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Morphophysiology of Tahiti lime grafted onto Sunki mandarin hybrids under salt stress

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ABSTRACT: This study aimed to evaluate the growth and physiology of citrus scion/rootstock combinations irrigated with saline water until the pre-flowering stage. The experiment was conducted in drainage lysimeters with capacity for 150 dm^3, in randomized block design in a 2 x 10 factorial scheme, corresponding to two electrical conductivities of water (S_1 = 0.3 and S_2 = 3.0 dS m^{-1}) and ten scion/rootstock combinations (nine hybrids and one commercial variety) grafted with Tahiti lime, in three repetitions and one plant per plot. Grafted seedlings were transplanted one year after sowing, subjected to salt stress from 15 days after transplanting until the pre-flowering period, and evaluated for gas exchanges and growth. The irrigation with 3.0 dS m^{-1} saline water did not influence the photosynthetic activity of the studied citrus scion/rootstock combinations until the pre-flowering. The genotype Santa Cruz Rangpur lime (LCRSTC) was more sensitive to irrigation water salinity in terms of growth. The least sensitive combinations to salinity were Tahiti lime grafted onto TSKFL x (LCR x TR) - 018, TSKFL x TRBK – 011 and TSKFL x TRBK - 30.

Key words: *Citrus* spp., *Poncirus trifoliata*, gas exchanges, salinity

Morfofisiologia da limeira acida Tahiti enxertada em híbridos de tangerineira Sunki sob estresse salino

RESUMO: Objetivou-se avaliar o crescimento e a fisiologia de combinações copa/porta-enxertos de citros irrigados com água salina até a fase de pré-floração. O experimento foi realizado em lisímetros de drenagem com capacidade de 150 dm^3, em delineamento de blocos casualizados em esquema fatorial 2 x 10, correspondendo a duas condutividades elétricas da água de irrigação (S_1 = 0,3 e S_2 = 3,0 dS m^{-1}) e dez combinações copa/porta-enxerto (nove híbridos e uma variedade comercial) enxertados com limeira acida Tahiti, com três repetições e uma planta por parcela. As mudas enxertadas foram transplantadas após um ano do semeio, sendo o estresse salino iniciado aos 15 dias após o transplantio, perdurando até o período de pré-floração, avaliando-se trocas gasosas e o crescimento. A irrigação com água salina de 3,0 dS m^{-1} não influencia a atividade fotossintética das combinações copa/porta-enxerto de citros estudadas até a pré-floração. O genótipo Santa Cruz limão-cravo (LCRSTC) foi mais sensível à salinidade da água de irrigação quanto ao crescimento. As combinações menos sensíveis à salinidade foram compostas pelo Tahiti enxertado com o TSKFL x (LCR x TR) - 018, TSKFL x TRBK – 011 e TSKFL x TRBK - 30.

Palavras-chave: *Citrus* spp., *Poncirus trifoliata*, trocas gasosas, salinidade

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Introduction

Brazil is the world's largest producer of citrus fruits and the largest exporter of concentrated and frozen orange juice. In 2017, the national production (oranges, lemons and mandarins) was higher than 19 million tons, and the Northeast was the second largest producing region, with a mean yield of 12.0 t ha^{-1} (IBGE, 2019), with great socio-economic relevance in this region.

However, this yield is still below the potential of the crop, and it is necessary to use more productive genetic materials and irrigation to mitigate the natural water deficit of this region (Braz et al., 2009). In addition, another problem is the high concentration of salts in its sources of water, because the irregular rainfalls are insufficient to leach the salts from the parent material, which then accumulate in the agricultural layer of the soil, resulting in problems of salinity and sodicity (Oliveira et al., 2010; Mesquita et al., 2015).

Irrigation using water of high salt contents may influence the growth and development of citrus plants, and they are considered sensitive to salinity (Levy & Syvertsen, 2004; Syvertsen & Garcia-Sanchez, 2014).

Studies have reported genetic materials used as rootstocks with potential tolerance to salinity (Fernandes et al., 2011; Silva et al., 2014; Barbosa et al., 2017; Brito et al., 2008, 2016, 2017). Thus, the use of salinity-tolerant rootstocks can allow the use of water with high salt levels or even saline soils (Grieve et al., 2007; Prior et al., 2007; Brito et al., 2014, 2015). Therefore, this study aimed to evaluate the physiology and growth of citrus scion/rootstock combinations under salt stress until the pre-flowering period.

Material and Methods

The experiment was carried out between February and August 2016 at the Centro de Ciências e Tecnologia Agroalimentar (CCTA) of the Universidade Federal de Campina Grande (UFCG), located in the municipality of Pombal, PB, Brazil, at geographic coordinates 6° 47' 20" S and 37° 48' 1" W, at an altitude of 194 m.

Temperature and rainfall were monitored during the experimental period. Maximum temperature ranged between 30 and 39 °C, while minimum temperature varied between 15 and 26 °C, with mean maximum and minimum temperatures of 34.1 ± 1.3 °C and 21.4 ± 2.0 °C, respectively, along the months from February 2016, beginning of the experiment, until August 2016, when the pre-flowering period ended (Figure 1A). In relation to the rainfall, it was concentrated in March and there were also some rain events in April and June, totaling 264 mm (Figure 1B), which is insufficient to ensure the production of citrus. Thus, it was necessary to replace 100% of the crop evapotranspiration (ETc), as citrus require from 600 to 1300 mm according to the literature (Mattos Junior et al., 2005).

