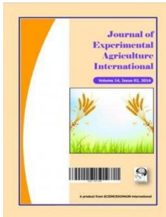

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Quality of Fruits from Grafted Tahiti Lime (*Citrus latifolia* Tan) Irrigated with Waters of Different Salinities

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Objective: In order to evaluate the quality of Tahiti acid lime fruits grafted on rootstocks under saline waters.
Experimental Design: The experiment was set up using a randomized block design, corresponding to ten citrus combinations, relative to Tahiti acid lime grafted on ten genotypes, and two levels of saline water used in irrigation.
Place and Duration of the Study: The experiment was realised at the Agro-Food Science and Technology Center of the Federal University of Campina Grande, Pombal Campus, Paraíba, from February 2016 to February 2017.
Methods: Were studied ten combinations of genotypes of Tahiti acid lime, and two saline water, using a factorial scheme, with three replications. The ten citrus genotypes were composed by 9 genotypes from two progenies, being four genotypes from the TSKFL x [*Poncirus trifoliata* Beneke (TRBK)] added to the control 'Rangpur Santa Cruz' lime (LCRSTC) and two irrigation water salinity levels (0.3 dSm^{-1} and 3.0 dSm^{-1}).
Results: When studying the analysed variables, can observe significant effects only for the genotype (G), when the variable pH was verified, and the salinity factor (S), when analysing the (dSm^{-1}), numbers of locules, soluble solids (SS - %), titratable acidity (TA - %) and ascorbic acid (AA - mg 100 mL^{-1}).
Conclusion: Citrus rootstocks did not differ in the chemical and physical characteristics of fruits with increased salinity.

Keywords: Citrus spp; postharvest; tolerance.

1. INTRODUCTION

The production of citrus plants in Brazil is a major highlight, being the largest exporter of concentrated and frozen juice in the world. In the year 2016, national production of (oranges, lemons, and mandarins) was 15 million tons higher, 76% of it is concentrated in the Southeast region of Brazil and 11.6% in the Northeast region of Brazil [1]. In addition to the food value, citriculture represents a generation of employment and income, especially in the Northeast region, however, productivity in this region is low, which is attributed to the water deficit, with the need to introduce irrigation to obtain an increase in production [2].

Citrus productivity is directly linked to hydric availability which ranges from 600 to 1200 mm/year [3]. Precipitation values above that found in the Northeast region. However, the use of rootstocks has ensured the success of the citriculture in the region, due to its adaptability to different soil and climatic conditions, clove lemon is the most commonly used rootstock in the citriculture [4]. According to Brito et al. [5] salinity up to 2.0 dSm^{-1} can be used, however, causing small restrictions on the growth of citrus genotypes recommended as rootstocks, notably in 'Volkameriano' lemon tree, Sunki Tropical tangerine, Cravo Santa Cruz lime and the trifoliated hybrid (HTR) -069. The adequate water supply through irrigation can provide the following benefits: a greater number of flowers and fruits, ensuring higher productivity, better fruit quality, larger size, and weight, accentuated staining; a greater amount of oil in the shell [6]. In saline conditions, the growth, development, and production of citrus plants may be reduced, which can be attributed to osmotic effects, the reduction in gas exchange or ionic order, such as the occurrence of nutritional and biochemical disorders [7,8].

The effect of salinity on agricultural production is enormous and can lead to large losses in agriculture. Because most of the cultivated plants are glycophytic (they are not able to grow in environments with high salt concentrations) and suffer severe effects from salt, which make it difficult for the plant to absorb water due to the high concentrations of ions in the substrate solution, which reduce the osmotic potential of this solution, thus reducing the availability of water and nutrients to the plant [9]. In view of the fact that the main quality attributes required for the Tahiti acid file in order to obtain a profitable marketing, both domestically and externally, are: shape, size, brightness, taste, nutritional value, food safety, green colouring, and turgescence. [10]. However, it was known that there could be many genetic and environmental effects on the quality [11].

Thus, given the relevance of citriculture represent to the economy and to the diet of the Brazilians and the sensibility that these species present the salinity, the objective was to evaluate the fruit quality of the Tahiti acid lime tree grafted on rootstocks irrigated with waters of different salinities.

