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Nutrient solution salinity effect of greenhouse melon (*Cucumis melon* L. cv. Néctar)

Efecto de soluciones nutritivas salinas en la producción de melón (*Cucumis melo* L. cv. Néctar) en invernadero

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Abstract

In Mossoró-RN, which is part of the semi-arid region of Brazil, a large part of the country's melon production is concentrated, whose great potential is currently limited by water quality due to salt concentration. Therefore, the objective of this work was to investigate the use of saline nutritive solutions in the irrigation of greenhouse melon (*Cucumis melo* L. cv. Néctar) culture in coconut fiber. The experiment was carried out using a randomized block design with a 5 x 2 factorial arrangement, with four replications, where the treatments consisted of nutritive solutions with five salinity levels (1.25 - control, 1.43, 1.86; 2.96 and 4.86 dS m^{-1}) and for two different times to evaluate fruit quality parameters (at harvest and after 12 days of storage). Increasing the salinity in the nutrient solution reduces fruits' mean weight, while total yield is only reduced with EC above 3.5 dS m^{-1}. Fruit length and diameter and peel and pulp thickness, SS and pH, decrease when submitted to nutrient solution with EC above 3.8 dS m^{-1}. The peel and pulp thickness, pulp internal cavity, firmness, SS, pH, TA and fruit SS/TA ratio were influenced by the storage period.

Keywords: fertigation, post-harvest, soilless cultivation, storage, substrate

Resumen

En Mossoró-RN, región semiárida de Brasil, se concentra gran parte de la producción de melón (*Cucumis melo* L. cv. Néctar) del país, no obstante su potencial productivo es limitado actualmente por la alta concentración de sales en el agua de riego. Por tanto, el objetivo del presente trabajo fue investigar el uso de soluciones nutritivas salinas conjuntamente con el riego del cultivo en un ambiente protegido, empleando como sustrato fibra de coco. El diseño experimental utilizado fue de bloques al azar con arreglo factorial 5 x 2, con cuatro repeticiones, donde los tratamientos consistieron en soluciones nutritivas con cinco niveles de salinidad (1,25 -control, 1,43; 1,86; y 4,86 dS m^{-1}) aplicadas durante dos épocas diferentes para evaluar parámetros de calidad de la fruta al momento de la cosecha y 12 días después de almacenamiento. El incremento de la salinidad en la solución nutritiva redujo el peso promedio de los frutos, mientras que el rendimiento total se redujo con aplicaciones de CE > 3,5 dS m^{-1}. La longitud y el diámetro del fruto, el espesor de la cáscara y de la pulpa, los sólidos solubles (SS) y el pH disminuyeron cuando se sometieron a CE > 3,8 dS m^{-1}. Otras características como espesor de la cáscara y de la pulpa, la cavidad interna, la firmeza, el SS, el pH, la acidez titulable (TA) y la relación SS/TA fueron afectadas por el período de almacenamiento.

Palabras clave: fertirrigación, poscosecha, cultivo sin suelo, almacenamiento, substrato

Introduction

Plants naturally respond to adverse conditions differently within each species, since gene expression can be heterogeneous, resulting in different levels of tolerance to stress. Among stress situations that are increasing in the agricultural setting, saline environments stand out, due to a series of factors such as excess application of fertilizers and the use of highly saline water.

Production environments may be an open field or a greenhouse, with the latter providing better control of environmental factors, both biotic and abiotic. Among production systems in protected conditions, hydroponic systems stand out. They are generally associated with the application of nutrient solution or fertigation, a practice that is used on a large scale and widely accepted by farmers.

Melon (*Cucumis melo* L. cv. Néctar) crop has a better response to fertigation, resulting in increased yields and fruit quality. Thus, hydroponic systems utilizing substrate or Nutrient Film Technique (NFT) allow the use of saline nutrient solution, making it a viable productive activity generating income for rural communities, with greater environmental safety. This is due to the operation of the drainage system and the fertilizing salts accumulated at the end of cultivation can easily be disposed out off system.

