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Initial productive performance of 'Tahiti' acid lime considering different rootstocks and levels of salt water[1]

Desempenho produtivo inicial da limeira ácida 'Tahiti' em distintos porta-enxertos e níveis de águas salinas

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ABSTRACT - The productive performance of citrus plants is limited by abiotic factors such as salinity. The response to these factors varies among rootstocks, and to guarantee sustainability of the production system, it is possible to identify the most suitable genotypes agronomically for each growing environment. Given the above, the aim of this study was to evaluate the productive performance of the 'Tahiti' acid lime combined with different citrus rootstocks irrigated with water at different levels of salinity during the first year of fruit production. Three levels of electrical conductivity of the irrigation water (0.14, 2.40 and 4.80 dS m^{-1}) and 13 rootstocks ('Santa Cruz Rangpur' lime, 'Indio', 'Riverside' and 'San Diego' citrandarins, 'Sunki Tropical' mandarin and eight hybrids generated by the Citrus Breeding Program of Embrapa Cassava & Fruits). The experimental design was of randomised blocks, with four replications and one plant per plot. The fruits were harvested from 300 to 720 days after transplanting (DAT) to pots with a capacity of 60 L, which had been adapted for use as lysimeters. Fruit production was determined by weight and number, in addition to measuring the size and the thickness of the peel. It was found that water of up to 2.4 dS m^{-1} can be used for citrus irrigation without significantly compromising early fruit production in the 'Tahiti' acid lime when grafted on the 'Sunki Tropical' mandarin, 'Riverside' citrandarin, and on the hybrids TSKC x TRBK - 007, TSKC x CTTR - 012, HTR - 069, TSKC x (LCR x TR) - 040 and TSKC x (LCR x TR) - 059, which resulted in an earlier start to production. At the salinity level of 4.8 dS m^{-1}, the 'Tahiti' acid lime proved to be more productive and less sensitive when grafted onto 'Sunki Tropical' mandarin, TSKC x TRBK - 007, TSKC x CTTR - 012, HTR - 069, and TSKC x (LCR x TR) - 040 hybrids.

Key words: *Citrus ×latifolia*. *Citrus* spp. *Poncirus* hybrids. Salt stress.

RESUMO - O desempenho produtivo dos citros é limitado por fatores abióticos, a exemplo da salinidade. A resposta a esses fatores é variável entre porta-enxertos, podendo-se identificar, em conformidade com cada ambiente de cultivo, genótipos agronomicamente mais adequados, que garantem a sustentabilidade do sistema produtivo. Diante do exposto, objetivou-se avaliar o desempenho produtivo da limeira ácida 'Tahiti' em combinação com distintos porta-enxertos irrigados com águas contendo diferentes níveis de salinidade, durante o primeiro ano de produção de frutos. Foram avaliadas três condutividades elétricas da água de irrigação (0,14, 2,40 e 4,80 dS m^{-1}) e 13 porta-enxertos (limoeiro 'Cravo Santa Cruz', citrandarins 'Indio', 'Riverside' e 'San Diego', tangerineira 'Sunki Tropical' e oito híbridos gerados pelo Programa de Melhoramento Genético de Citros da Embrapa Mandioca e Fruticultura). O delineamento experimental foi o de blocos casualizados com quatro repetições e uma planta por parcela. No período entre 300 e 720 dias após o transplantio (DAT) para vasos com capacidade de 60 L, adaptados como lisímetros, foram realizadas colheitas de frutos, contabilizando-se a produção de frutos, em peso e número, além de serem mensurados o tamanho e a espessura da casca destes. Constatou-se que águas de até 2,4 dS m^{-1} podem ser utilizadas na irrigação de citros sem comprometer, significativamente, a produção da inicial de frutos da limeira ácida 'Tahiti' quando enxertada na tangerineira 'Sunki Tropical', no citrandarin 'Riverside' e nos híbridos TSKC x TRBK - 007, TSKC x CTTR - 012, HTR - 069, TSKC x (LCR x TR) - 040 e TSKC x (LCR x TR) - 059, que determinaram maior precocidade de início de produção. Quanto ao nível de salinidade da água de 4,8 dS m^{-1}, a limeira ácida 'Tahiti' mostrou-se mais produtiva e menos sensível em combinação com a tangerineira 'Sunki Tropical' e com os híbridos TSKC x TRBK - 007, TSKC x CTTR - 012, HTR - 069, and TSKC x (LCR x TR) - 040.

Palavras-chave: *Citrus ×latifolia*. *Citrus* spp. Híbridos de *Poncirus*. Estresse salino.

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INTRODUCTION

Commercial citrus plants comprise two distinct individuals, the scion and rootstock, which complement each other by a process of symbiosis. They are grown in different types of soil and climate (ALMEIDA *et al*., 2018), associating with species and hybrids of genus *Citrus* (L.) and related genera, such as *Fortunella* (Swing.) and *Poncirus* (Raf.).

Produced throughout Brazil, citrus fruits include sweet oranges [*C.* ×*sinensis* (L.) Osbeck], tangerines (various species, especially *C. reticulata* Blanco), acid limes, particularly 'Tahiti' [*C.* ×*latifolia* (Yu. Tanaka) Tanaka], true lemons [*C.* ×*limon* (L.) Burm. f.] and grapefruits (*C.* ×*paradisi* Macfad.), among other species and hybrids.

The southeast, south and northeast of the country are the main producers, especially of sweet oranges, of whose juice Brazil is the largest producer and exporter in the world (IBGE, 2020).

In the northeast, as throughout the country, citrus cultivation is of great socioeconomic importance, generating jobs and income both directly and indirectly, and promoting regional development. However, the productivity of orchards in the northeast is relatively low, around 12 t ha^{-1} (IBGE, 2020), far below the potential for the area, estimated at 40 t ha^{-1} (SILVA *et al*., 2013). This may be associated with water restrictions due to the low and irregular rainfall, in addition to the restricted availability of good quality water for irrigation purposes (GHEYI *et al*., 2016).

