Investigation note

Electrical conductivity of the nutrient solution its effect on the yield and nutraceutical quality of bell pepper

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Abstract

The ionic concentration of the nutrient solution in hydroponic systems influences the yield and quality of the harvested fruits. From this perspective, the objective of this study was to determine the effect of the electrical conductivity (EC) of the nutritive solution (NS) on the yield and content of bioactive compounds in bell pepper fruits. Under a completely randomized experimental design with ten repetitions, pepper plants were irrigated with a NS at different EC (1, 2, 3.2 and 4 dS m^{-1}), yield was determined and biactive compounds were quantified in fruits. The results indicate that an electrical conductivity of 3 or higher improves nutraceutical quality but decreases bell pepper yield. The agronomic management of EC in NS is an alternative to increase the nutraceutical quality and antioxidant capacity of bell pepper fruits developed under hydroponic conditions.

Keywords: *Capsicum annuum* L, nutraceuticals, soilless crops.

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Bell pepper is one of the most widely cultivated vegetable species in the world (De Charlo *et al*., 2012). Mexico is the main supplier of this product to the United States and Canada markets (Diaz *et al*., 2013). The states with the highest production are Sinaloa, Sonora and Guanajuato (SAGARPA, 2016). The interest in the consumption of bell pepper is due, to a great extent, to its content of bioactive compounds, which are a rich source of antioxidants that can vary between genotypes of different color and in the ripe stage as in the full ripening stage (Chávez *et al*., 2015).

These antioxidant phytochemicals can prevent some types of cancer, they also have an effect on the control of cardiovascular diseases, atherosclerosis and positively influence the prevention of the aging process (Selahle *et al*., 2015). The area sown by this crop is continuously increasing and represents 16% of the area sown under protected agriculture conditions in the country, only surpassed by the tomato crop, which is grown in 70% (SAGARPA, 2012).

In these production systems, an important factor in the yield and quality of the crops is the ionic concentration of the NS; expressed as EC (Preciado-Rangel *et al*., 2003). Proper management of NS EC is a crucial point (Trejo-Téllez and Gómez-Merino, 2012), because low values of N cause nutritional deficiencies, mainly N, and high values induce nutrient absorption problems due to their osmotic potential high, which limits ion absorption by the root.

It is also used to improve the content of bioactive compounds in the edible part of the plant (Lam *et al*., 2020), at the expense of a decrease in yield (Moya *et al*., 2017). From this perspective, the objective of this research was to determine the effect of the EC of NS on the nutraceutical properties of the fruit without reducing the yield.

Plant material and growing conditions

The experiment was developed in a semi-automatic, circular greenhouse, covered with a layer of plastic polyethylene and a semi-automatic cooling system, located at the Technological Institute of Torreón, Torreón, Coahuila, Mexico (24° 30’ and 27° north latitude, 102° 00’ and 104° 40’ west longitude and 1 120 masl). Seedlings of bell pepper (*Capsicum annuum* L), with four true leaves and a height between 15-20 cm (one seedling per pot), were placed in 20 L black plastic bags, like pots, with river sand and vermiculite (80:20), as a substrate. The river sand was washed and disinfected with a 5% sodium hypochlorite solution. The pots were placed in double rows with a density of 3 plants m^2. With a drip irrigation system, it was irrigated three times a day, spraying with 1 L pot^{-1} d^{-1} from transplanting to flowering and 2 L pot^{-1} d^{-1} from flowering to harvest.

Experimental design and treatments

The experimental design was completely randomized. The treatments consisted of four nutrient solutions with different electrical conductivity (1, 2, 3 and 4 dS m^{-1}) based on the Steiner (1984) nutrient solution, the pH of the nutrient solutions was kept between 5 and 5.5. Each treatment included 10 plants and each plant was a replica. Tap water was used to prepare each nutritive solution, the analysis of the water reported an EC: 0.49, pH: 6.97, cations (me L^{-1}): Ca^{2+} 3.63, Mg^{2+} 0.15, K^+ 0.02, Na^+ 1.64 and anions (me L^{-1}) HCO_3^- 1.55, Cl^- 2.09 and SO_4^{2-} 1.02, therefore, it was classified as C_2S_1 (Ayers and Westcot, 1985).

Evaluated parameters

Yield

The weight of the fruits of each plant was harvested using an Ohaus® portable digital scale and was obtained with an approximation of 0.01 g. The data obtained are reported in kg plant^{-1}.

Equatorial diameter of the fruit

The longitudinal and transverse diameters were obtained from the fruits, for this a Truper model 14388 digital vernier was used and they were expressed in millimeters (mm).

Soluble solids content

The soluble solids content of bell pepper fruits was determined with an Atago refractometer (Master 2311). Four fruits were taken from each treatment and repetition. The fruits were cut to extract a drop and place it on the lens of the refractometer, this was repeated for each fruit, the results were expressed in °Brix.