Results from research on melon tolerance to salinity have shown that such tolerance depends on the cultivar. Pereira *et al.* (2017) investigate the effects of water salinity for irrigation on melon cultivars (yellow melon, cultivar AF646) (0.54 to 3.9 dS m^{-1}) and found that the high salinity of irrigation water reduces the yield. Morais *et al.* (2018) verified that the increasing salinity levels in the nutrient solution reduced photosynthetic efficiency, stomatal conductance, transpiration rates and increased intercellular CO_2 concentrations in melon plants. The results from these investigations are specific to the condition of soil salinity; however, studies on the tolerance of this crop to nutrient solution salinity conditions in a greenhouse should be produced in order to increase the database for farmers and others involved in the melon production chain.

The increase of the number of melon producers has generated a great demand for technical information about the culture. Considering both the importance of this crop for the region and the small number of studies available, was evaluated the effects of different concentrations of saline nutrient solution on the production and quality of greenhouse melon fruits grown in substrate (coconut fiber) in a semi-arid region of Brazil.

Material and methods

Samples and installation of the experiment

The experiment was carried out in a greenhouse at the Department of Environmental and Technological Sciences of the Semiarid Rural Federal University (UFERSA), located in Mossoró (5° 11´S, 37° 20´W, and 18 m). The region's climate, according to the Köppen classification, is of the BSwh' type (hot and dry), with an average annual rainfall of 673.9 mm and temperate and relative humidity averages of 27 °C and 68.9%, respectively.

Uniform musk-melon plant obtained from a commercial nursery, were grown in 1.2 m-long coconut fiber (Golden Mix®) -filled bags in a greenhouse assembled in an arc-type structure (6.4 m wide, 18 m long, and 3.0 m high) covered with a low-density polyethylene film with an anti-ultraviolet additive and a thickness of 150 μ, protected at the sides with a black screen.

The coconut fiber-filled bags has circular format with plastic material of 11 L, with 1.55 x 0.30 m, containing a perforated ½" PVC tube at its lower base to ensure excess irrigation drainage, placed on asbestos tiles. In each bag we planted 5 melon plants and, the bags were spaced out 1.20 m between rows and 0.5 m between the plants in same bag. The plants were transplanted on March 10, 2014, and irrigated with a basic nutrient solution (pH 6.0) of the following macronutrient composition (g per 1000 L): N, 210.5; P, 50; K, 270; Ca, 170; Mg, 40; S, 52. Micronutrient concentrations were (mg L^{-1}) Cu, 0.1; Mn, 0.5; Mo, 0.05; Zn, 0.3; Fe, 2.2.

The plants were irrigated according to the hydric demand, manually utilizing graduated recipient. The concentration of nutrient solution was calculated by weighing the coconut fiber-filled bags so that the substrate moisture reached maximum retention capacity, just after the leeching of nutrient solution. The application of nutrient solution was begun just after transplanting, and lasted until the end of the crop cycle, with two daily applications at 8 and 11 a.m,

The experimental design consisted of randomized blocks in two-factorial array 5 x 2 (nutrient solution salinity x times to evaluate fruit quality parameters). The first factor consisted of five levels of the nutrient solution salinity (1.25 – control, 1.43, 1.86, 2.96, and 4.86 dS m^{-1}) in the irrigation water and second factor the different times to evaluate fruit quality parameters (at the time of harvest and after 12 days of harvest). The four highest salinity levels were attained by adding NaCl to the basic nutrient solution (1.25 dS m^{-1}) prepared with tap water from the public supply.

Steaks were installed to induce vertical growth of the melon plants, up to 2.0 m height in single stems. The fruits were thinned out to two per plant. The melon fruits were harvested 60 days after planting, transported to the post-harvest laboratory, and evaluated at the time of harvest and after 12 days of storage (24 ± 1 °C and 50 ± 2% RH).