The low productivity can also be attributed to the use of rootstock varieties that are subject to biotic problems, such as the 'Rangpur' lime (*C.* ×*limonia* Osbeck), mostly found in the Coastal Tablelands of the northeast, whose shelf life is shortened by its susceptibility to diseases, such as citrus decline, which, combined with limiting water conditions, results in a reduction in productivity, as the rootstock is unable to provide the scion with the desirable productive characteristics (BASTOS *et al*., 2014).

In areas subject to salinity, which are common in the semi-arid region of the northeast, the levels of citrus productivity are even lower; this can be avoided with the use of scion/rootstock combinations that are tolerant to this type of abiotic stress, together with suitable crop management (BRITO *et al*., 2018, 2021).

Although the rootstock is mainly responsible for the sustainability of the citrus orchard in the growing environment, attention should be paid to the importance of the scion variety in the context of crop adaptation to salt stress, as verified by Brito *et al*. (2021), who point out that the TSKFL x CTTR - 013 hybrid, obtained by the Citrus Breeding Program of Embrapa Cassava & Fruits - CBP, showed greater sensitivity to salinity when grafted with the 'Tahiti' acid lime than when the scion variety was the 'Star Ruby' grapefruit. This shows that, because of its behaviour, the 'Tahiti' acid lime is of interest in studies aimed at identifying rootstocks that are tolerant to salinity. The mentioned hybrid resulted from a cross between the 'Sunki of Florida' mandarin [*C. sunki* (Hayata) hort ex Tanaka] (TSKFL) with the 'Troyer' citrange [*C.* ×*sinensis* x *Poncirus trifoliata* (L.) Raf.] (CTTR).

As such, citrus cultivation in areas of semi-arid climate using water with electrical conductivities greater than 1.1 dS m^{-1} [the limit for salt tolerance established for the sweet orange by Maas (1993)], can be viable, provided compatible and tolerant scion/rootstock combinations are used (BARBOSA *et al*., 2017; FERNANDES *et al*., 2011).

Given the above, the aim of this study was to evaluate production in the 'Tahiti' acid lime combined with different rootstocks and under irrigation with different levels of salinity, during the initial stage of fruit production.

MATERIAL AND METHODS

The research was carried out in the experimental area of the Federal University of Sergipe, Sertão Campus, in the district of Nossa Senhora da Glória, Sergipe, at 10º12'18" S and 37º19'39" W, and an altitude of 294 m. The climate is predominantly hot and dry semi-arid, with a mean annual rainfall of 750 mm and mean annual temperature of 24 ºC (Figure 1).

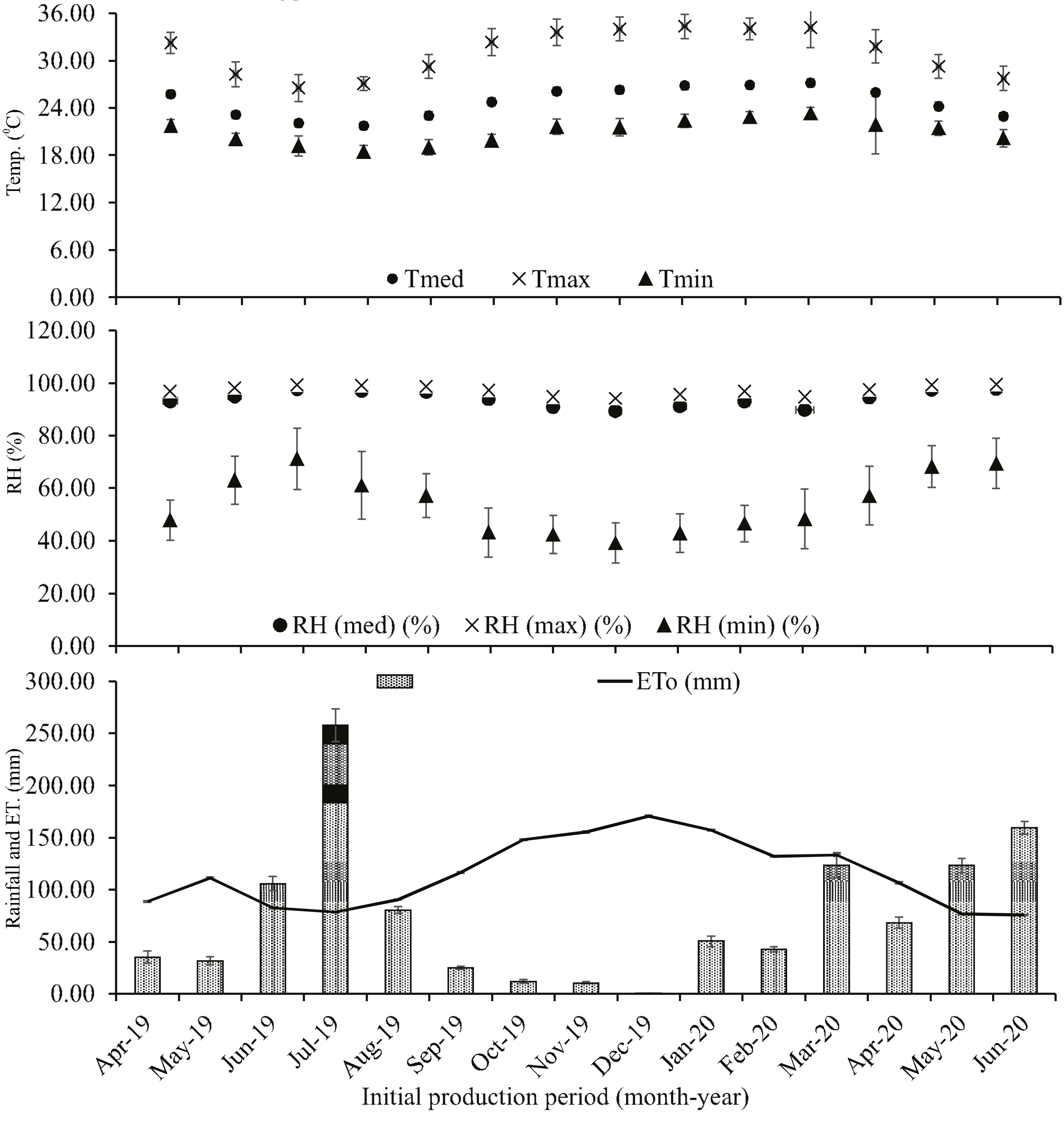
The mean relative humidity was close to 100% throughout most of the research period, with a minimum of 39.1% and maximum of 99.5% (Figure 1B). The accumulated rainfall during the study was 1125.2 mm, higher than the local average, and evapotranspiration was 1723 mm, characterising a negative balance (Figure 1C).