Bioactive compounds

Sample preparation

Fresh fruit samples were washed with distilled water for 2 min to remove residues and lyophilized for 10 d. The dried material was then manually crushed (in mortar) and stored in Eppendorf plastic tubes at -18 °C until extracts were obtained.

Phenolic compound extracts

A 100 mg dry sample was mixed with 5 mL of methanol in a plastic screw cap tube. This was placed on a shaker (ATR Inc., USA) for 24 h (20 rpm) at 5 °C. The tubes were centrifuged at 30 000 x *g* for 5 min and the supernatant was removed for analytical tests.

Determination of total phenols

Total phenolic content was measured using a modification of the Folin-Ciocalteu method (Singleton *et al*., 1999). 30 µl of extract was mixed with 270 µl of distilled water in a test tube, to then add 1.5 ml of Folin-Ciocalteu reagent (Sigma-Aldrich, St Louis MO, USA) diluted (1:15) and vortexed for 10 sec. After 5 min, 1.2 ml of sodium carbonate (7.5% w/v) was added and the mixture was stirred for 10 s.

The solution was placed in a 45 °C water bath for 15 min, and then allowed to cool to room temperature. The absorbance of the solution was read at 765 nm on a UV spectrophotometer (Genesys 10). To calculate the phenolic content, a calibration curve was performed using gallic acid as standard, and the results were recorded in mg of gallic acid equivalent per 100 g on a dry weight basis (mg AGE/100 g PS).

Antioxidant capacity

The equivalent antioxidant capacity in Trolox was evaluated according to the *in vitro* $ABTS^+$ method published by Esparza-Rivera *et al*. (2006). An $ABTS^+$ solution was prepared with 40 mg of ABTS (Aldrich, St. Louis, Missouri, USA) and 1.5 g of manganese dioxide (Fermont, Nuevo León, Mexico) in 15 ml of distilled water. The mixture was vigorously stirred and allowed to stand covered with aluminum foil for 20 minutes. The solution was then filtered on Whatman 40 paper (GE Healthcare UK Limited, Little Chalfont, Buckinghamshire, UK) and the absorbance was adjusted to 0.7 ±0.01 at a wavelength of 734 nm using 5 mM phosphate buffer solution.

For the determination of antioxidant capacity, 100 µl of sample and 1 ml of $ABTS^+$ solution were mixed, and after 60 and 90 seconds of reaction the absorbance of the sample was read at 734 nm. A standard curve was prepared with Trolox (Aldrich, St. Louis, Missouri, USA) and the results were reported as equivalent antioxidant capacity in equivalent mM in Trolox per g dry base (mM equiv Trolox/g BS). The analyzes were carried out in triplicate.

Statistical analysis

The data obtained from the results were subjected to an analysis of variance and the simultaneous Tukey test $p \leq 0.05$ was used for the separation of means.

Yield

The yield decreases with an EC greater than 2 dS m^{-1}, the lower yield caused by the increase in the EC of the NS, is due to the decrease in the size and weight of the fruits (Figure 1a), similar results are reported by (Fallik *et al*., 2019), when indicating that the yield of bell pepper decreases as salinity increases, due to the fact that the pepper is a crop sensitive to salinity (Ben-Gal *et al*., 2008), with a higher EC at 3 dS m^{-1}, they exceed the nutrient requirements of the crop (Sonneveld and Van der Burg, 1991); however, not all cultivars respond in a similar way (Aktas *et al*., 2006).

The reduction in yield due to the smaller size of the fruits is attributable to the fact that they present a greater difficulty in absorbing water, caused by a high concentration of ions in the rhizosphere, thus affecting the expansion of the fruits, in addition to the above as well some nutrients can be reduced, mainly those that are absorbed by mass flow, which can cause problems with blossom end rot (Terraza *et al*., 2008). It is also possible that the decrease in yield is caused by low photosynthesis, which decreases the availability of CO_2 as a result of diffusion limitations (Flexas *et al*., 2007) and by a decrease in the conductance of CO_2 in the stomata and mesophyll (Ashraf and Harris, 2013).

Total soluble solids

The soluble solids in pepper fruits increased as the EC increased in the NS (Figure 1c). Similar results were found by Navarro-López *et al*. (2012), finding that an EC of 3 and 4 dS m^{-1} significantly increased TSS in pepper fruits. The greater accumulation of soluble solids in the fruit is due to the fact that when there is a high EC in the NS, there is a reduction in the flow of water towards the fruit and an increase in the hydrolysis of sucrose, which would produce fructose and glucose, in response to the high osmotic potential in the nutrient solution (Fallik *et al*., 2019), which causes an active accumulation of solutes in the fruits as simple sugars (glucose, fructose and sucrose), thereby reducing the osmotic potential , thus facilitating the absorption of water in the fruits (Goykovic-Cortes and Saavedra-del Real, 2007).