Physical characteristics

The following production variables were analyzed: average weight of ripe fruits obtained by electric precision scales, and fruit yields by extrapolating the total average weight to Mg ha^{-1}. To evaluate the quality of melon fruits, the following variables were date recorded at the end of the experiment: (1) length and diameter of fruits (mm): calculated using a digital pachymeter (Model Shan, China); (2) weight loss of fruits (%): calculated each period on electronic precision scales, considering the difference between the initial weight of the fruit and that obtained at each sample period (storage); (3) peel and pulp thickness (mm): two measures were taken on each side from the mid-region of the fruit using a digital pachymeter (Shan, China); (4) pulp firmness (N). Pulp firmness was determined, after taking out four discs from the skin surface in the equatorial area, using a Fruit Pressure Tester TR penetrometer, fitted with an 8 mm-diameter probe.

The external and internal appearance was calculated subjectively considering the absence and presence of defects, using the following subjective scales adapted from Chaves *et al.* (2014): 1 = severe intensity (51 to 60% of the fruit affected), 2 = medium intensity (31 to 50% of the fruit affected), 3 = light intensity (11 to 30% of the fruit affected), 4 = traces of defects (1 to 10% of the fruit affected), and 5 = lack of defects (less than 1% of the fruit affected). For external appearance, the following were considered as defects: stains, dents, withering, and attack by micro-organisms. For internal appearance, pulp collapse, liquid in the cavity, attack by micro-organisms, and withering were evaluated. Fruits considered unmarketable were those with scores below 3.0 for any evaluation.

Physicochemical and chemical characteristics

Total soluble solids (TSS) were evaluated whit an Atago N1 refractometer (PR-100 model, Atago Co. Ltd., Tokyo). Titratable acids (TA) were measured with 0.1 N NaOH, reducing sugar by the anthrone method (Yemn & Willis, 1954), and pH was measured directly in the pulp with a digital potentiometer (AOAC, 2016).

Vitamin C was evaluated by titration with Tilman solution (DPHI – 2.6 dichlorophenol-indophenol to 0.02%) as in the methodology proposed by Strohecker & Henning (1967). Data of fruit yield parameters and fruit quality were subjected to analysis of variance (Variance Analysis - SISVAR software). Regression analyses and mean tests were used for the variables collected, based on the Tukey test at 5% probability.

Results

The average fruit weight was significantly affected only by nutrient solution salinity. In general, the average fruit weight was reduced as solution salinity increased (Figure 1A). The marketable yield of melon fruit was significantly influenced by the levels of nutrient solution salinity. The higher yield was observed in ECs 3.49 dS m^{-1} (49.39 Mg ha^{-1}); later there was a tendency for reduction with an increase in salinity levels (Figure 1B). A significant effect on fruit length (Figure 1C) and diameter (1D) was observed only for the EC of nutrient solution, where an increase in solutions with EC of 1.25 to 2.96 dS m^{-1} was initially observed, followed by a tendency for reduction with EC of 4.86 dS m^{-1}.

Significant interaction was not verified between the EC factor and the timing of fruit quality analysis factor on peel thickness, pulp thickness, and pulp cavity characteristics. However, the isolated factors were significant. During storage there was a reduction in the Pell Thickness (PeT) and Pulp Thickness (PuT) (Table 1).

Table 1. Characteristics of 'Galia' melon (cv. *Néctarr*) as effected by the timing of fruit quality analysis, at harvest or after 12 days of storage.

Time	Fruit Characteristics*							
	PeT	PuT	PC	PF	TSS	TA	pH	TSS/TA
	------------- mm	-----------		N	------ %	-----		
Harvest	4,61a*	28,91a	38,43b	37,94a	10,26a	0,12a	6,55 a	92,07b
Storage	4,26b	23,05b	43,41a	8,83b	9,65b	0,08b	6,35 b	126,59a

* Means with identical lowercase letters in the same columns are not statistically different (Tukey–Kramer test, P > 0.05).

Pell Thickness (PeT); Pulp Thickness (PuT); Pulp Cavity (PC); Pulp Firmness (PF); Total soluble solids (TSS); pH; Titratable Acids (TA); and TSS/TA ratio.