The experimental design used was in randomized blocks, in a 10 x 2 factorial scheme, corresponding to: 10 scion/rootstock combinations, using Tahiti lime as scion variety grafted onto ten citrus genotypes, from the Citrus Genetic

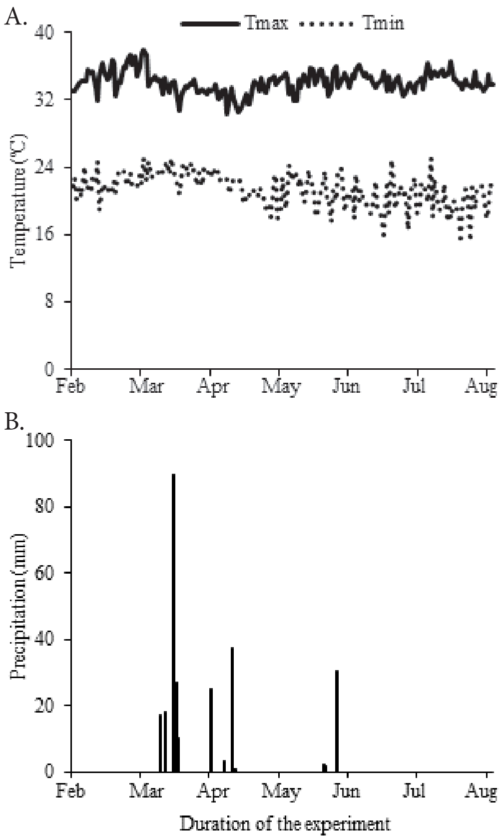


Figure 1. Variation of temperature (A) and rainfall (B) along the months from February to August 2016, equivalent to the pre-flowering period

Improvement Program (PMG-Citros) of Embrapa Mandioca e Frutas Tropicais, namely: five genotypes from the cross: Sunki mandarin; [three from the 'Common' selection (TSKC) and two from the Florida selection (TSKFL)] x [Rangpur lime (LCR) (*Citrus limonia* L. Osbeck) x *Poncirus trifoliata* (TR)]; four genotypes from the cross TSKFL x [*Poncirus trifoliata* Beneke (TRBK)]; and one commercial variety, Santa Cruz Rangpur lime (LCRSTC), since it is the most used material in the Brazilian citriculture as rootstock, and two electrical conductivities of irrigation water (ECw), S1 = 0.3 and S2 = 3.0 dS m^{-1}, with three repetitions and one plant per plot. Treatments began to be applied at 15 days after transplanting (DAT) the seedlings to the lysimeters and continued until the early flowering (pre-flowering). The combinations of all factors resulted in 20 treatments (2 ECw levels x 10 genotypes).

The seedlings used were apogamous, produced in 2 L plastic bags and, after acclimation to the region for 15 days, transplanted to 5 L bags. Seedlings were initially supported with one stake and, after reaching 50 cm in height, were pruned, allowing three branches to grow in the crown, thus forming small-crown seedlings, and then transplanted to the lysimeters at 365 days after sowing (DAS).

A spacing of 2 x 2 m was used between lysimeters, which were made of polypropylene boxes (150 L) painted white to increase reflectance and reduce heat conservation in soil. Valves (18 mm diameter) were installed at the bottom of each lysimeter and connected to a tube, to allow the drained water to be collected in a 18 L plastic container in order to determine water consumption.

Each lysimeter was filled with soil material classified as Entisol – Fluvents, whose attributes are presented in Table 1, from an area of UFCG's experimental farm, located in the municipality of São Domingos, PB, Brazil, following the characterization of diagnostic horizons, with samples collected in the 0-0.20 and 0.20-0.40 m layers. A mixture of crushed stone (8 L) + sand (7 L) was placed at the bottom of each lysimeter, forming a 0.04 m thick layer, in order to facilitate the drainage of water excess.

The lysimeters were filled with soil in such a way to simulate a hole with 40 cm diameter and 40 cm depth using a cylinder with these dimensions. The internal side of this cylinder received a mixture with 40 L of soil and 20 L of aged bovine manure (Table 1), while the external side received 60 L of soil, in a total of 135 L. After filling, the cylinder was removed and basal fertilization was applied using single superphosphate, in addition to a layer of mulch, composed of 1 kg of corn straw, to reduce evaporation.

Irrigations, according to each level of salinity, were performed using a localized irrigation system with flow-regulating drip tapes of 1.9 L h^{-1} per dripper, with five drippers per plant.

Irrigation management was carried out by the water balance method, to replenish the mean daily water volume consumed by plants. A leaching fraction was applied every week, obtained by dividing the volume consumed along the week (L) by 0.9 to obtain a value of 0.10, allowing the reduction of part of the salts accumulated in the root zone.

Until 15 days after transplanting, plants were irrigated using water of low electrical conductivity (0.3 dS m^{-1}), from the local supply system. From this period on, the solutions with different levels of electrical conductivity began to be applied. The irrigation solution with high level of salinity (3.0 dS m^{-1}) was prepared considering the relationship between ECw and the concentration of salts (10 * meq L^{-1} = 1 dS m^{-1} of ECw), according to Rhoades et al. (1992), valid for ECw from 0.1 to 5.0 dS m^{-1}, which encompass the level to be prepared, using water from the local supply system.

The nutritional management followed the recommendations proposed by Mattos Junior et al. (2005), considering the analyses of soil and manure, and also taking all the additional care related to weed control and prevention of pests and diseases, normally recommended in the production of citrus fruits (Mattos Junior et al., 2005).