2. MATERIALS AND METHODS

The work was developed at the Experimental Area of the Campina Grande Federal University (Campus Pombal, PB, Brazil) located at 6º46'13 '' south latitude and 37º48'06 '' west longitude, at an altitude of 184 m. The predominant climate in the region according to the classification of Köppen is BSh, ie hot semiarid, with an annual rainfall of 750 mm and rainfall concentrated in the months of December to April [12].

2.1 Environmental Variables

During the experimental period, temperature and precipitation were monitored. It was observed that the maximum temperature was 36.9°C and the minimum temperature was 20.9°C on average (Fig. 1). The temperature is one of the factors that alter the growth and development of the citrus plants, according to information contained in Mattos Júnior et al. [13]. In order to have maximum growth in the vegetative phase, it is interesting to have a temperature between 23 and 31ºC, also observing that temperatures below 12ºC and above 32ºC cause a reduction in growth rates; however, this information is relative to sweet orange, which can be modified according to the canopy/rootstock combination.

As for rainfall, it was observed that the average 64.9 mm found for the study period (Fig. 2), was insufficient to guarantee the high productivity of the citrus crop, which demand, according to the Lima literature [13], precipitation between 600 and 1200 mm. For the cultivation of Tahiti acid lime in the semi-arid Braz et al. [2], indicated with insufficient, being necessary to replenish water with 100% of evapotranspiration of the crop (ETc), which for the situation of these authors ranged between 4.7 and 5.2 mm, that is, between 1700 and 1900 mm year.

The experimental design was a randomized complete block design, with a factorial scheme of type 10 x 2, with three replications composed of two factors. The respective salinity levels were applied in 10 citrus canopy / citrus rootstock combinations, related to the Tahiti acid lime tree as crown, which was grafted on 10 rootstocks, 9 from two citrus progenies (5 and 4 genotypes respectively) and a control genotype, all from the Embrapa Mandioca and Fruticulture Citrus Genotype Breeding Program (PGM-Citrus).

The citrus plants were derived from five genotypes related to the cross between the Sunki mandarin [three of Common Selection (TSKC): TSKC X (LCR XTR) – 017; TSKC X (LCR XTR) – 032; TSKC X (LCR XTR) – 059, and two of the Florida: TSKFL X (LCR XTR) – 012 and TSKFL X (LCR XTR) – 018 related to

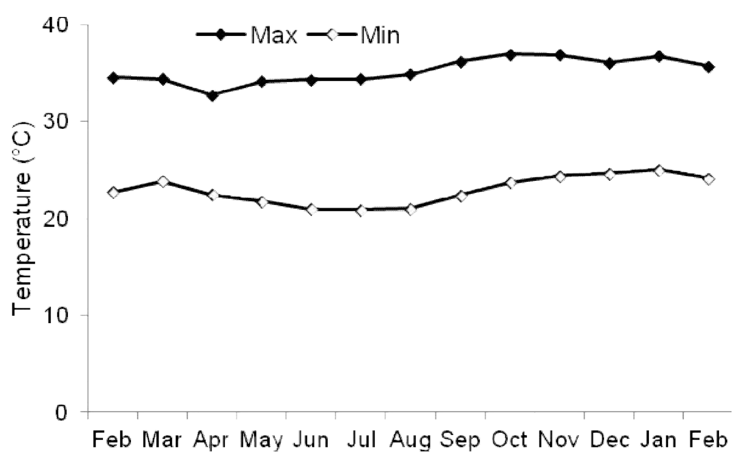

Fig. 1. Variation of temperature data ºC, during the conduction of the experiment (February 2016 to February 2017), obtained from the INMET website