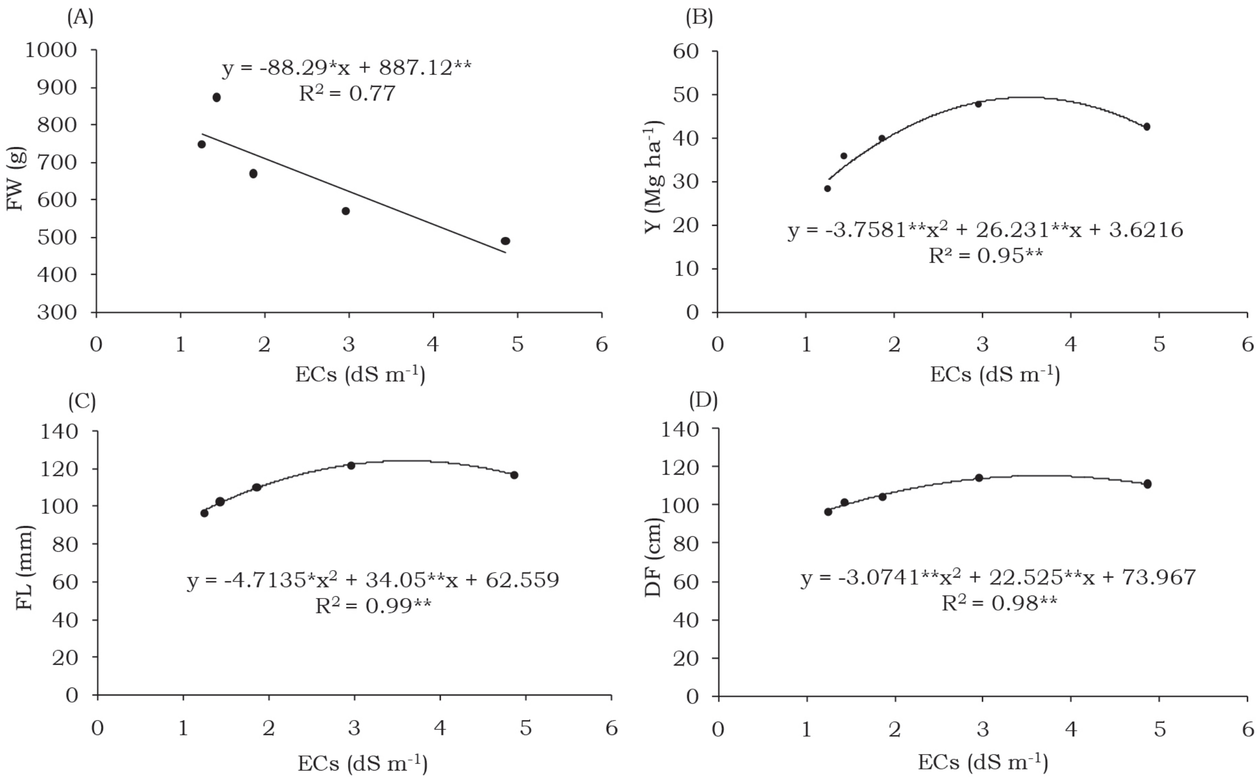

Figure 1. Fruit weight – FW (A), Yield – Y (B), Fruit length - FL (C) e Fruit Diameter – FD (D) of 'Galia' melon (cv. Néctarr) in greenhouse irrigated with nutrient solution differing in EC_s level

Both peel and pulp thickness and pulp cavity had a higher value with EC of 2.96 dS m^{-1}, and then a tendency for reduction was observed with an increase in the nutrient solution salinity (Figures 2A, 2B, and 2C), similarly to the behavior observed for length and diameter (Figures 1C and 1D). Significant interaction was verified between times to evaluate post-harvest quality parameters and the electric conductivity of nutrient solution on the external appearance of the melon fruit. At the time of harvesting fruits, decreases in scores were recorded when salinity levels of the nutrient solution increased. After 12 days of storage (24 ± 1 °C and 50 ± 2% RH), the external appearance score of the melon fruit varied from 4.2 in lower solution salinity (1.25 dS m^{-1}) and 4.0 in higher solution salinity (4.86 dS m^{-1}) (Figure 2D). The internal appearance of the melon was not influenced by the salinity levels; however, significant differences were observed between the day of harvesting (score of 4.9) and after 12 days of storage (score of 4.3).

