis-Hernández[1], Alejandro Moreno-Reséndez[4]

[1]División de Estudios de Posgrado e Investigación, Instituto Tecnológico de Torreón, Carretera Torreón-San Pedro, Torreón, Coahuila, México, [2]Centro de Investigación en Alimentación y Desarrollo, A.C. Unidad Delicias, Delicias, Chihuahua, México, [3]Facultad de Ciencias Químicas Unidad Gómez Palacio, Universidad Juárez del Estado, de Durango, Gómez Palacio, Durango, México, [4]Universidad Autónoma Agraria Antonio Narro, Unidad Laguna. Torreón, Coahuila. México

ABSTRACT

The aim of the current study was to evaluate the effect of organic nutrient solutions over yield, quality and antioxidant capacity of hydroponic cucumber (*Cucumis sativus* L.) fruits produced under greenhouse conditions. The organic solutions used were compost and vermicompost teas, and the Steiner nutrient solution was used as control. Evaluated variables were: yield, quality, and antioxidant capacity of cucumber fruits. Nutritive solutions affected yield and antioxidant capacity of the produce. Steiner solution obtained a higher yield (41.8 - 44.4%) than organic nutritive solutions; however organic cucumber samples had higher antioxidant capacity. Compost tea treatment obtained the highest antioxidant capacity among all treatments, resulting 42% higher than inorganically fertilized produce. Compost tea is a viable alternative as a nutrient source in the production of hydroponic cucumber under greenhouse conditions with an improved nutraceutical quality.

Keywords: *Cucumis sativus* L.; Antioxidant capacity; Yield; Organic fertilization

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a horticultural produce with a high demand world widely (Eifediyi and Remison, 2010). In México 10% of the total greenhouse area cultivated is dedicated to this crop (González, 2009); therefore, the producers are searching for new production systems that increase yield and produce quality. Protected agriculture, like greenhouse conditions, and hydroponics are agricultural systems that have resulted effective for obtaining yield increases and better produce quality (Preciado et al., 2011). However; it is known that such production systems require a large agrochemical agent's supply, especially regarding nitrogen fertilizers, which generally are expensive (Mohammadi and Omid, 2010) and can cause environmental pollution. On the other side consumers prefer fresh vegetable produce with high antioxidant compounds content (Wang 2006), since those bioactive compounds reduce the risk of chronic degenerative diseases (Llacuna and Mach 2012). Hence, the organic production of vegetables is a feasible alternative to obtain free-chemically agents produce with a high antioxidant capacity, which is an indicator of the nutraceutical value of fruits and vegetables (Singh et al., 2012). Another advantage of the organic production of vegetables is the possible use of non-synthetic materials such as manure, compost and vermicompost, as well as their liquid extracts like teas, as nutritional sources, substituting the application of inorganically formulated fertilizers. These organic fertilizer solutions contain a high amount of mineral nutrients, beneficial microorganisms (Edwards et al., 2010), and growth promoting agents such as humic and fulvic acids (Arancon et al., 2007). Besides, compost and vermicompost teas) have been used as nutrient source in several hydroponic crops (Márquez et al., 2013; Preciado et al., 2014), in addition that can be applied using pressurized irrigation under protected agricultural conditions as in a greenhouse (Shrestha et al., 2012). Moreover, the production costs of organic nutritive solutions are lower compared to those of traditional inorganic fertilizer solutions (Wrzodak et al., 2012).

***Corresponding author:**
Pablo Preciado-Rangel, División de Estudios de Posgrado e Investigación, Instituto Tecnológico de Torreón, Carretera Torreón-San Pedro km 7.5, Torreón, Coahuila. México. E-mail: ppreciador@yahoo.com.mx

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MATERIALS AND METHODS

Plant material vegetal and growth conditions

The study was performed in an automatic greenhouse tunnel type covered with plastic, with an area of 144 m^2, located in the Instituto Tecnológico de Torreón in Torreón, Coahuila (México) between 24°30' y 27°N, and between 102°00' y 104°40'W, at an altitude of 1120 masl. Fresh type cucumber cultivar Luxell (Nunhems®) was produced under greenhouse conditions. Cucumber plants were transplanted when seedlings were 15-20 cm high and had 2- real leaves, they were placed in 20 L black plastic bags as pots which contained river sand and vermiculite (80:20) as a hydroponic substrate (one seedling per pot). River sand was previously washed and sanitized using a 5% sodium hypochloride solution. Pots were then sorted in a single line separated 0.4 m between planta and 1.4 m between rows. Polinization was performed manually every day at 12:00-14:00, from flowering start to fruit development. Plants were pruned to one single stem attached whit string to the greenhouse frame, while fruits were placed in plastic mesh pockets tied to the support structure. A drip irrigation system was used to irrigate the plants by spraying three times per day, with a volume of 0.500 L pot^{-1} day^{-1} from transplant to flowering, and 1.0 L pot^{-1} day^{-1} from flowering to harvest. During the growth period, all axillary vegetative buds were removed from the main stem, and periodically the stem was attached to the twine with plastic plant clips.