During the experimental period, from April 2019 to June 2020, the average temperature ranged from 21.7 ºC to 27.2 ºC, with a minimum for the period of 18.4 ºC and a maximum of 34.3 °C (Figure 1A).

The experimental design was of randomised blocks with four replications in a split-plot scheme. Thirteen rootstocks provided by CBP and described in Table 1 were evaluated in the main plot using the Tahiti acid lime as the scion variety.

The subplot comprised three electrical conductivities for the irrigation water (ECw of 0.14, 2.4 and 4.8 dS m^{-1}), with the lowest salinity related to water from the São Francisco River, and the others obtained by diluting the water from a tubular well

Figure 1 - Maximum, mean and minimum temperatures (A), maximum, mean and minimum relative humidity (B), rainfall, and reference evapotranspiration (C) seen during the initial production period, from the agrometeorological station close to the experimental area. Nossa Senhora da Glória, Sergipe, Brazil



(EC_w = 30.0 dS m^{-1}) with water from the São Francisco River. Each experimental unit consisted of one plant. Irrigation with the treatment water was started 30 days after transplanting (DAT) the plants of the different scion/rootstock combinations into pots with a capacity of 60 L, adapted for use as lysimeters, and continued throughout the first fruit production cycle, from 300 DAT to 720 DAT, during which time flowering persisted.

As such, there were 39 treatments (13 scion/rootstock combinations x 3 types of salt water), repeated in four blocks, each consisting of one working plant, giving a total of 156 plots.

After preparation, the water was stored in 1000 L plastic tanks, one for each type of water used; these were properly protected to avoid evaporation, the entry of rainwater, and contamination by external agents, which could compromise the quality of the water.

The plants of each scion/rootstock combination were produced by Viveiro Tamafe® Ltda., a partner of Embrapa Cassava & Fruits, following the recommendations for the production of certified citrus seedlings. To produce the nursery plants, 2-L plastic bags were used containing Basaplant® commercial substrate, consisting of pine bark, humus and vermiculite.

The nursery plants remained in the bags for 10 months, when they were ready to be transplanted into 60-L pots, adapted for use as lysimeters, which were kept in the experimental area at UFS, Sertão Campus, as mentioned. The lysimeters were filled with soil taken from an area close to the experiment, characterised as a Red Yellow Argisol, which was properly sieved using a no. 10 mesh.

The lysimeters were filled by first depositing a 4-cm layer of gravel, followed by a 17-cm layer of soil, and finally another 29-cm layer of soil mixed with tanned cattle manure, so that each lysimeter was filled with 45 L of soil and 10 L of manure, giving a total of 55 L.

Up to 30 days after transplanting, the plants were irrigated with water of low electrical conductivity (ECw) from the São Francisco River, obtained from the local water supply. At the end of this period, application of the different types of water began. Irrigation was carried out every two days, using drip irrigation installed in the lysimeters, as the plants had by now adapted to the growing environment.

The water balance method was used in irrigation management to replace the average daily consumption of the plants plus a leaching fraction. The volume to be applied (mL) was divided by 0.9, corresponding to a leaching fraction of 10%, with the aim of maintaining a part of the salts accumulated in the root zone from the irrigation water, as per Expression (1).

$$VI = \frac{(Va - Vd)}{1 - FL} \qquad (1)$$

where: VI = volume to be irrigated in the subsequent irrigation event (mL); Va = volume applied during the previous irrigation event (mL); Vd drained volume (mL); FL = coefficient used to obtain a leaching fraction of approximately 10% (1-0.10).

To collect the drained water, each lysimeter was perforated at the base and connected to a hose that allowed the drained fluid to flow into an 18-L vessel and the drained volume to be measured.

Nutritional management of the plants followed the recommendations of Mattos Junior *et al*. (2005), adopting weed control, and the prevention and control of pests and diseases normally recommended in citrus production. The following activities were carried out: cleaning the irrigation system, preparing the treatment water solutions and collecting the fruit.

At the end of the production period, soil samples were collected from each experimental plot to determine the salinity, with the data shown in Table 2, considering the result of the mean values of the scion/rootstock combinations and blocks for each level of salinity of the applied water. In general, it was found that the electrical conductivity of the saturation extract (ECse) ranged from 3 to 15 dS m^{-1}, the pH between 5 and 6, and the sodium adsorption ratio (SAR) between 2 and 40, allowing the soil that received water at 0.14 dS m^{-1} to be characterised as normal and those that received water at 2.4 and 4.8 dS m^{-1} as saline-sodic, as per Ayers and Westcot (1999).