There was a significant interaction between the factors studied for fruit mass loss. This suggests that increased EC and storage time resulting in greater less of mass. The fruit mass loss after 12 days in storage reached 5.40% for an EC of 1.25 dS m^{-1} and 6.62% for an EC of 4.86 dS m^{-1} (Figure 2E).

Pulp firmness was not significantly affected by the nutrient solution salinity level, recording average of 23.7, 23.6, 23.96, 25.68 e 19.98 N to EC of 1.25, 1.43, 1.86, 2.96 e 4.86 dS m^{-1}, respectively. However, an accentuated reduction of 76.73% was observed after storage (Table 1). TA were significantly affected by nutrient solution salinity, the times to evaluate post-harvest quality parameters, and their interaction. TA of the melon fruit increased with high salinity levels and reduced after 12 days of storage. The pH had a tendency to reduce with a higher salinity level (4.86 dS m^{-1}) and also reduced with storage, but the difference in the average values was minimal (Figures 3A and 3B, Table 1).

No significant interaction in SS was found between nutrient solution salinity levels and storage, but the isolated factors were significant. SS levels increased up to ECs of 3.62 dS m^{-1}, reaching a maximum value of 11%, and then had a tendency for reduction with increased ECs (Figure 3C). During storage, the alteration of SS was minimal. For the SS/TA ratio, only time in storage was significant, with an increase after storage (Table1). There was a significant interaction for soluble sugars, when on the day of harvesting there was a tendency for reduction with increased salinity levels, and after storage they increased with increased salinity (Figure 3D).