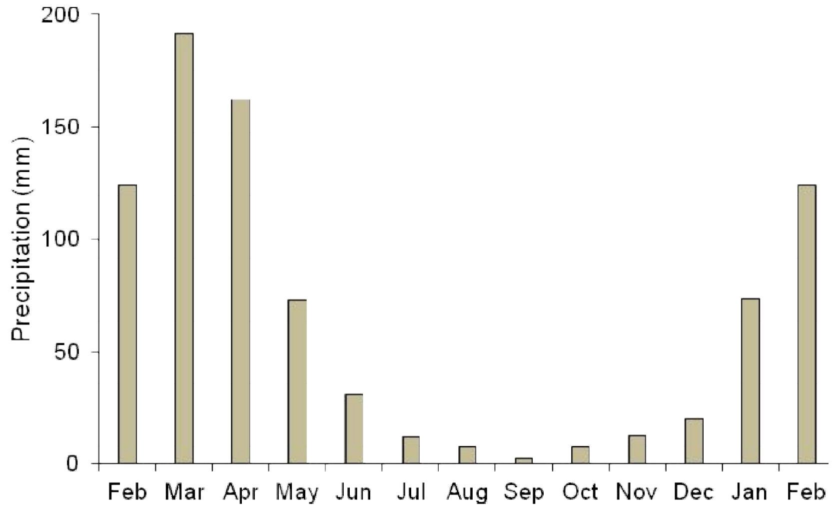

Fig. 2. Variation of precipitation data (mm), during the conduction of the experiment (February 2016 to February 2017), obtained from the AESA website

the crossing TSKFL x Clove Lemon (*Citrus limonea* L. Osbeck) x *Poncirus trifoliata* (TR), and 4 genotypes [TSKFL X TRBK – 011; TSKFL X TRBK – 017; TSKFL X TRBK – 028; TSKFL X TRBK – 030] of the cross between TSKFL X [*Poncirus trifoliata* Beneke (TRBK) added to the control (Cravo Santa Cruz lemon tree – LCRSTC) and two irrigation water salinity levels (0.3 dSm^{-1} and 3.0 dSm^{-1}). The application of water of higher conductivity was started at 15 days after transplanting (DAT) of the seedlings to the lysimeters and lasted until the first crop cycle, one year after the transplant.

2.2 Installation and Conduction of the Experiment

The seedlings of each citrus genotype grafted with the Tahiti acid lime tree were obtained from the seedling nursery of Embrapa Mandioca and fruit growing in Cruz das Almas-BA, following the recommendations for production of certified seedlings and using source materials After acclimatisation to the region, they were transplanted into bags with a capacity of 5 L, where pruning was performed on the main stem at 50 cm, leading to three lateral shoots forming a canopy, the transplant occurred February 15, 2016.

A layer of 15 L of gravel and sand was used to fill the lysimeters, being 8 and 7 L respectively, which formed a 0.04 m high layer, in order to facilitate underground drainage (Fig. 3B). Following this layer the filling simulated a field planting pit, with dimensions of 40 cm in diameter and 40 cm in depth, for this purpose, the mixture between 40 L of Fluovian soil following the characterisation of soil diagnostic horizons, with collections (Fig. 3A), with 20 L of tanned bovine manure and phosphate fertilisation with superimposed (Table 1), which were placed in the center of the lysimeter with the aid of a cylinder of the specified dimensions, the outside of the cylinder was filled with 60 L of soil (Fig. 3D) so that the lysimeters were filled with a volume of 135 L.

Fig. 3. Soil collection area to fill lysimeters (A), gravel and coarse sand layer (B), drain outlet (C), lysimeter filling with the cylinder in the center (D) and cover with crushed corn husk (E).

Each lysimeter was made from a water tank of 150 L capacity, painted white, in order to increase the reflectance and reduce the heat conservation in the lysimeter's interior soil, then an 18 mm meter was placed of at the base of the lysimeter (Fig. 3C), in order to favor the drainage and estimation of the water consumption by the plants. The seedlings of the respective genotypes were transplanted 30 days after filling the lysimeters and were followed by a bed of dry matter from corn and sugarcane ground, in the 1 kg portion per lysimeter (Fig. 3E). In order to raise the relative humidity of the air and reduce the albedo, the emerald grass was planted in the soil between the lysimeters. The chemical characterisation of soil and manure used in the test is shown in Table 1.