Table 1 - List of the rootstocks used in the study

Number	Rootstock	Number	Rootstock
1	‘Santa Cruz Rangpur’ lime	8	TSKC x CTTR - 012
2	‘Indio’ citrandarin	9	TSKFL x CTTR - 013
3	‘Riverside’ citrandarin	10	HTR - 069[1]
4	‘San Diego’ citrandarin	11	TSKC x (LCR x TR) - 0401
5	‘Sunki Tropical’ mandarin	12	TSKC x (LCR x TR) - 0592
6	TSKC x TRBK - 007	13	TSKC x CTARG - 019
7	TSKFL x TRBK - 030		

‘Santa Cruz Rangpur’ lime (*Citrus ×limonia* Osbeck); HTR = trifoliate hybrid resulting from crossing the ‘Pera’ sweet orange [*C. ×sinensis* (L.) Osbeck] with the ‘Yuma’ citrange [C. ×*sinensis* x *Poncirus trifoliata* (L.) Raf.]; LCR = ‘Rangpur’ lime; TSKC = common ‘Sunki’ mandarin [C. *sunki* (Hayata) hort. ex Tanaka]; TR = *P. trifoliata*; TSKFL = ‘Sunki of Florida’ mandarin; TRBK = *P. trifoliata* ‘Benecke’; CTARG = ‘Argentina’ citrange; CTTR = ‘Troyer’ citrange. [1] Rootstock variety in process of registration in the National Cultivar Registry (RNC) of the Ministry of Agriculture, Livestock and Supply (Ministério da Agricultura, Pecuária e Abastecimento - MAPA). [2] Rootstock variety registered in RNC-MAPA under the name BRS Bravo

Table 2 - Chemical characteristics of the soil solution and exchangeable sodium percentage (ESP) for each level of salinity, resulting from the mean value of samples taken from the plots

Salinity	pH	ECse dS m^{-1}	Ca^{2+}	K^{+}	Na^{+}	Mg^{2+}	SAR ($mmol_c$ dm^{-3})$^{-0.5}$	ESP %
			---------- $mmol_c$ dm^{-3} ----------					
0.14	5.618	3.971	1.125	7.402	2.350	1.135	2.160	1.123
2.40	5.955	9.542	0.601	13.195	36.200	1.603	34.707	20.900
4.80	6.005	14.763	7.218	15.575	81.500	2.675	40.453	31.500

pH = hydrogen potential; ECse = electrical conductivity of the saturation extract; SAR = sodium adsorption ratio

During the fruit production phase, which began 300 days after transplanting (DAT), harvests were carried out as the fruit matured (GAYET; SALVO FILHO, 2003), followed by counting and weighing to determine the number of fruit per plant (NFPL), fruit weight per plant (FW) and mean fruit weight (MFW), using an analytical balance with a precision of 0.01 g. In addition, the mean longitudinal fruit diameter (MLFD), mean transversal fruit diameter (MTFD) and mean peel thickness (MPT) were determined.

The data were submitted to the Shapiro-Wilk normality test ($p < 0.05$), followed by analysis of variance using the model described in Expression (2).

$$Y = m + Bk + Gi + Aj + GAij + Eijk \quad (2)$$

where 'Y' is the phenotypic observation vector; 'm' is the fixed mean vector; 'B', 'G', 'A' and 'E' are the incidence matrices for the effects; 'k' is the fixed effects vector for the blocks, genotypes and salinities; 'i' is the effects vector for the genotypes, assumed to be random; 'j' is the effects vector for salinity, assumed to be random; 'ij' is the interaction effects vector, for which the R 3.6® software (BHERING, 2017) was used.

Whenever there was a significant effect from the factors or the interaction, the means comparison test (Tukey, $p < 0.05$) was carried out for the factor salinity and the means grouping test (Scott-Knott, $p < 0.05$) for the factor genotype.

Finally, the data were standardised to obtain a null mean and unit variance, and submitted to principal component analysis (PCA), which resulted in linear combinations of the variables analysed using the highest eigenvalues in the correlation matrix (HAIR *et al*., 2009). The Past3® software was used to construct a biplot of the groups of genotypes and variables (SETIMELA *et al*., 2007).

RESULTS AND DISCUSSION

By analysing fruit production (Table 3), an effect was seen from the interaction between the rootstocks and levels of water salinity on the number of fruit per plant (NFPL) and mean fruit weight (MFW) ($p \leq 0.05$). Whereas, when the factors were studied in isolation, there were significant differences between the genotypes used as rootstocks on mean fruit weight (MFW) in the 'Tahiti' acid lime ($p \leq 0.01$), and the effect of salinity ($p \leq 0.01$) on the number of fruit per plant (NFPL), fruit weight per plant (FW) and mean fruit weight (MFW).

No significant differences were noted among rootstocks or the effect of salinity on the size or shape of the fruit of the 'Tahiti' acid lime (Table 3); this may be related to the plant's ability to maintain these characteristics even under the effect of salinity, which can cause a reduction in the growth of citrus plants (ADAMS; AC-PANGAN; ROSSI, 2019; BRITO *et al*., 2021).

Furthermore, the effect of the interaction between the rootstocks and salinity is related to the different behaviours that citrus show under such stress, since tolerance to salinity varies with the species, with the scion/rootstock combination, and among the stages of plant development (BRITO *et al*., 2014), the latter being controlled by various genes and influenced by environmental factors (SYVERTSEN; GARCIA-SANCHEZ, 2014).

The number of fruit per plant was reduced by the salinity of the water, but differently between rootstocks (Figure 2). Regarding the lowest level of salinity, 0.14 dS m^{-1} (Figure 2A), according to the means grouping test, there was no difference between the genotypes. However, it was found that the 'San Diego' and 'Indio' citrandarins, 'Sunki of Florida' mandarin (TSKFL) x *Poncirus trifoliata* 'Benecke' (TRBK) - 007 (TSKC x TRBK - 007) and TSKFL x TRBK - 030 afforded less variability in the number of fruit, as identified by the boxplots.