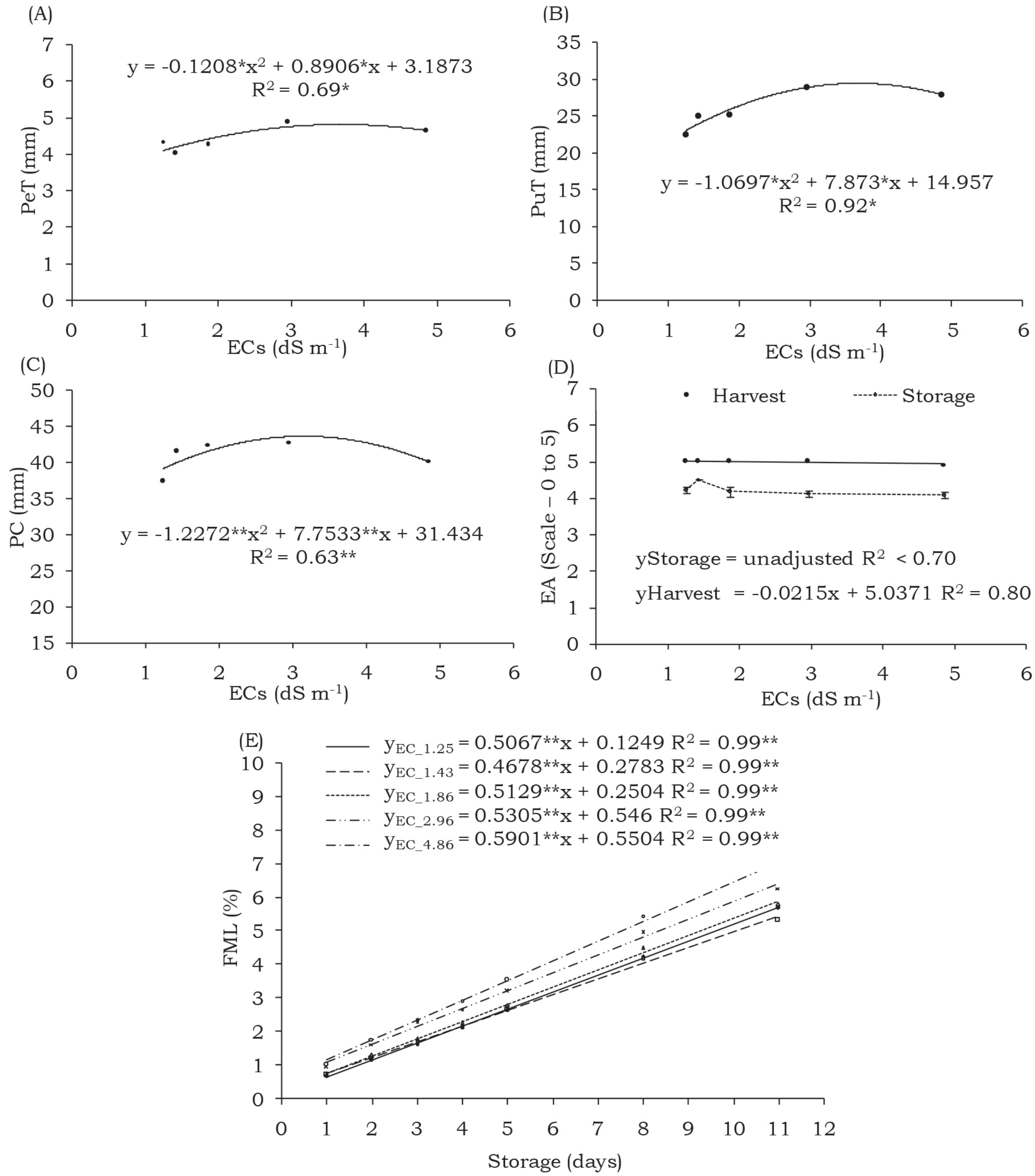

Figure 2. Pell Thickness – PeT (A), Pulp Thickness – PuT (B), Pulp Cavity – PC (C), external appearance - EA – (D) and fruit mass loss – FML (E) of 'Galia' melon (cv. Néctarr) in greenhouse irrigated with nutrient solution differing in EC_s level