2.3 Preparation of Irrigation Water

As only two levels of the conductivity of the irrigation water, only 3.0 dSm^{-1}, it was necessary to be prepared, which was produced with the addition of NaCl, in addition, the water of lower conductivity 0.3 dSm^{-1} comes from the local water supply system. For the preparation of the water with higher conductivity, the relation between EC and the concentration of salts (10 * meq = 1 dSm^{-1} of EC), extracted from Rhoades et al. [14], valid for EC from 0.1 to 5.0 dSm^{-1}, in which the level to be prepared is, based on the water supply on site. The salt was weighed according to the treatment, added to the water until reaching the desired EC level, and the values were verified with a portable conductivity meter that has electrical conductivity adjusted to a temperature of 25ºC.

After preparation, the waters were stored in properly protected 500 L containers in order to avoid evaporation, rainwater infiltration and contamination with materials that could compromise quality. Irrigations were carried out with a localised irrigation system (Fig. 4A), by means of dripping tapes with high pressure and 1.9 Lh^{-1} flow per dripper, with five drippers per lysimeter. The ribbons were distributed in the lysimeters in the form of a circle, with the aid of an iron bar 4.2 forming a closed system (Fig. 4A). Irrigation management was performed by the water balance method, in order to restore the average daily consumption of the plants and an additional fraction, dividing the volume value to be applied (mL) by 0.9 to obtain a fraction of leaching corresponding to 10%, in order to promote the leaching of excess salts from the irrigation water (Expression 1). VI = (Va-Vd) 1-F Exp.1 Where: VI = volume to be irrigated in the next irrigation event (mL); Va = volume applied in the previous irrigation event (mL); Vd = drained volume (mL), and FL = coefficient used to obtain a leaching fraction of approximately 10%, moisture was also monitored by tensiometer and by Reflectometry in the TDR time domain.

Fig. 4. Irrigation system (A) and view of experiment (B).

Table 1. Chemical characteristics of the soil and manure used to fill the lysimeter of citrus plants

	pH	C.E	P	N	K	Na	Ca	Mg	SB*	(t**)	MO
	$CaCl_2$	$dS\ m^{-1}$	mg/dm^3	%	$Cmol_c/dm^3$			$g\ Kg^{-1}$			
Soil	7.26	0.03	7	0.16	0.52	0.36	4.55	2.35	7.79	7.42	3
Manure	6.47	1.09	98	2.44	3.82	1.54	4.52	2.63	12.51	10.97	40

** sum of bases; **exchangeable cations*

To perform the collection of the drained water, each lysimeter was drilled in the base, to connect a hose, which allows the flow of the drained fluid to an 18L container, allowing to measure the drained volume. Up to 15 days after transplant, the plants received water with low electrical conductivity (EC), from the local supply system, EC (0.3 dSm^{-1}), from this period water was applied with the different levels of electrical conductivity lasting until the end of the harvest. The nutritional management followed recommendations by soil and manure analysis, along with that proposed by Mattos Júnior et al. [13], recommended for cultivation, adopting all other precautions to control weeds, prevention, and control of pests and diseases, normally recommended in the production of citrus seedlings [13].

2.4 Characteristics Analysed

The effect of the different treatments was analysed from the following evaluations: number of fruits per kg (NF); number of locules per fruit (NL); volume of juice per kg (VOL mL); weight of juice per kg (PSg); pH; electrical conductivity (EC dSm^{-1}); soluble solids (SS%); titratable acidity (AT%) and ascorbic acid (AA mg 100 mL^{-1}).

The harvest period referring to the first crop cycle began in December 2016, extending until February 2017. The fruits for each plot were harvested when they presented physiological maturation, the harvest occurred in the proportion of 1 kg of fruit by genotype of each treatment, and these were identified locally. Harvested, fruits were counted and washed (Fig. 5A). Afterward, the fruits were cut in half and the number of locules counted (Fig. 5B), then with the aid of a juicer the juice was collected (Fig. 5C) and the volume was measured with a beaker (Fig. 5D), after the samples were stored in identified plastic containers and covered with foil, followed by plastic film to eliminate losses and eventual contamination, and then refrigerated (Fig. 5E).