Physiological variables were determined at 180 days after the beginning of stress application (DABS), using a portable photosynthesis meter (LCPro+ - ADC BioScientific Ltda), operating with irradiation of 1200 μmol photons m^{-2} s^{-1} and CO_2 from the environment at 3 m height from soil surface, to obtain the following variables: CO_2 assimilation rate (A) (μmol m^{-2} s^{-1}), transpiration (E) (mol H_2O m^{-2} s^{-1}), stomatal conductance (gs) (mol H_2O m^{-2} s^{-1}) and internal CO_2 concentration (Ci), in the third leaf counted from the apex. These data were used to quantify the instantaneous water use efficiency (WUEi) (A/E) [(μmol m^{-2} s^{-1}) (mol H_2O m^{-2} s^{-1})$^{-1}$] and instantaneous carboxylation efficiency (CEi) (A/Ci).

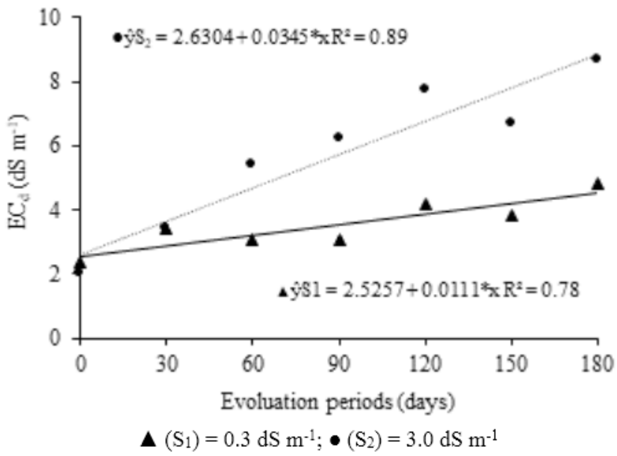
Every 30 days, from the time when the different irrigation waters began to be applied, the following variables were determined: number of leaves (NL); stem diameter of rootstock (SD-R), measured in the collar region; stem diameter at the grafting point (SD-GP); and stem diameter of scion (SD-S), measured 2 cm above the grafting point, using a digital caliper, with results expressed in mm.

The obtained data were subjected to analysis of variance by F test. In the cases of significance, the data were subjected to regression analysis at $p \leq 0.05$ (Ferreira, 2011).

Results and Discussion

The period of rainfall, time of exposure of plants to water salinity reduces the progressive increase in the electrical conductivity of the drainage water (EC_d) in the first months of cultivation (Figures 1B and 2). Application of 3.0 dS m^{-1} water caused a daily accumulation of salts of approximately 0.0345 dS m^{-1}, resulting in an average electrical conductivity of 8.49 dS m^{-1} among the scion/rootstock combinations at 180 DABS. Converting this value to electrical conductivity in the saturation extract (EC_{se}), according to Ayers & Westcot (1999), would result in an estimated EC_{se} of 4.3 dS m^{-1}, a value much higher than the salinity threshold of citrus (2.0 dS m^{-1}), according to Syvertsen & Garcia-Sanchez (2014), confirming the existence of salt stress.

For gas exchanges, there was no significant influence of either the interaction between genotypes and water salinity or the single factors, in any of the evaluation periods, which



*Significant at $p \leq 0.05$ by F test

Figure 2. Variation in the electrical conductivity of the drainage water (EC_d) as a function of time of exposure of plants to water salinity

Table 1. Chemical characteristics of the soil and of the manure used to fill the lysimeters cultivated with citrus plants

	pH $CaCl_2$ (2:1)	EC (dS m^{-1})	P (mg dm^{-3})	N (%)	K	Na	Ca	Mg	SB	T	OM (g kg^{-1})
					($cmol_c$ dm^{-3})						
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

EC - Eletrical conductivity; SB - Sum of bases; T - Cation exchange capacity; OM - Organic matter may be related to some process of acclimation to the stress (Table 2). According to Syvertsen & Garcia-Sanchez (2014), this may occur when the increase in the concentration of salts in the soil occurs progressively. In addition to this condition, it should be considered that rainfalls occurred until May 2016, which minimized the concentration of salts in soil, because the rains were concentrated in a few days, especially in March 2016 (90 mm), which caused the leaching of part of the salts accumulated in the soil, from the irrigation water (Figure 1B).

In relation to the growth variables, the interaction between scion/rootstock combinations and electrical conductivity of irrigation water had a significant effect only on the number of leaves at 180 DABS, but significant differences were observed between the genotypes and between the levels of salinity, separately, in all growth variables in at least one evaluation period (Table 3). An analysis of the scion/rootstock combinations showed significant differences in all periods evaluated for stem diameter of rootstock (SD-R). For stem diameter at the grafting point (SD-GP), there were differences between genotypes at 60, 90, 120 and 180 DABS, and for stem diameter of scion (SD-S), differences occurred at 90, 120, 150 and 180 DABS. Differences in the number of leaves between genotypes were observed only in the evaluations conducted at 30 and 180 DABS, which denotes genetic variation of the materials, although some of them have a kinship.