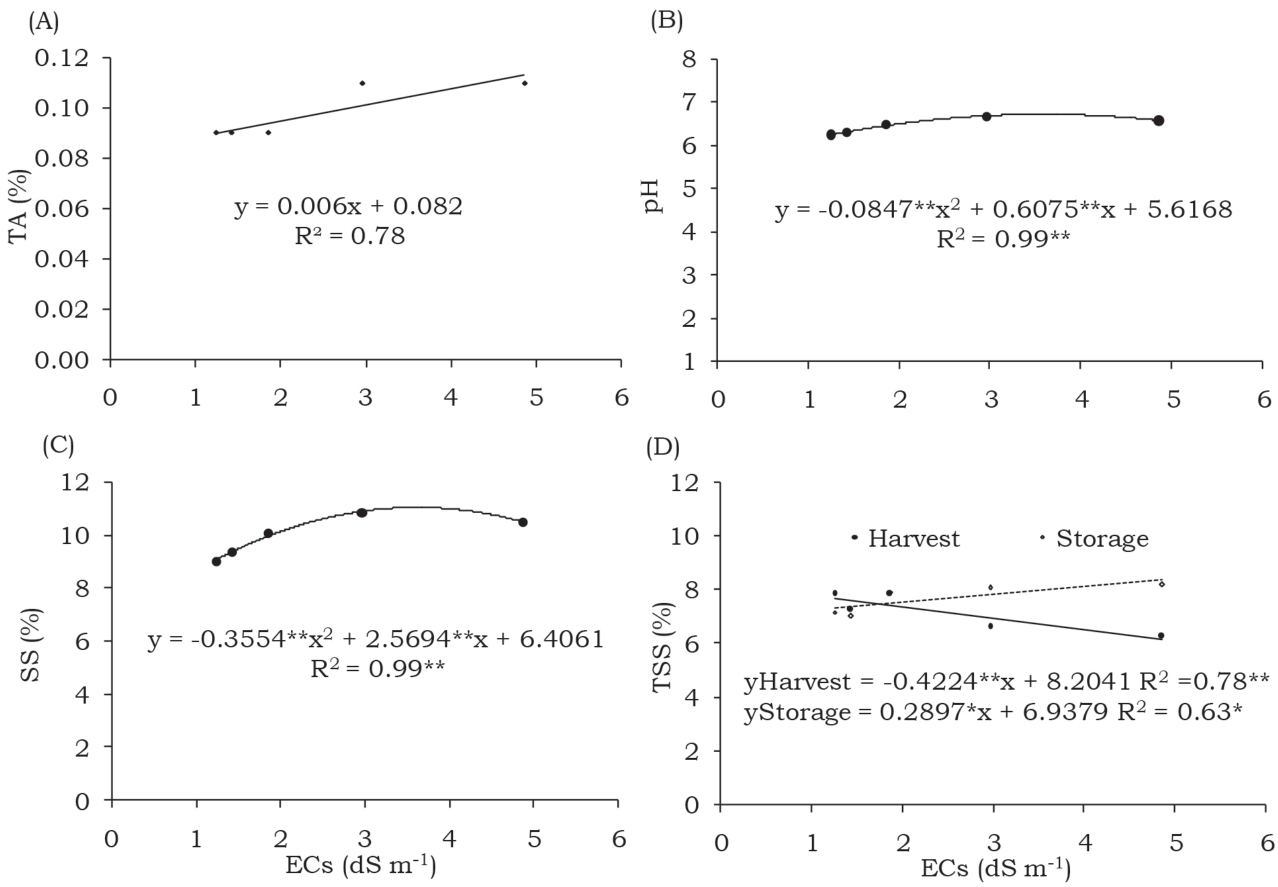

Figure 3. Titratable Acids – TA (A), pH (B), soluble solid – SS (C) and Total soluble sugar – TSS (D) of 'Galia' melon (cv. *Néctarr*) in greenhouse irrigated with nutrient solution differing in ECs level

Discussion

The negative effect of salinity on the average weight of melon fruits was reported in other studies. Pereira *et al.* (2017) reported that the average weight of marketable fruit decreased when the solution salinity increased. Freitas *et al.* (2014) found losses of 11% per dS m^{-1} in the fruit yield of Orange Flesh melon crops irrigated with high-saline water (EC 4.5 dS m^{-1}). Salinity influenced the commercial productivity of melon culture. Acosta-Motos *et al.* (2017) e Morais et al. (2018) explain that certain physiology processes, for example, reduced photosynthetic efficiency, stomatal conductance, transpiration rates and increased intercellular CO_2 concentrations in melon plants, are sensitive to the effect of salts, so that the growth rate, biomass production, and yield of agricultural plants are reduced.

The lower effect of salinity on melon production may be associated to the cultivation system in coconut fiber because of the high water uptake capacity of this substrate, which is around 85% of moisture. This reduced the concentration of salts in the nutrient solution and, consequently, the negative effects of salinity on plant growth. In addition, use of a substrate makes the matrix potential inert and does not interfere in water retention. On the other hand, the substrate facilitates absorption of water by the plants (Lobet *et al.*, 2014). The water applied to leaching fraction also resulted in a loss accumulation of salt in the root zone.

The data in this present work is consistent with Freitas *et al.* (2014) when they verified that the yield of Orange Flesh melon (County hybrid) was negatively influenced by increased salinity levels, the total production and commercial production had reduction of 4.241 and 3.927 Mg ha^{-1} per unit increase in electrical conductivity of irrigation water, respectively. Terceiro Neto *et al.* (2013) investigated the effect of nutrient solution salinity on the yield of melon crop during early vegetative grown, from the beginning of flowering up to the beginning of fruit set, and found that they stopped accumulating total mass in fruits.

The length and diameter of the melon fruit can be affected by the salinity of the nutrient solution, because these characteristics are associated to fresh mass of the fruit directly, which decreases as the salinity of nutrient solution increase increase (Dias *et al.*, 2015). Salinity may damage the physiological, growth, and development processes of the plant, since it affects the general water balance of the plant (Morais *et al.*, 2018).