The analyses were carried out in the Laboratory of Chemistry, Biochemistry and Food Analysis of the Federal University of Campina Grande, Pombal Campus. For pH analysis (Fig. 5F), a digital potentiometer with a glass membrane electrode and a resolution of 0.01 was used. The electrical conductivity was determined directly in the sample, using a bench conductivity meter (Fig. 5G). Soluble solids determination was expressed in ºBrix with the use of a portable refractometer with a resolution of 0.2 (Fig. 5H). The titratable acidity (Fig. 5I) was performed following the Adolfo Lutz Institute's standards expressed as a percentage of citric acid [15]. The ascorbic acid contents (Fig. 5J) were determined by the method of the Adolfo Lutz Institute [15].

2.5 Statistical Analysis

The data obtained were submitted to a variance of analysis when a significant effect was detected for the F test, the Scott and Knott test was applied at the 5% probability level using the software Sisvar® 5.6 [16].

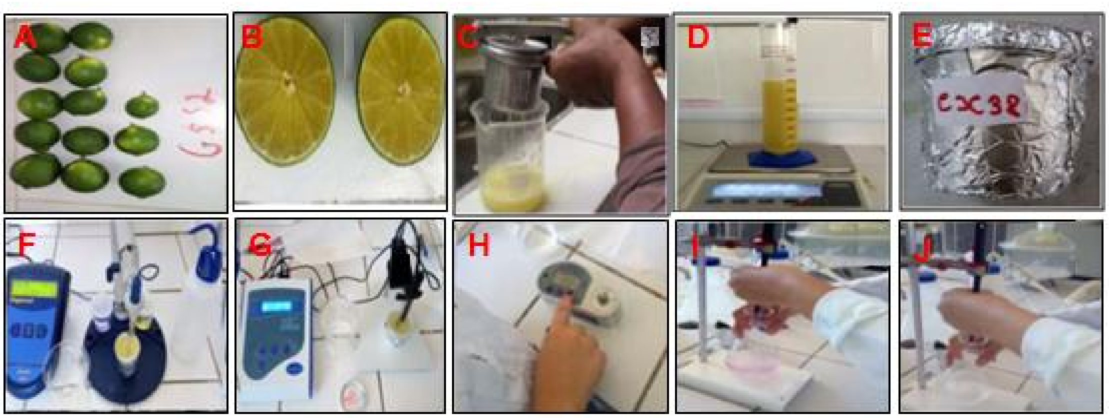

Fig. 5. Fruit counts (A), number of loci per fruit (B), juice extraction (C), juice volume and weight (D), juice conditioning (E), hydrogenation potential, pH , electrical conductivity (G), soluble solids (H), titratable acidity (I), ascorbic acid (J).

3. RESULTS AND DISCUSSION

By studying the analysed variables, we can observe significant effects only for the genotype (G), when the variable pH was verified, and the salinity factor (S), when analysing the (dSm^{-1}), numbers of locules, soluble solids (SS%), titratable acidity (AT%) and ascorbic acid (AA mg 100 mL^{-1}) (Table 2). What can be observed is that the physical characteristics of the fruits did not suffer as much with the increase of the salinity, these plants come from a young orchard, and the fruits analysed come from the first year of production and are not fit to commercialise, as they present sizes smaller than those required by the commercial standard. According to Luchetti et al. [6] averages of length and diameter range from 5.5 to 7.0 cm and 4.7 to 6.3 mm, respectively.

In relation to the variable number of locules, a significant effect was observed only for the salinity factor (Table 2), where the plants irrigated with water of lower salinity 0.3 dSm^{-1} had on average 11.0 locules per fruit, already those with EC of 3.0 dSm^{-1} had 10.6 inoculants, that is, superiority of only 3.6%. Thus, there is a certain tolerance of genotypes to the salts in relation to this characteristic, since, the salinity tolerance is variable between species, between genotypes and even in a species, between stages of development of the plant, emphasising that in each stage, salinity tolerance is controlled by more than one gene and highly influenced by environmental factors [17,18,19,20].

It is important to point out that it is of great value to the research that no significant effect has been found. This demonstrates the potential of the genotypes under study since they were studied in the rootstock stage, during the grafting phase, that is, the canopy/rootstock and field combination in the production phase. With regard to the pH variable, a significant effect is observed only for the genotype factor (Table 2), presenting a general mean of 3.36, showing that genotype TSKFL x (LCR x TR) – 018 was highlighted with the highest mean 2.72 and the genotype TSKC x (LCR x TR) – 017 with the lowest mean of 2.02 (Table 3), as were studied two progenies and within the same progeny, since in citrus, there is a genetic variation even in individuals from the same parents, and segregation may occur [17,18]. This corroborates with the results found by Silva et al. [21] when studying the perception of stress in citrus genotypes under irrigation with salinised waters in the rootstock phase through gas exchange evaluations.