The application of water at 2.4 dS m^{-1} (Figure 2B) caused a general reduction in the number of fruit per

Table 3 - Analysis of variance of the number of fruit per plant (NFPL), fruit weight per plant (FW), mean fruit weight (MFW), mean longitudinal fruit diameter (MLFD), mean transversal fruit diameter (MTFD) and mean fruit peel thickness (MPT) for the 'Tahiti' acid lime [*Citrus ×latifolia* (Yu. Tanaka) Tanaka]/rootstock (RS) combinations under water salinity, 270 days after the start of salt stress

Source of Variation	DF	MEAN SQUARE					
		NFPL	FW	MFW	MLFD	MTFD	MPT
Block	3	58.99^{ns}	231500.83^{ns}	323.33**	25.92^{ns}	346.95**	0.71*
RS	12	119.92^{ns}	298621.30^{ns}	47.91**	10.99^{ns}	9.96^{ns}	0.14^{ns}
Error 1	36	85.84	191893.86	40.37	12.33	6.36	0.18
Salinity (Sal)	2	10281.82**	27051122.46**	251.53**	8.06^{ns}	3.26^{ns}	0.04^{ns}
RS x Sal	24	175.66*	284288.68*	72.519*	13.33^{ns}	7.20^{ns}	0.14^{ns}
Error 2	78	72.50	168967.88	29.59	15.472	11.60	0.19
CV 1 (%)		31.71	32.96	13.97	7.62	5.84	15.86
CV 2 (%)		30.52	30.93	11.96	8.54	7.89	16.40
Mean		29.215	1329.011	45.471	46.067	43.200	2.705

ns, * and ** = not significant, significant at 5% and at 1% according to the F-test, respectively; CV = Coefficient of variation; DF= Degree of freedom

plant, and allowed two distinct groups of rootstocks and one intermediary group, according to Tukey test. One related to the lower average number of fruits per plant, including the common 'Sunki' mandarin (TSKC) x 'Troyer' citrange (CTTR) - 012 (TSKC x CTTR - 012), TSKFL x CTTR - 013, TSKC x ['Rangpur' lime (LCR) x *P. trifoliata* (TR)] - 040 [TSKC x (LCR x TR) - 040] and TSKC x 'Argentina' citrange (CTARG) - 019 (TSKC x CTARG - 019). The second group included the 'San Diego', TSKC x TRBK - 007 and TSKFL x TRBK - 030 citrandarins, as well as the TSKC x (LCR x TR) - 059 citrimoniandarin, which displayed more stable fruit production, as shown by the lower variance of the boxplot. Highlight that the low number of fruits observed, especially in combinations with the rootstocks TSKC x CTTR - 012 and TSKC x (LCR x TR) - 040, can be relative to the necessity of more time for the beginning production.

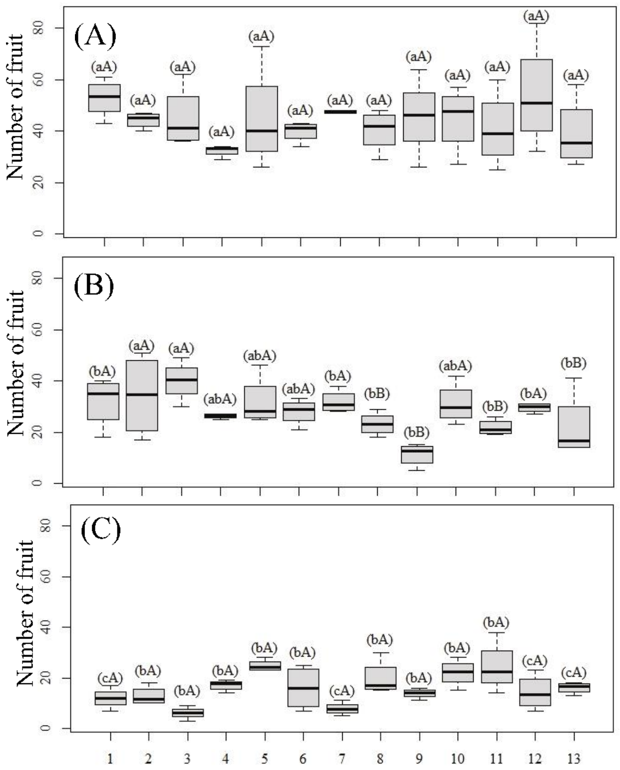
Increasing the water salinity to 4.8 dS m^{-1} caused a reduction in the number of fruits in all scion/rootstock combinations (Figure 2C), this was, however, less marked where the rootstocks were the 'Sunki Tropical' mandarin and the hybrids, TSKC x TRBK - 007, TSKC x CTTR - 012, HTR - 069 and TSKC x (LCR x TR) - 040, showing the lower sensitivity of these rootstocks to salinity. This result confirms those of Brito *et al*. (2021) in relation to the HTR – 069 trifoliolate hybrid.

It should be noted that analysing these results shows that the TSKC x TRBK – 007 citrandarin, which behaved well in terms of water at both 2.4 dS m^{-1} and 4.8 dS m^{-1}, is a rootstock that induces early fruit production in the 'Tahiti' acid lime, the opposite of that seen with the TSKC x CTTR - 012 citrangedarin and TSKC x (LCR x TR) - 040 citrimoniandarin, which showed better behaviour in terms of fruit production at the highest level of salinity, 4.8 dS m^{-1} only. These rootstocks proved to be very tolerant to salinity.

Studies with citrus genotypes under water salinity, conducted by BRITO *et al*. (2014) and BARBOSA *et al*. (2017), state that water at an electrical conductivity of up to 2.0 dS m^{-1} can be used with no restrictions on plant development, and physiological behaviour, especially with regard to genotypes recommended as rootstocks, tolerant to this abiotic stress, Troyer citrange, 'Volkamer' lemon (LVK) (*C. ×volkameriana* V. Ten. & Pasq.), HTR - 069, 'Santa Cruz Rangpur' lime, TSKC x Swingle citrumelo (CTSW) [*C. paradisi* Macfad. x *P. trifoliata* (L.) Raf.] – 041, LVK x LCR – 038 and 'Florida' rough lemon (*C. ×jambhiri* Lush.). This is confirmed in the present study with the use of water at 2.4 dS m^{-1}, which determined a reduction in fruit production within acceptable levels, albeit a little high, which may also be related to water balance, since there was considerable rainfall during the experimental period (Figure 1C), despite an ECse of 9.5 dS m^{-1} being seen (Table 2).