Reduction in pulp thickness of the fruit caused by increased salinity of the nutrient solution was also reported by Sousa *et al.* (2016). The authors observed that the irrigation water salinity negatively affected fruit mass, fruit diameter and pulp diameter of mini watermelon (cv. Smile). The pulp thickness can predict yield by measuring the edible part of the fruits. Thus, pulp thickness is commensurable to the fresh fruit mass which can be estimated by the length and fruit pulp diameter (Dantas *et al.*, 2018).

Although storage and salinity levels compromised the external appearance of the melon fruits, this was not enough to make them unsuitable for consumption at the end of storage. The various actions on the cellular protoplasm caused by excess saline may result from functional disturbances and injuries, reducing osmotic potential and provides ionic actions (Harter *et al.*, 2014), absolute growth rate in beginning growth (Medeiros *et al.*, 2014), however no effect the fruit quality (Sousa *et al.*, 2016; Terceiro Neto *et al.,* 2013).

The firmness of the melon fruits was high shortly after harvesting, considering that they showed values higher than that recommended for the external market (30 N). Loss of firmness during storage is a phenomenon associated with degradation of plant cell wall components (Paniagua *et al.*, 2014). Maintenance of pulp firmness is an important practice for the shelf life of fruit after harvest by favoring the integrity of its tissue during storage and preserving its properties for a longer time. Terceiro Neto *et al.* (2013) and Pereira *et al.* (2017) also observed no effect of salinity levels (0.54 to 4.78 dS m^{-1}) on pulp firmness of melons (cvs. Sancho, Medellín, Mandacaru, Néctarr, Galia e Sedna).

It is of interest to know that the acidity in melon fruits has less significant variation due to its reduced concentration, and non-representativeness on fruit flavor intervention (Dantas *et al.*, 2018). The negative response of pH as a function of irrigation water salinity was also observed by Sousa *et al.* (2016), who worked with of mini watermelon plants (cv. Smile).

Many countries adopt values of TSS content as a market reference for acceptability of their fruit production, considering minimum variation of 8 to 10 °Brix. In this study, all fruits of the plants fertilized with a solution of 1.25 to 4.86 dS m^{-1} had mean values of TSS above the minimum required by the market. This behavior of the melons seems to be related to the maintenance of SS when submitted to irrigation with saline nutrient solution.

There is a tendency of reduction in the SS contents of fruits with increasing EC levels in the nutrient solution, which may be associated to the reduction of the leaf area of plants (Sousa *et al.*, 2016), since the smaller the leaf area of plants, the smaller their photosynthetic capacity will be. However, some researches show that saline stress in cucurbit species results in increased SS content (Terceiro Neto *et al.*, 2013).

Increasing salinity levels in the nutrient solution reduced photosynthetic efficiency, stomatal conductance, transpiration rates and increased intercellular CO_2 concentrations in melon plants (Morais *et al.*, 2018). This response of plants to the environment may be partially associated with foliar abscission mediated by ethylene production. Decreased growth can be considered a mechanism to minimize water loss through transpiration (Acosta-Motos *et al.*, 2017). With an increase in salinity, photosynthesis and respiration processes are reduced, directly influencing carbohydrate synthesis and TA (Acosta-Motos *et al.*, 2017), affecting the nutritional status of the plant in different ways and inhibiting, for example, the obtainment of the essential element K^+ due to competition for space in the transporting of proteins and through the still incompletely deciphered intracellular processes (Taiz and Zeiger, 2017).

Conclusions

Increasing the salinity on the nutrient solution reduces linearly fruits' mean weight, while total yield is only reduced with EC above 3.5 dS m^{-1}.

The physical characteristics, such as fruit length and diameter and peel and pulp thickness, and chemical characteristics, such as SS and pH, had negative effects EC above 3.8 dS m^{-1}.

The peel and pulp thickness, pulp internal cavity, firmness, SS, pH, TA, and fruit SS/TA ratio were influenced by the storage period (12 days at 24 ±1 °C and 50 ±2% UR), and the melon fruit maintained a good quality for consumption.

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