Regarding the effect of salinity, SD-GP and SD-S were significantly influenced in the evaluations conducted at 150 and 180 DABS, whereas for the number of leaves there was an effect at 180 DABS, which corroborates the theory that salinity effect is a function of the time and intensity of the stress (Barbosa et al., 2017). In addition, rainfalls occurred in the first months of exposure of citrus plants to the stress, which diluted the salts and this may have provided conditions for acclimation to the stress. Therefore, this is an adequate strategy for planting citrus orchards in the first months of the year, since the tolerance to salinity varies with genotype, development

Table 2. Summary of variance analysis for internal CO_2 concentration (CI), transpiration (E), stomatal conductance (gs), CO_2 assimilation rate (A), water use efficiency (WUE) and instant carboxylation 180 days after the beginning of stress application (DABS)

Sources of variation	Mean square							
	Period (DABS)	Genotypes (G)	Salinity (S)	G X S	Block	Erro	Mean	CV (%)
Ci	180	710.155^{ns}	777.600^{ns}	730.637^{ns}	506.116^{ns}	612.951	230.56	10.74
E	180	0.1425^{ns}	0.0001^{ns}	0.1203^{ns}	0.6051*	0.1237	1.266	27.78
gs	180	0.0004^{ns}	0.00001^{ns}	0.0003^{ns}	0.0014*	0.0005	0.057	32.54
A	180	1.958^{ns}	0.411^{ns}	1.967^{ns}	17.602**	1.349	4.789	24.25
WUE	180	1.1221^{ns}	0.6680^{ns}	0.5309^{ns}	32.6171**	0.8693	3.981	23.42
EICi	180	0.00003^{ns}	0.00002^{ns}	0.00004^{ns}	0.00025**	0.00002	0.020	24.89
DF		9	1	9	2	38	-	-

*, ** - Significant at p ≤ 0.05 and p ≤ 0.01 by F test; NS - Not significant; DF - Degrees of freedom; CV - Coefficient of variation

Table 3. Summary of variance analysis for rootstock stem diameter (SD-R), stem diameter measured at the grafting point (SD-GP), stem diameter measured in the scion (SD-S) and number of leaves (NL) after 30, 60, 90, 120, 150 e 180 days after the beginning of stress application (DABS)

Sources of variation	Mean square							
	Period (DABS)	Genotypes (G)	Salinity (S)	G X S	Block	Erro	Mean	CV (%)
SD-R	30	9.827**	0.342^{ns}	0.939^{ns}	4.128^{ns}	1.581	11.549	10.89
	60	18.329**	3.672^{ns}	2.577^{ns}	8.438^{ns}	3.554	14.457	13.04
	90	27.507**	0.110^{ns}	3.006^{ns}	8.048^{ns}	3.450	17.513	10.61
	120	31.825**	0.518^{ns}	2.141^{ns}	12.758^{ns}	5.597	20.393	11.60
	150	42.880**	23.381^{ns}	4.923^{ns}	10.544^{ns}	5.855	24.092	10.04
	180	51.469**	19.091^{ns}	4.314^{ns}	19.610^{ns}	5.497	26.429	8.87
SD-GP	30	2.381^{ns}	0.463^{ns}	2.035^{ns}	2.399^{ns}	1.670	13.378	9.66
	60	6.951*	0.004^{ns}	2.822^{ns}	5.849^{ns}	2.476	16.062	9.80
	90	13.393**	0.028^{ns}	2.897^{ns}	8.075^{ns}	3.475	19.406	9.61
	120	12.452*	7.808^{ns}	6.127^{ns}	6.052^{ns}	4.489	22.293	9.50
	150	13.488^{ns}	31.631*	6.650^{ns}	8.976^{ns}	6.490	25.373	10.04
	180	20.449**	36.746*	6.642^{ns}	4.084^{ns}	5.672	28.087	8.48
SD-S	30	1.347^{ns}	0.196^{ns}	1.057^{ns}	1.395^{ns}	0.762	9.918	8.80
	60	2.788^{ns}	0.011^{ns}	2.^{631ns}	0.552^{ns}	1.361	12.257	9.52
	90	5.569*	0.295^{ns}	2.796^{ns}	2.456	2.456	15.214	10.30
	120	9.773**	1.030^{ns}	4.614^{ns}	4.604^{ns}	3.100	18.040	9.76
	150	16.001*	35.737*	2.755^{ns}	4.188^{ns}	5.928	21.073	11.55
	180	14.222*	62.352**	6.379^{ns}	13.188^{ns}	5.347	23.614	9.79
NL	30	3667.075**	93.750^{ns}	493.564^{ns}	3134.466*	805.624	113.783	24.95
	60	4044.118^{ns}	64.066^{ns}	1056.325^{ns}	1598.616^{ns}	1999.985	170.433	26.24
	90	8254.444^{ns}	41.666^{ns}	2735.296n^{ns}	8081.016^{ns}	4755.525	246.666	27.96
	120	29890.992^{ns}	10036.266^{ns}	7734.933^{ns}	21519.650^{ns}	15069.755	372.200	32.98
	150	51571.71^{ns}	150801.06*	15280.84^{ns}	54802.06^{ns}	29515.69	489.566	35.09
	180	656469.600**	144342.489**	36666.415*	31512.467*	9104.660	649.933	14.68
DF		9	1	9	2	38	-	-

*, ** - Significant at p ≤ 0.05 and p ≤ 0.01 by F test; NS - Not significant; DF - Degrees of freedom; CV - Coefficient of variation

stage and stress intensity (Silva et al., 2014; Barbosa et al., 2017; Brito et al., 2017). Syvertsen & Garcia-Sanchez (2014) report that temperature and rainfall conditions may intensify or mitigate salt stress on citrus. Furthermore, this adaptation could be observed in the data of gas exchanges, which indicated no significant effect of water salinity.

For the interaction between scion/rootstock combinations and the effect of salinity on rootstock stem diameter at 180 DABS, there was a significant effect only on the combination between the Tahiti lime and LCRSTC, with a reduction of about 16% in SD-R (Figure 3J).