Salinity caused a reduction in fruit weight per plant (Figure 3) in all scion/rootstock combinations, although the formation of distinct groups of rootstocks only occurred when water at a lower level of salinity was applied, with the highest production seen in the rootstocks 'Santa Cruz Rangpur' lime, 'Indio', 'Riverside' and TSKFL x TRBK – 030 citrandarins,

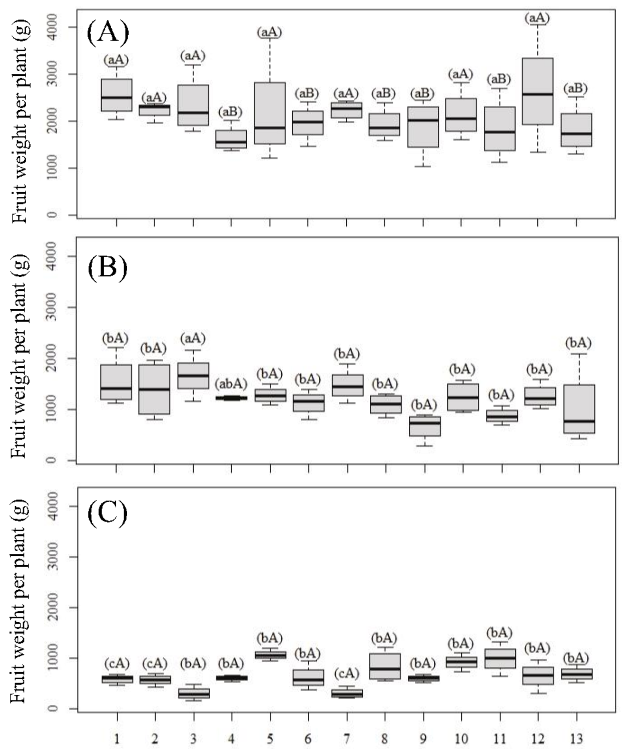
Figure 2 - Boxplot of the mean number of fruit per plant in the ‘Tahiti’ acid lime [*Citrus ×latifolia* (Yu. Tanaka) Tanaka] grafted onto 13 rootstocks under irrigation with water at 0.14 dS m^{-1} (A), 2.40 dS m^{-1} (B), and 4.80 dS m^{-1} (C), with a breakdown of the Tukey means comparison test for the factor salinity in each combination, and the Scott-Knott means grouping test among combinations for each level of salinity, both at 5% probability. A list of the rootstocks used is shown to the side of the figure



1 - ‘Santa Cruz Rangpur’ lime (*Citrus ×limonia* Osbeck). 2 - ‘Indio’ citrandarin [*C. sunki* (Hayata) hort. ex Tanaka x *Poncirus trifoliata* (L.) Raf.]. 3 - ‘Riverside’ citrandarin. 4 - ‘San Diego’ citrandarin. 5 - ‘Sunki Tropical’ (*C. sunki*) mandarin. 6 - Common ‘Sunki’ mandarin (TSKC) x *P. trifoliata* ‘Benecke’ selection (TRBK) - 007. 7 - ‘Sunki of Flórida’ mandarin (TSKFL) x TRBK - 030. 8 -TSKC x ‘Troyer’ citrange [*C. ×sinensis* (L.) Osbeck x *P. trifoliata*] (CTTR) - 012. 9 - TSKFL x CTTR - 013. 10 - HTR - 069 [trifoliolate hybrid resulting from crossing the ‘Pera’ sweet orange (*C. ×sinensis*) with the ‘Yuma’ citrange]. 11 - TSKC x [‘Rangpur’ lime (LCR) x *P. trifoliata* (TR)] - 040. 12 - TSKC x (LCR x TR) - 059. 13 - TSKC x ‘Argentina’ citrange (CTARG) - 019. Boxplots with the same lowercase letter do not differ statistically between levels of salinity by the Tukey test ($p < 0.05$). Boxplots with the same uppercase letter belong to the same rootstocks group by the Scott-Knott test ($p < 0.05$)

‘Sunki Tropical’ mandarin, HTR - 069, and TSKC x (LCR x TR) - 059 citrimoniandarin as shown by the Scott-Knott test ($p < 0.05$).

Figure 3 - Boxplot of the mean fruit weight per plant (g) in the ‘Tahiti’ acid lime [*Citrus ×latifolia* (Yu. Tanaka) Tanaka] grafted onto 13 rootstocks under irrigation with water at 0.14 dS m^{-1} (A), 2.40 dS m^{-1} (B), and 4.80 dS m^{-1} (C), with a breakdown of the Tukey means comparison test for the factor salinity in each combination, and the Scott-Knott means grouping test among combinations for each level of salinity, both at 5% probability. A list of the rootstocks used is shown to the side of the figure



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Furthermore, in addition to being among the rootstocks inducing the highest fruit production when irrigated with low salinity water, the ‘Riverside’ citrandarin, the ‘Sunki Tropical’ mandarin and the HTR - 069 trifoliate hybrid were related to more stable production, as noted in the boxplots between the levels of salinity (Figure 3).

Citrus cultivation is based on the rootstock varieties, as these influence several characteristics of the scion variety, such as the quality and quantity of the fruit, the vigour and size of the plant, tolerance to abiotic factors, and resistance/tolerance to biotic factors (SANTANA *et al*., 2018). It should be noted that the combinations of ‘Tahiti’ and the rootstocks studied in this work are at the beginning of the production phase, and the results presented are still preliminary.