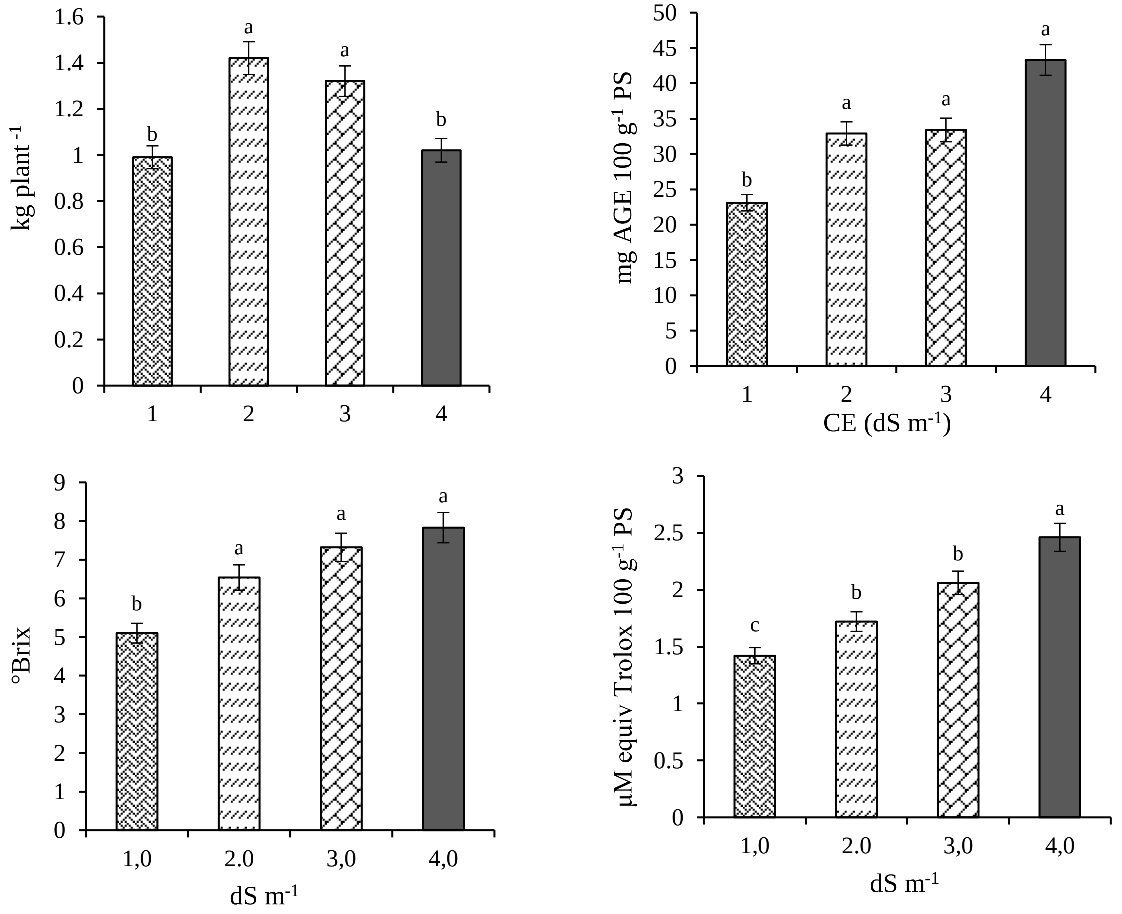

Figure 1. Effect of the electrical conductivity of the nutritive solution, on the yield, total soluble solids, phenolic compounds and antioxidant activity of bell pepper fruits.

Phenolic compounds and antioxidant activity

The consumption of foods rich in bioactive compounds is associated with a lower risk of cancer diseases and prevention of many diseases, hence the importance of increasing the biosynthesis of these compounds in the fruits before harvest and their subsequent consumption. The synthesis and accumulation of bioactive compounds in plants is generally stimulated by biotic or abiotic stress such as salinity, these compounds have the function of protecting lipids, proteins and nucleic acids from serious oxidative damage (Navarro *et al*., 2006).

As the EC in the NS increases, the content of phenolic compounds (Figure 1b) and the antioxidant activity (Figure 1d) in pepper fruits increases. The total phenol content and total antioxidants increased an average of 46 and 42%, respectively, between the lowest and highest EC. This behavior is caused by the high EC of the NS that induces a saline stress and therefore the plants will produce a higher content of antioxidant substances for their defense against oxidative stress (Navarro *et al*., 2006; Carmine *et al*., 2017).

The increase in bioactive compounds in fruits is desirable because antioxidant compounds protect human cells from free radicals, which cause damage to cells and increase the risk of developing cancer, cardiovascular diseases and other degenerative disorders (Carranco *et al*., 2011).

Conclusions

The electrical conductivity in the nutrient solution affects the yield and quality of bell pepper fruits. An electrical conductivity of 3 dS m^{-1} or higher improves nutraceutical quality, but significantly decreases bell pepper yield.

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