However, considering the stem diameter as a function of time, other combinations were also affected and daily growth rate decreased from 0.11 to 0.09 mm in TSKFL x (LCR x TR) – 017 between the salinity levels of 0.3 and 3.0 dS m^{-1}, respectively, which corresponds to a reduction of 7.4% (Figure 3A). In TSKC x TRBK – 028, the daily growth rate decreased from 0.12 to 0.10 mm, between the salinity levels of 0.3 e 3.0 dS m^{-1}, respectively, corresponding to a reduction of 10.7% (Figure 3H).

For the other combinations, the daily growth rates were similar between the salinity levels, which denotes tolerance of the materials (Figures 3B, C, D, E, F, G and I). Despite the distinction in the growth in diameter of the combinations, there is a relation between SD-R and SD-GP in most combinations (Figures 3 and 4), an indication that there is compatibility between the rootstocks and the scion. Thus, both the upward flow of water and nutrients to the shoots and the redistribution of photoassimilates to the other plant parts are facilitated (Brito et al., 2014, 2015).

When there is a disproportionate increase in the growth of either the scion or the rootstock, a callus forms in the region due to depositions of organic compounds, which causes Elephant's Foot, a physiological anomaly that becomes more evident when plants are more than one year old

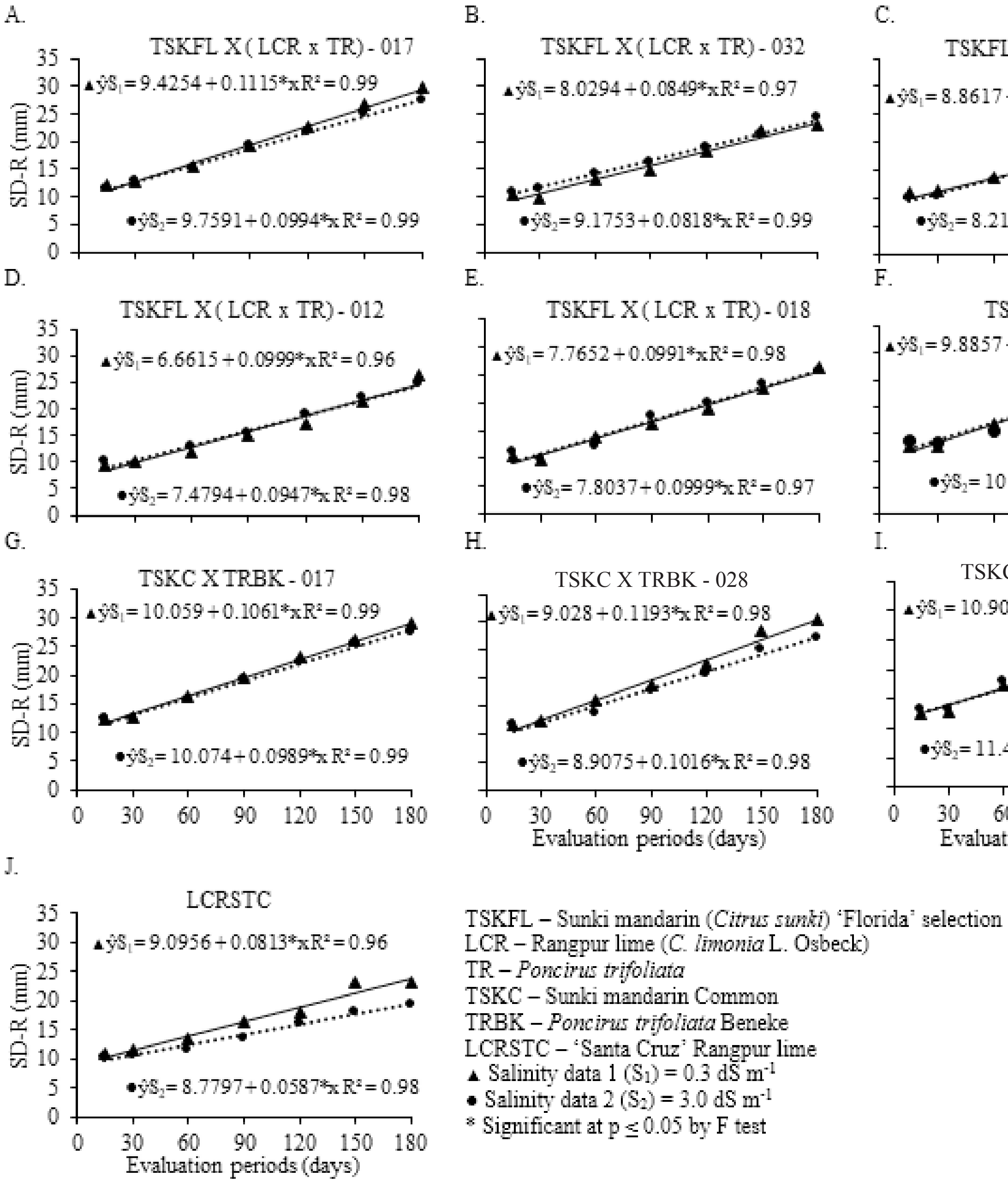


Figure 3. Rootstock stem diameter (SD-R) for the combinations between Tahiti lime and each genotype of citrus rootstock as a function of time in days after the beginning of saline water application (S_1 = 0.3 and S_2 = 3.0 dS m^{-1})