The mean fruit weight (MFW) also suffered a reduction for increases in the level of salinity of the water, with differences between rootstocks (Figure 4), which were more marked when applying water at 2.4 dS m^{-1} (Figure 4B), presenting fruit with a higher mean weight when the rootstock was the TSKFL x CTTR – 013 citrangedarin.

It is important to point out that at the beginning of the production process there are variations and fluctuations in fruit production, which stabilise between the 5 th and 7 th year of production, when the plants reach a higher level of economic return (BLUMER; POMPEU JUNIOR, 2005; CARVALHO *et al*., 2016).

Salinity also determined greater variability in mean fruit weight for combinations of different scions with various rootstocks. It should be noted that at the electrical conductivity of 0.14 dS m^{-1}, the highest amplitudes were seen with the HTR - 069 trifoliolate hybrid and the TSKC x CTARG – 019 citrangedarin. While at 2.4 dS m^{-1}, the greatest variations occurred for the rootstocks ‘Santa Cruz Rangpur’ lime, ‘Riverside’ citrandarin, and TSKC x (LCR x TR) - 059 citrimoniandarin. Considering irrigation at 4.8 dS m^{-1}, the greatest variations occurred with the rootstocks ‘Santa Cruz Rangpur’ lime, TSKC x TRBK - 007 citrandarin and the TSKC x CTARG – 019 citrangedarin, as shown by the boxplot analysis (Figure 4).

The productive performance of the different scion/rootstock combinations under salinity can be viewed, in general terms, using principal component analysis (Figure 5) from the dispersion of the results, showing higher scores for the first (CP1) and second (CP2) components, which, together, accounted for 77.3% of the response (Figures 5A and 5B).

From the component analysis, it can be seen that the vectors related to salinity are obtuse, with angles greater than 90º, compared to the vectors related to the production variables (Figure 5A), confirming the negative correlation between these variables, especially the number and weight of fruit per plant, which have an angle of nearly 180º from the vectors for soil sodium (NaSoil) and electrical conductivity in the saturation extract (ECse).

Figure 4 - Boxplot of the averages for mean fruit weight (g) per plant in the ‘Tahiti’ acid lime [*Citrus ×latifolia* (Yu. Tanaka) Tanaka] grafted onto 13 rootstocks under irrigation with water at 0.14 dS m^{-1} (A), 2.40 dS m^{-1} (B), and 4.80 dS m^{-1} (C), with a breakdown of the Tukey means comparison test for the factor salinity in each combination, and the Scott-Knott means grouping test among combinations for each level of salinity, both at 5% probability. A list of the rootstocks used is shown to the side of the figure