For the salinity factor, the genotypes irrigated with EC water equal to 0.3 dSm^{-1} presented a lower average than the genotypes irrigated with water of higher EC 3,0 dSm^{-1}, being these of 2.35 and 2.36 respectively, and did not differ statistically. This means that the increase in salinity did not influence fruit pH, so changes in juice pH after fruit ripening are almost imperceptible in sensory analysis tests. Citrus fruits commonly present pH between 2.0 for limes, lemons, and other acid fruits and approximately 5.0 for ripe mandarins and oranges [22].

Table 2. Number of fruits (NF), number of locule (NL), juice volume (VOL), juice weight (PS), pH, electrical conductivity, soluble solids (SS), titratable acidity and ascorbic acid (A, A mg / 100 mL) in Tahiti acid lime fruits grafted on rootstocks irrigated with waters of different salinities

Sources of variation	(G)	(S)	G X S	Block	Error	Mean	CV %
Nº of fruits	25.65^{ns}	52.18^{ns}	58.18^{ns}	22.79	23.57	17.64	27.51
Nº of locules	0.41^{ns}	2.99^{**}	0.54^{ns}	0.14	0.23	10.78	4.49
Vol. of juice	13476.58^{ns}	3474.72^{ns}	19839.11^{ns}	369.54	13790.39	372.14	31.56
Weight of juice	7601.08^{ns}	22080.0^{ns}	7031.45^{ns}	9504.24	5942.60	375.10	20.55
pH	0.30^{**}	0.18^{ns}	0.08^{ns}	1.06	0.09	2.36	12.96
CE (dSm^{-1})	0.44^{ns}	2.02^{**}	0.13^{ns}	3.33	0.21	4.31	10.74
SS (%)	0.40^{ns}	23.44^{**}	0.820^{ns}	41.53	0.52	8.40	8.62
AT (%)	0.16^{ns}	7.45^{**}	0.15^{ns}	0.312	0.12	5.89	5.94
AA (mg 100 mL^{-1})	224.81^{ns}	578.52^{**}	17.71^{ns}	20.24	16.63	38.08	10.71
DF	9	1	9	2	38	-	-

, = significant at the 0.05 and 0.01 probability level; NS = not significant; GL = degree of freedom; CV = coefficient of variation.*

Table 3. Test of means related to pH; in fruits of the Tahiti acid lime tree grafted on different rootstocks irrigated with waters of different salinities

Genotypes	pH
TSKC X (LCR XTR) – 017	2.02B
TSKC X (LCR XTR) – 032	2.43A
TSKC X (LCR XTR) – 059	2.16B
TSKFL X (LCR XTR) – 012	2.45A
TSKFL X (LCR XTR) – 018	2.73A
TSKFL X TRBK – 011	2.36A
TSKFL X TRBK – 017	2.51A
TSKFL X TRBK – 028	2.31A
TSKFL X TRBK – 030	2.09B
LCRSTC	2.59A

Different uppercase letters indicate a significant difference between hybrids by the Skott-Knott test at the 5% probability level.

It was verified that the effect caused by the treatments was significant only for the salinity factor (Table 2), where these genotypes presented an average of 4.31 dSm^{-1}, being the genotypes were irrigated with waters of lower EC 0.3 dSm^{-1} presented a lower average 4.13 dSm^{-1} and genotypes that were irrigated with water of higher EC 3.0 dSm^{-1} presented an average of 4.49 dSm^{-1}, that is, the genotypes irrigated with water of higher salinity presented a superiority of 8.02% (Table 4), which may be attributed to a greater displacement of salts in the filling of the fruits. However, for genotypes, the LCRSTC control presented an average of 4.72 dSm^{-1} followed by the TSKFL x TRBK – 028 4.70 dSm^{-1} genotypes, whereas the TSKFL x TRBK – 017 genotypes presented lower average for this variable is 3.78 dSm^{-1}.