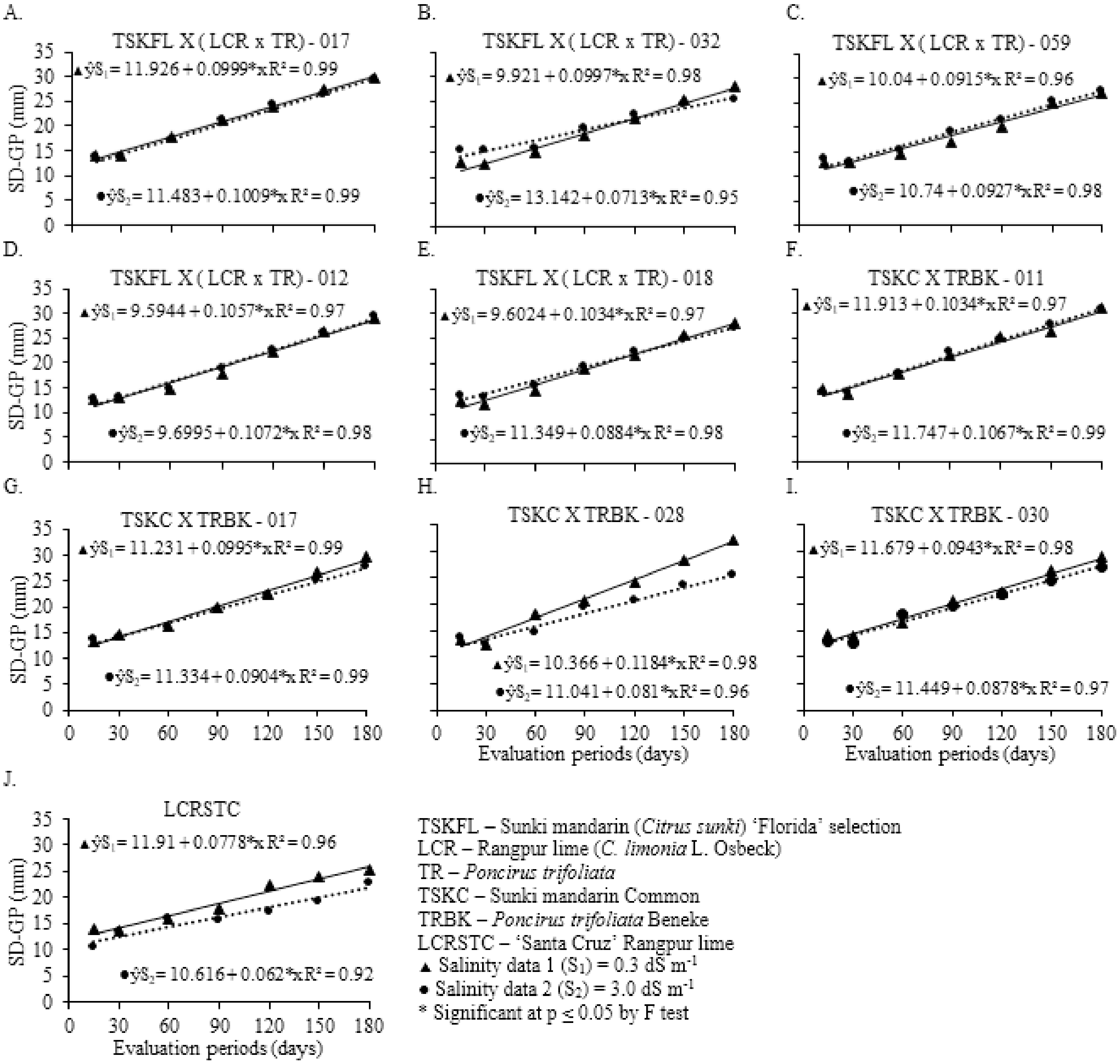


Figure 4. Stem diameter measured at the grafting point (SD-GP) in the combinations between Tahiti lime and each genotype of citrus rootstock as a function of time in days after the beginning of saline water application (S_1 = 0.3 and S_2 = 3.0 dS m^{-1})

(Mattos Junior et al., 2005). In this study, although it is early for a conclusion regarding this compatibility, the hybrids TSKFL x (LCR x TR)-032, TSKFL x (LCR x TR)-059, TSKFL x (LCR x TR)-012 and TSKFL x (LCR x TR)-018 showed higher growth of stem diameter measured at the grafting point, compared to the stem diameter of the rootstock, which may be indicative of this problem (Figures 4B, C, D and E).

The scion stem diameter (SD-S) was the most affected by salinity at 180 DABS because, in addition to a higher number of genotypes classified with the lowest mean, the differences between growth rates of the plants under the two levels of salinity were larger. The largest reductions were observed in TSKC x TRBK-028, TSKFL x (LCR x TR)-032 and LCRSTC, which were equivalent to 22.3, 8.3 and 13.4%, respectively, between the lowest and highest levels of salinity (Figures 5B, H and J).

Scion development is related to the compatibility with the rootstock and its vigor, but it is worth pointing out that the compatibility is decisive for the plant itself to have an adequate development under salt stress conditions, which was evident in the combination with the genotype TSKFL x (LCR x TR) – 032 (Figure 5B). The stem diameter of this rootstock was 2.5% higher in plants irrigated with 3.0 dS m^{-1} water, compared to those irrigated with low-salinity water (Figure 3B). However, the stem diameters at the grafting point and of scion decreased by 6.8 and 8.3%, respectively (Figures 4 and 5), making it evident that the compatibility of this genotype with the scion was affected by water salinity, since the rootstock showed an increment under these conditions.