Experimental design and treatments

The treatments were established in a completely randomized experimental design using 15 plants per treatment, being each plant a treatment replicate. The applied fertilization treatments consisted of an inorganic nutrient solution (Steiner, 1984); and compost tea and vermicompost tea, according to Edwards et al. (2010). Inorganic nutrient solution (Steiner, 1984) was prepared using highly soluble commercial fertilizers. Organic nutrient solutions were adjusted with citric acid to a pH of 5.5 (Capulín-Grande et al., 2007), and electrical conductivity (EC) of 2.0 dS m^{-1} by diluting with tap water to avoid phytotoxicity (Preciado et al., 2011) (Table 1). Tap water used to prepare the organic solutions had a CE: 0.49, pH; 6.97; cations (me L^{-1}): Ca^{2+} 3.63, Mg^{2+} 0.15, K^+ 0.02, Na^+ 1.64; anions (me L^{-1}) HCO_3^- 1.55, Cl^- 2.09 y SO_4^{2-} 1.02, which is classified as C2S1 (Ayers and Westcot, 1994).

Table 1: Chemical composition of the nutrient solutions applied in production of hydroponic cucumber in greenhouse

Nutrient	Steiner solution	Compost tea	Vermicompost tea
N	168.0	32.0	21.0
P	31.0	16.0	9.0
K	273.0	110.4	238.3
Ca	180.0	62.2	168.8
Mg	48.0	4.6	6.0
Na	37.7*	175.6	163.7
Cl	74.2*	419.0	663.4

*Contained in water used for solution preparation

Analytical tests

The evaluated variables were yield (total product weight per plant), produce quality parameters (product weight, length and diameter), and antioxidant capacity ($ABTS^+$ method) of cucumber. Quality parameters were determined using 10 fruits per treatment.

Determination of antioxidant capacity

Extract preparation

A sample of 5 g (fresh cucumber pulp) was mixed with 10 mL of methanol in a screw cap plastic tube, which were placed in a shaker (ATR Inc., EEUU) for 6 hours (20 rpm) at 5 °C. The tubes were then centrifuged at 3000 rpm for 10 min, and the supernatant was extracted for analytical tests.

Antioxidant capacity equivalent in Trolox (DPPH+ method).

The antioxidant capacity equivalent in Trolox was evaluated using a modification of the method published by Brand-Williams et al. (1995). A $DPPH^+$ methanolic solution was prepared, adjusting the absorbance of the solution at 1.100 ± 0.010 at a wavelength of 515 nm. The antioxidant capacity test was run by mixing 50 μl of sample extract and 0.950 ml of $DPPH^+$ solution, and reading the mixture absorbance after 3 min of reaction at a wavelength of 515 nm. A standard curve was prepared with Trolox (Aldrich, St. Louis, Missouri, EEUU), and the results were reported in μM equivalent in Trolox per g of fresh weight (μM equiv Trolox g^{-1}m FW).

Statistical analysis

Data of the evaluated variables were analyzed by an analysis of variance, and mean comparisons were conducted using the Tukey test ($P \leq 0.05$).

RESULTS AND DISCUSSION

The nutrient solutions affected yield, quality and antioxidant capacity of cucumber fruits ($P < 0.05$, Table 2), having the cucumbers fertilized with Steiner solution the highest values in yield, weight and fruit size among all treatments. Regarding

Table 2: Commercial quality and antioxidant capacity of hydroponic cucumber fruits produced under different nutrient solutions

Treatments	Yield g plant^{-1}	Weight* g	Length* cm	Diameter* cm	Antioxidant capacity[1]
Steiner solution	2485.4 a[†]	359.3 a	21.9 a	5.2 a	979.4 b[1]
Compost tea	1752.9 b	317.2 b	19.6 b	4.9 b	1391.1 a
Vermicompost tea	1721.7 b	331.8 b	19.5 b	4.9 b	879.9 b

[†]Values followed by different letter in columns are significantly different (Tukey, $P<0.05$). *Results of an unit (entire fruit). [1]Results expressed in μM equivalent in Trolox/100 g FW (fresh weight)

yield, the inorganic fertilization treatment obtained a higher yield (41.8 - 44.4%) than cucumber obtained using organic solutions, which is attributed not only to the nutrient content but also to the adequate ionic balance of the Steiner solution (Preciado et al., 2011). Besides, fruit weight of organically fertilized cucumber was lower in 13.3% (compost tea), and 8.3% (vermicompost tea) compared to fruits produced using Steiner solution. However, all fruits obtained in the experiment had an acceptable commercial quality and were classified as fancy (USDA, 1997).