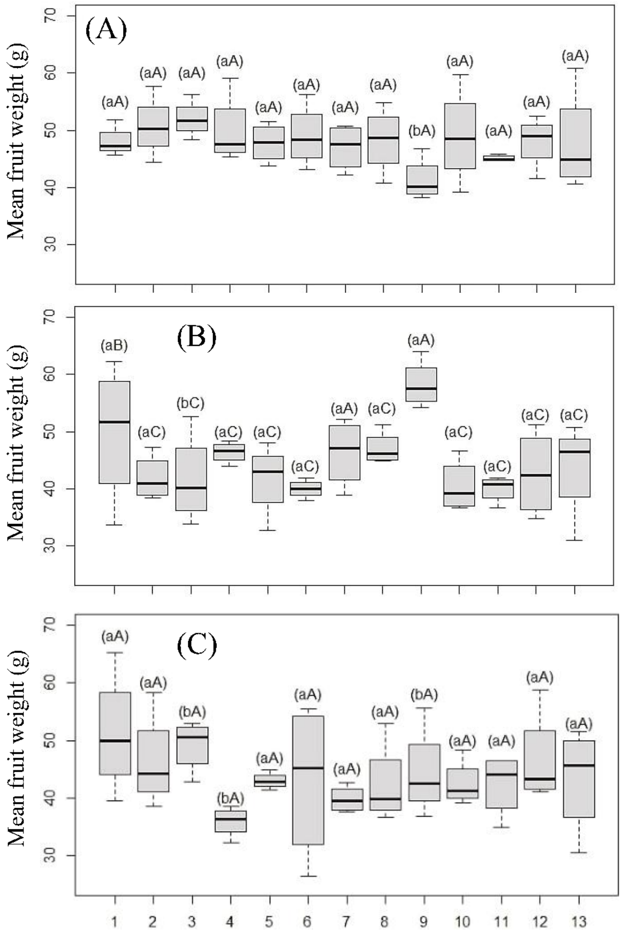

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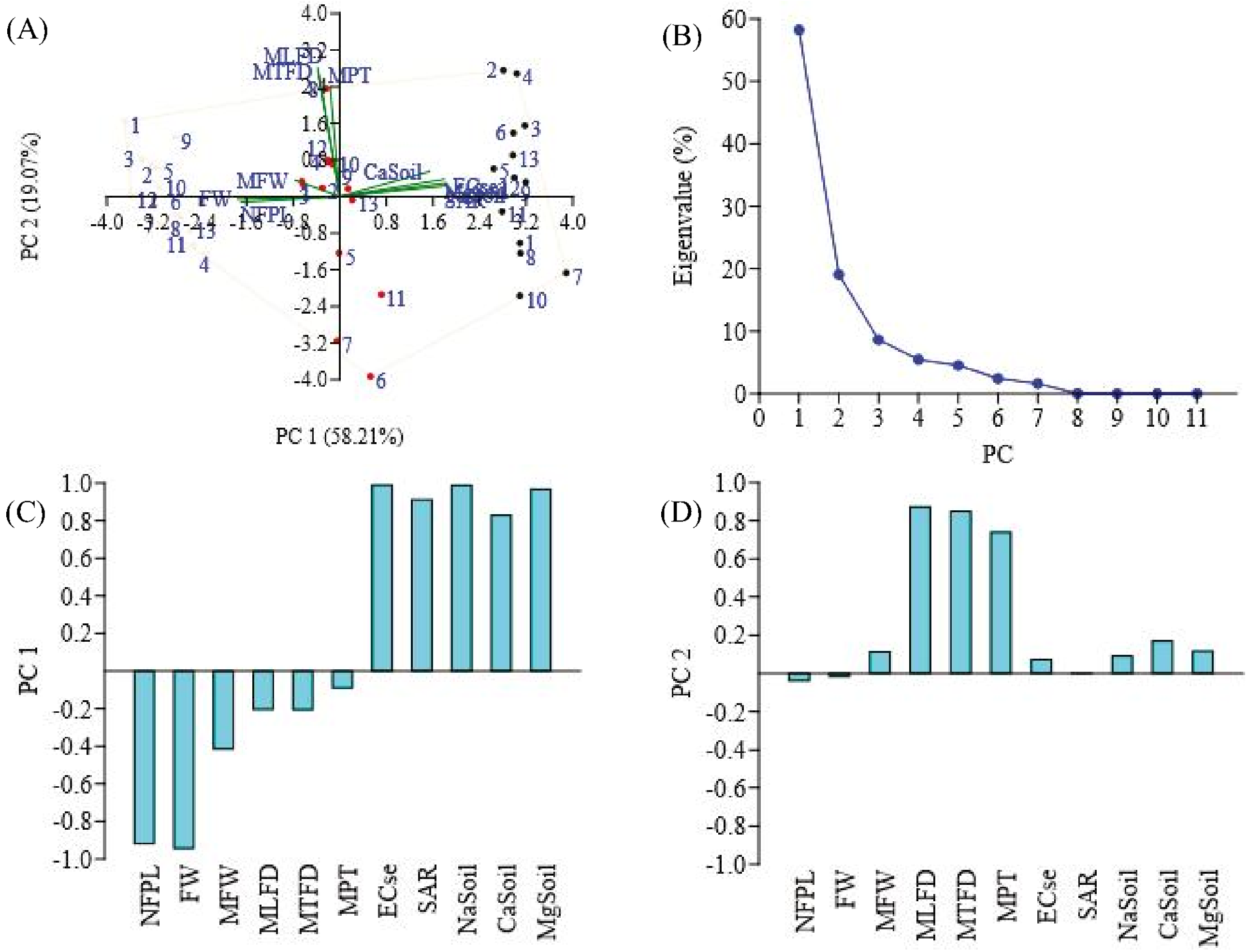
Figure 5 - Dispersion of 13 rootstocks combined with the ‘Tahiti’ acid lime [*Citrus* ×*latifolia* (Yu. Tanaka) Tanaka], based on the scores of the first (CP1) and second (CP2) principal components under water salinity (A), the eigenvalues of the principal components (B), the correlation among the variables in principal component 1 (C), and the correlation between the variables in principal component 2 (D)



NFPL = number of fruit per plant; FW = fruit weight per plant; MFW = mean fruit weight; MLFD = mean longitudinal fruit diameter; (MTFD) = mean of the transversal fruit diameter; MPT = mean peel thickness; ECse = electrical conductivity of the saturation extract; SAR = sodium adsorption ratio; NaSoil, CaSoil and MgSopil = Sodium, calcium and magnesium content of the soil sorption complex. 1 - ‘Santa Cruz Rangpur’ lime (*Citrus ×limonia* Osbeck). 2 - ‘Indio’ citrandarin [*C. sunki* (Hayata) hort. ex Tanaka x *Poncirus trifoliata* (L.) Raf.]. 3 - ‘Riverside’ citrandarin. 4 - ‘San Diego’ citrandarin. 5 - ‘Sunki Tropical’ (*C. sunki*) mandarin. 6 - Common ‘Sunki’ mandarin (TSKC) x *P. trifoliata* ‘Benecke’ selection (TRBK) - 007. 7 - ‘Sunki of Flórida’ mandarin (TSKFL) x TRBK - 030. 8 - TSKC x ‘Troyer’ citrange [*C. ×sinensis* (L.) Osbeck x *P. trifoliata*] (CTTR) - 012. 9 - TSKFL x CTTR - 013. 10 - HTR - 069 [trifoliate hybrid resulting from crossing the ‘Pera’ sweet orange (*C. ×sinensis*) with the ‘Yuma’ citrange]. 11 - TSKC x [‘Rangpur’ lime (LCR) x *P. trifoliata* (TR)] - 040. 12 - TSKC x (LCR x TR) - 059. 13 - TSKC x ‘Argentina’ citrange (CTARG) - 019

CONCLUSIONS

1. The salinity of the water used in irrigation reduced the number and weight of fruit per plant and mean fruit weight in the ‘Tahiti’ acid lime;
2. Water up to 2.4 dS m^{-1} can be used for irrigation of the ‘Tahiti’ acid lime without significantly compromising production when grafted on the ‘Riverside’ and TSKC x TRBK – 007 citrandarins, the TSKC x CTTR – 012 citrangedarin, the trifoliolate hybrid HTR – 069, and the TSKC x [(LCR) x (TR)] - 040 and TSKC x [(LCR) x (TR)] - 059 (BRS Bravo) citrimoniandarins and the ‘Sunki Tropical’ mandarin;
3. The ‘Tahiti’ acid lime grafted on the ‘Sunki Tropical’ mandarin, the HTR - 069 trifoliate hybrid and the TSKC x (LCR x TR) - 040 citrimoniandarin, TSKC x TRBK - 007 citrandarin, and TSKC x CTTR - 012 citrangedarin is less sensitive to the 4.8 dS m^{-1} level of water salinity, showing no decrease in production;
4. Soil sodium and electrical conductivity show the most negative correlations with production in citrus genotypes.

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