Regarding the effect of salinity on the number of leaves at 180 DABS, most combinations showed reductions as water salinity increased (Figure 6). However, no significant difference was observed in the combinations of Tahiti lime with TSKFL x (LCR x TR) – 018, TSKC x TRBK – 011, TSKC x TRBK – 017 and TSKC x TRBK – 030 (Figures 6E, F, G and I), especially

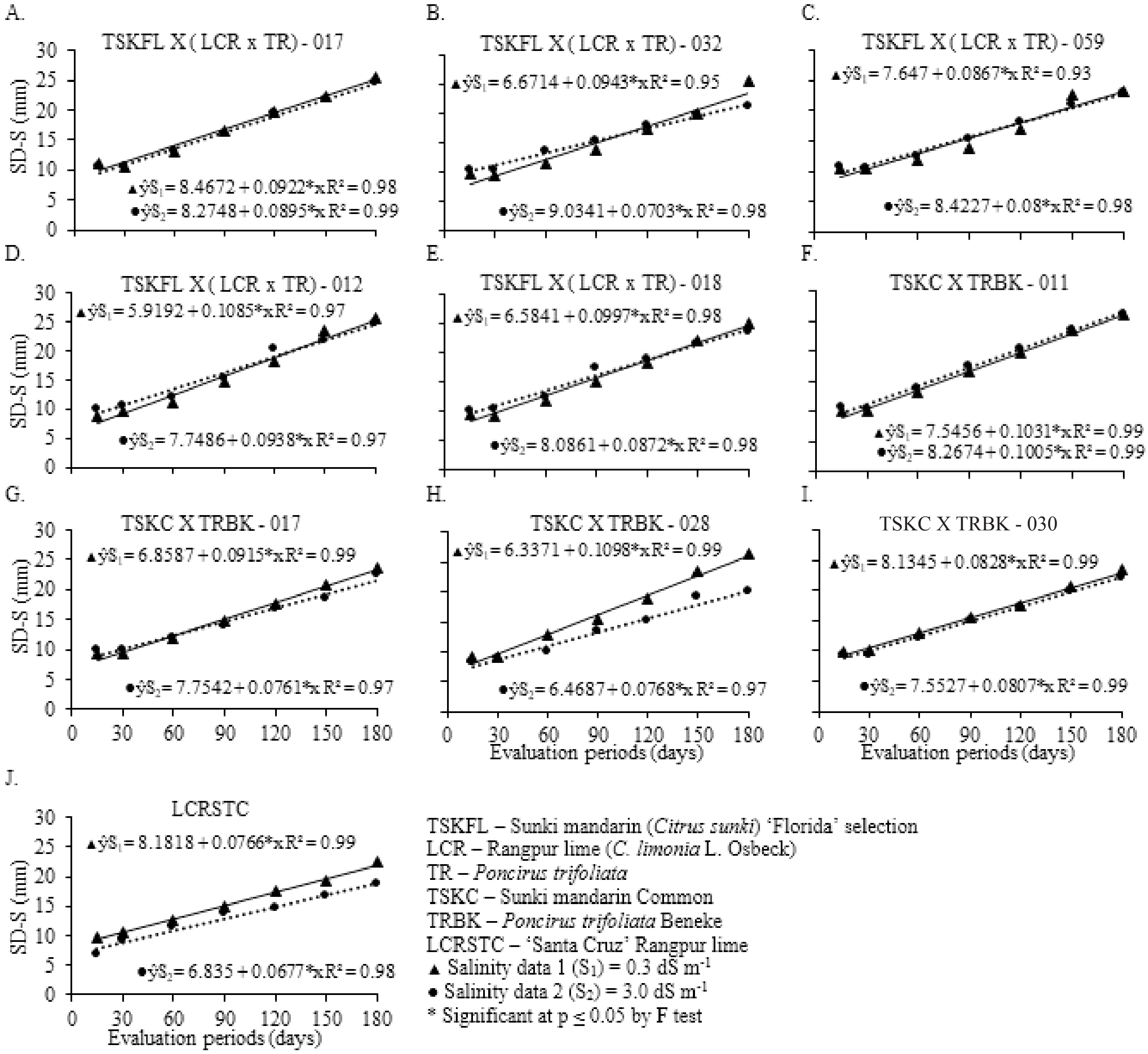


Figure 5. Stem diameter measured in the scion (SD-S) (mm) in the combinations between Tahiti lime and each genotype of citrus rootstock as a function of time in days after the beginning of saline water application (S_1 = 0.3 and S_2 = 3.0 dS m^{-1})

TSKFL x TRBK – 030, in which the number of leaves under saline water irrigation was similar to that obtained in plants irrigated with low-salinity water, denoting the potential of this combination.

The largest effects of salinity were observed on the combinations of Tahiti lime with the hybrids TSKFL x (LCR x TR) – 012 and TSKC x TRBK – 028, besides the LCRSTC, which showed reductions of 30.5, 42.2 and 32.5%, respectively, between the two levels of salinity at 180 DABS (Figures 6D, H and J). Among these genotypes, TSKFL x (LCR x TR) – 012 stood out with an exponential growth, showing the largest differences at 150 and 180 DABS (Figures 6D, H and J).

It can be observed that the progressive stress increased the percentage of reduction in those combinations because, under saline conditions, the growth, development and production of citrus plants can be reduced, which can be attributed to the effect of toxic ions, especially chlorine, sodium and boron, and to the osmotic stress (Levy & Syvertsen, 2004; Zhao et al., 2007). Tolerance to salinity varies between species, between genotypes and, even within the same species, between stages of plant development, highlighting that, at each stage, the tolerance to salinity is controlled by more than one gene and highly influenced by environmental factors (Hussain et al., 2012; Syvertsen & Garcia-Sanchez, 2014), which may justify the differences in the results of tolerance for the combinations.