Regarding the soluble solids content (SS%), it was only significant when studying the isolated factors, which had a significant effect on salinity (Table 2), it was reported that the plants when irrigated with conductivity water 3.0 dSm^{-1} presented 13.86% superiority when compared to plants irrigated with water of 0.3 dSm^{-1} (Table 4). Some arguments to relate the content of soluble solids to the amount of water applied through irrigation consist of conditions of lower availability of water in the soil, the concentration of sugars in the fruits tends to increase, considering the lower water absorption by the plant and, consequently, a lower dilution of these solids when submitted to water deficit [23,24]. The genotype TSKFL x TRBK - 030 with the highest average of 8.75% and the genotype TSKC x (LCR x TR) - 017 with the lowest genotype average of 7.95%, although they did not differ statistically.

Table 4. Test of average referring to significant variables (NL); (EC - dSm^{-1}); (SS - %); (AT - %) and (AA - mg 100 mL^{-1}) in Tahiti acid lime fruits grafted on different rootstocks irrigated with waters of different salinities

Significant variables	Irrigation water levels	
	0,3 dSm^{-1}	3,0 dSm^{-1}
Nº de locules	16.91B	18.58A
Conductivity (dSm^{-1})	4.13B	4.49A
Soluble Solids (SS%)	7.78B	9.03A
Titratable Acidity (AT%)	5.54B	6.25A
Ascorbic acid (mg 100 mL^{-1})	34.98B	41.19A

Distinct capital letters on the same line indicate a significant difference between hybrids by the Skott-Knott test at the 5% probability level.

According to (Table 4), the titratable acidity variable (AT%) was only influenced by the salinity factor, where the plants that received higher salinity waters stood out in relation to those that received lower salinity water in 11.22% (Table 4). The genotype TSKC x (LCR x TR) – 032 presented the highest average 6.07% and genotype TSKFL x TRBK – 017 showed the lowest average 5, 64%, so that the values found in this work are considered acceptable being close to the values present in the literature for citrus fruits, similar to those reported by Silva et al. [25] and Alves Júnior et al. [26], whose treatments involving different irrigation slides did not cause significant difference for titratable acidity.

Based on (Table 2), the ascorbic acid levels were not influenced by the salinity factor when studied alone, with an overall average of 38.08 mg 100 mL^{-1}, and the plants that underwent irrigation with a higher EC of 3.0 dSm^{-1} had an increase of 15.08% (Table 4), in the amount of ascorbic acid when compared to the plants that were irrigated with water of local supply 0.3 dSm^{-1}. TSKC X (LCR x TR) – 032 was higher with 41.03 mg 100 mL^{-1} and TSKFL x TRBK – 028 genotype showed the lowest mean 33.82 mg 100 mL^{-1}, however, the values found resemble the ascorbic acid levels found in the tangerine-pocã, clove lemon and Galician lemon described by the Brazilian Food Composition Table, which was 41.8; 32.8 and 34.5 mg of ascorbic acid 100 mL^{-1} of juice respectively [27].

Considering the importance of the chemical qualities, especially the ascorbic acid content for citrus fruits, it is important to highlight that, although a significant effect was found for these characteristics, the values found did not decrease with the increase of the salinity in the irrigation water of the genotypes (Table 4), this may be linked to the fact that plants subjected to saline stress tend to increase the internal concentration of solutes, so that its potential is high, thus avoiding the loss of water to the soil. This ability to resist is mainly related to the intensity of compartmentalisation of the saline ions within the vacuoles and the maintenance of a favourable K^+ / Na^+ balance in the cytosol [28].

However, it was evident that the salinity of the water had an effect on the variables, so that this influence did not alter its postharvest quality, which can be related to the fact that most of the genotypes were considered salinity tolerant during the port phases graft and after grafting [29].

4. CONCLUSIONS

The different citrus rootstocks did not differ in the characteristics of fruit weight, number of locules, volume, and weight of juice. The irrigation with EC water of 3.0 dSm^{-1} allowed the highest number of locules, electrical conductivity, soluble solids, titratable acidity, and ascorbic acid. There was no significant interaction (genotype x water salinity) on the studied variables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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