The lower yield, weight and size of organic produce compared to inorganically produced cucumbers could be attributed to the low nutrient concentration of organic fertilizer solutions (Márquez et al., 2014), as well to the imbalanced nutrient ratio in the compost and vermicompost teas supplied. Low nutrient concentration in organic solutions resulted from the solutions dilution in order to avoid phytotoxicity in plants (Gutiérrez et al., 2008). Moreover, Preciado et al. (2011) and Márquez et al. (2014). reported that not only the low nutrient concentration but also the imbalanced nutrient ratio in the nutrient solutions affect the normal plant growth; thereby regularly result in a lower size and weight of fruits. Hence, in the current study the lower fruit weight and size in cucumbers produced under the organic treatments could have been mostly caused by a nitrogen deficit since it is known that an insufficient nitrogen supply during crop growth and development affects negatively vegetable and fruit yield, size and weight (Sainju et al., 2003; Jasso-Chavarria et al., 2005; Rodriguez et al., 2005).

Nutritional content of vegetable or fruits is affected by multiple factors such as genetics (plant crop and cultivar) (Zhao et al., 2006), and environmental conditions (soil type, climate, irrigation and cultivation practices) (Bourn and Prescott, 2002), including fertilization (organic and conventional) (Lombardi-Boccia et al., 2004). The results obtained in this experiment show that the nutrient solutions affected the antioxidant capacity of hydroponic cucumber ($P < 0.05$). Besides, the compost tea treatment obtained the highest antioxidant capacity in fruit, resulting 42.0% higher in antioxidant capacity than inorganically fertilized fruits (Table 2). Differences among treatments regarding antioxidant capacity of cucumber fruits could be attributed to the low nutritional content in the diluted organic solutions applied (Zhao et al., 2006). Low content of nutrients in the organic solutions could cause nutritional stress in cucumber plants during growth, promoting increases of phenolic compounds production, thereby resulting in a higher antioxidant capacity of organic fruits. Moreover, it has been reported that the production of nitrogen-containing compounds such as amino acids, proteins and alkaloids increases in crops under production systems sufficient in nitrogen supply (Hallmann and Rembiałkowska 2012). Nevertheless, Herms and Mattson (1992) state that plants produce higher amounts of sugars (simple and complex) and secondary metabolites (pigments, vitamins, organic acids, terpenoides and phenolic compounds) when subjected to a deficit of soluble nitrogen supply, which happened in the present study in cucumber plants fertilized with the organic nutrient solutions. Regarding phosphorous and magnesium, the low levels of these nutrients in the organic solutions could have contributed to an increase of antioxidant capacity in fruits (Dixon and Pavia, 1995; Olivos et al., 2012). The antioxidant capacity of organic cucumbers produced was higher than those fertilized using inorganic nutrient solution. These results agree with other researchers who also reported a higher antioxidant capacity and phenolic content in melons (Salandanan et al., 2009), tomatoes (Toor et al., 2006), strawberries (Häkkinen and Törroönen, 2000), and apples (Weibel et al., 2000) grown under organic nutrient supply compared to chemically fertilized fruits. Hence, it is feasible to recommend the application of organic nutrient solutions such as compost tea as fertilizer alternatives for production of hydroponic cucumber with acceptable commercial quality and improved antioxidant capacity.

CONCLUSIONS

The nutrient solutions applied in the current study (compost and vermicompost tea, and inorganic Steiner solution) affected the yield, quality and antioxidant capacity of cucumber. All fruits produced had acceptable commercial quality; however, cucumber produced using organic solutions had higher antioxidant capacity than chemically fertilized produce. It is feasible to recommend the application of compost tea as a fertilizer alternative for production of hydroponic cucumber with a better antioxidant capacity.

Authors contributions

All authors contributed extensively to the work presented in this article. G.S.L and P.P.R.: Designed and performed research, wrote and revised the manuscript. E.S.Ch.: Contributed to the development of experimental part.

J.R.E.R.: Performed chemical analyses and reviewed the manuscript. M.F.H.: Performed statistical analysis and helped in data interpretation and discussion of results. A.M.R.: Revised the manuscript. All authors read and approved the final manuscript.

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