Other genotypes also showed a significant reduction in the number of leaves as the levels of salinity increased and, at 180 DABS, the combinations of Tahiti lime with the hybrids TSKFL x (LCR x TR)-017, TSKFL x (LCR x TR)-032 and TSKFL x (LCR x TR)-059 showed reductions of 27.2, 22.1 and 16.9% between the lowest and highest levels of water salinity (Figures 6A, B and C). However, it is worth noting that CO_2 assimilation was not affected by salinity. Despite that, some genotypes stood out in terms of growth variables related to stem diameter, which was more evident in the stem diameter of the scion. This may be related to the number of leaves because the higher the

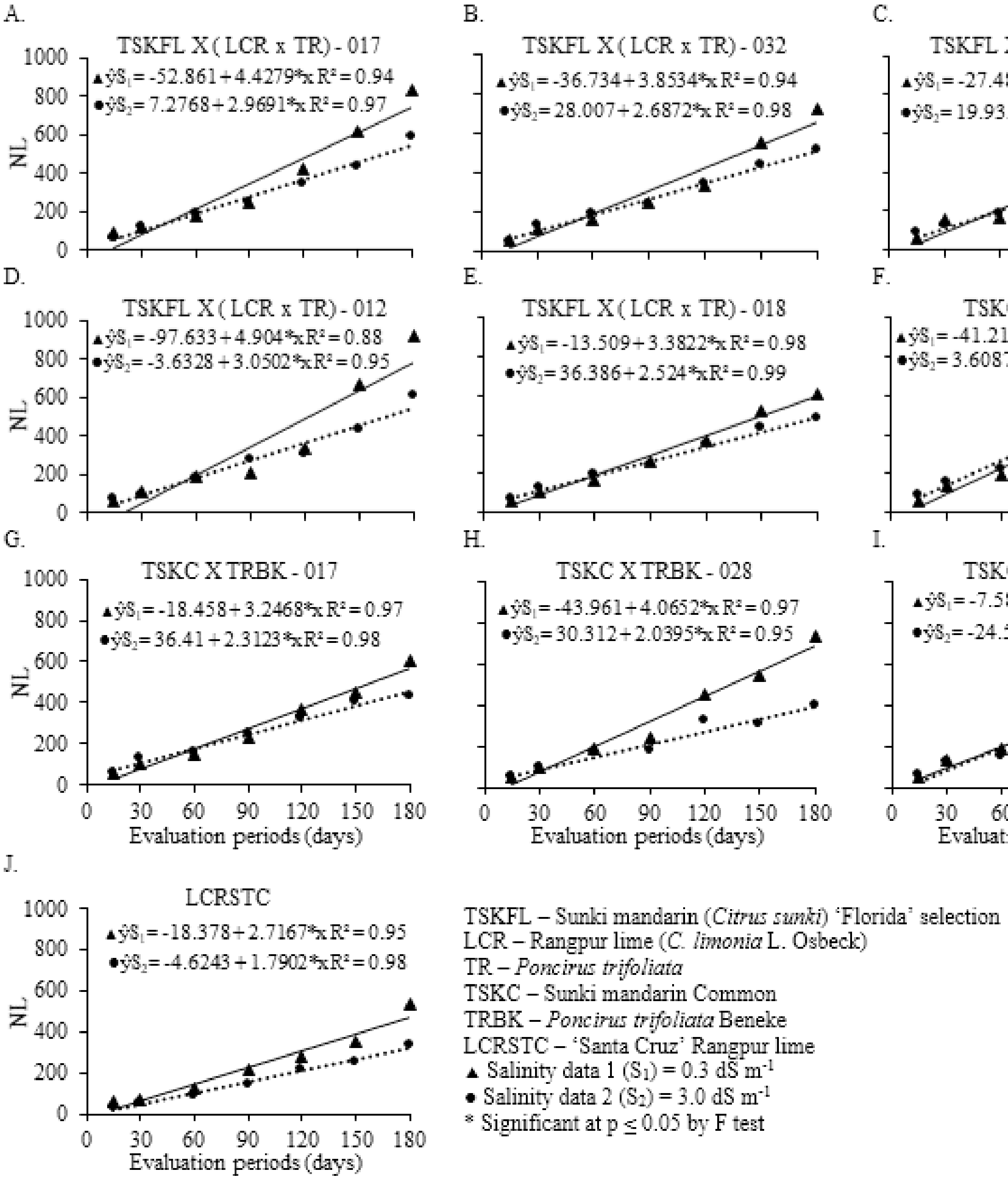


Figure 6. Number of leaves (NL) in the combinations of Tahiti lime grafted onto each genotype of citrus rootstock as a function of time in days after the beginning of saline water application (S_1 = 0.3 and S_2 = 3.0 dS m^{-1})

number of leaves, the larger the production of photoassimilates. Unlike gas exchanges, whose evaluations represent a point in time, growth evaluations are cumulative, so small differences in gas exchanges which were not statistically significant were sufficient to make the growth significant over time. Perhaps, this could be better explained with leaf area, by establishing the relationship between leaf area and CO_2 assimilation.

Conclusions

1. Irrigation with 3.0 dS m^{-1} saline water had no influence on the photosynthetic activity of the studied citrus scion/rootstock combinations until the pre-flowering.

2. The largest reductions of growth as a function of salinity were observed in the combinations of Tahiti lime grafted onto TSKFL x (LCR x TR) – 012, TSKC x TRBK – 028 and the control LCRSTC, which was the most sensitive to salinity.

3. The least sensitive combinations to salinity were composed of Tahiti lime grafted onto TSKFL x (LCR x TR) – 018, TSKC x TRBK – 011 and TSKC x TRBK – 30.

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