Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 30 September 2025
https://doi.org/10.14295/CS.v16.4325

Performance of 'Tahiti' acid lime on new rootstocks resistant to citrus gummosis

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Abstract

The objective of this study was to evaluate the vegetative growth of 'Tahiti' acid lime on citrus rootstocks. The experiment was established in December 2016 at the Federal Institute of Mato Grosso, Guarantã do Norte Campus, MT. The experimental design was a randomized block with 13 treatments, four replications, and five plants/plot. The treatments included commercial and hybrid rootstocks, named and coded as follows: 'Cravo Santa Cruz' lemon tree (LCRSC), 'Cravo CNPMF - 03' lemon tree (LCR-03), 'Swingle' citrumelo (CTSW), 'Sunki Tropical' tangerine tree (TSKTR), 'San Diego' citrandarin (CTRSD), 'Indio' citrandarin (CTRI), HTR - 069, TSKC x TRFD - 003, TSKC x TRFD - 006, TSKC x CTSW - 028, TSKC x (LCR x TR) - 059, LVK x LCR - 038, and LRF x (LCR x TR) - 005. The planting spacing and density were 6.25 m x 2.75 m, 582 plants per hectare. The variables assessed were plant height, rootstock and grafting trunk diameter, rootstock/grafting compatibility ratio, vegetative vigor index (IVV), and canopy diameter and volume. All rootstock/scion combinations exhibited graft compatibility and vegetative growth of the canopy in accordance with the physiology of 'Tahiti' acid lime up to 36 months of age. Except for CTRSD, the largest canopy volumes and IVV were observed in plants on commercial rootstocks, while HTR - 069 and LRF x (LCR x TR) - 005 induced the lowest values, with LRF x (LCR x TR) - 005 resulting in the smallest plant height.

Keywords: Citrus × latifolia, Poncirus trifoliata, planting density, grafting, rootstock diversification

Introduction

Citrus farming stands out in Brazilian fruit production due to its economic and social importance, with increasing participation of lemons and acid limes in the sector statistics, especially the 'Tahiti' acid lime [Citrus ×latifolia (Yu. Tanaka) Tanaka]. In 2023, the harvested area of lemons and acid limes was 60,687 hectares, with a production of 1,724,330 tons, representing about 10% of the total production of oranges, tangerine trees, true lemons, and acid limes. The state of Mato Grosso produces 3,254 tons on an area of only 378 hectares (IBGE, 2023).

According to Coelho & Mascarenhas (1991) and Coelho et al. (1998), there is a great potential for citrus production when considering edaphoclimatic aspects. The edaphoclimatic requirements of 'Tahiti' acid lime tree can be met in areas of the Amazon biome, as demonstrated by research results from them (Silva et al., 2007), Rondônia (Miranda, 2010), and Acre (Rodrigues, 2018).

The greatest limitation to the development of 'Tahiti' acid lime tree production in Mato Grosso lies in the replacement of the vigorous 'Cravo' lemon rootstock (C. ×limonia Osbeck), which has high tolerance to water deficit stress that induces early production, offers high productivity, and it is tolerant to citrus sadness; all of them are important traits for citrus plants (Pompeu Júnior, 2005). However, 'Cravo' lemon tree is susceptible to citrus gummosis, considered the main fungal disease affecting citrus rootstocks (Stuchi & Cyrillo, 1998). In the Centro Oeste and Norte regions, where high rainfall rates elevated temperatures, and prolonged periods of saturated soil and air are common, the process of disease-infection and dissemination is accelerated, leading to higher mortality rates in plants earlier. Although high resistance to gummosis is considered the main trait

Received: 21 November 2024
Accepted: 22 January 2024

of a good rootstock for successful citrus production in the Centro Oeste region, modern citrus farming tends toward high-density and ultra-high-density orchards as to mitigate the effects of Huanglongbing (HLB) disease as to facilitate the process of automating orchard activities. So, it requires the use of rootstock cultivars that promote high productive efficiency associated with smaller canopy volumes, compared to 'Cravo' lemon tree (Stuchi & Girardi, 2010; Mademba-Sy et al., 2012; Passos et al., 2006).

Some hybrids of trifoliata are widely adopted in São Paulo's citrus farming, such as the 'Swingle' citrumelo (C. ×paradisi Macfad. x P. trifoliata) (Carvalho et al., 2019), while others are in the early stages of adoption, such as the 'Indio' and 'San Diego' citrandarins [C. sunki (Hayata) hort. ex. Tanaka x P. trifoliata] (Santos, 2019; Rodrigues et al., 2019a; Rodrigues et al., 2019b). The hypothesis is that citrus rootstocks are resistant to gummosis, showing greater vegetative growth and consequently higher production when compared to the susceptible 'Cravo Santa Cruz' lemon tree rootstock. Thus, the objective of this study was to evaluate the vegetative growth of 'Tahiti' acid lime tree on citrus rootstocks up to three years of age in the Amazon biome in the north of Mato Grosso.

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Material and Methods

The experiment was conducted in the north region of Mato Grosso, in Guarantã do Norte, within the Amazon biome, characterized by a Köppen-Geiger climate type Am (tropical monsoon), with an average annual temperature of 27.3ºC, a monthly maximum of 36ºC, and a monthly minimum of 21ºC. The average annual rainfall was 2,327 mm, and the soil type was Dystrophic Yellow Red Latosol (Seplan/MT, 2011). The experiment was set up at the experimental farm of the IFMT-Guarantã do Norte Advanced Campus (09º47'15"S and 54º54'36"W, altitude 345 m) on December 9th, 2016. The soil properties of the experimental area in Guarantã do Norte are presented in **Table 1**.

The seedlings were produced at Embrapa Agrossilvipastoril in Sinop, MT. The seeds of the rootstocks came from basic plants of PMG Citrus, Cruz das Almas - BA. Certified citrus budwoods were obtained from the nursery and kept in a shade house at Estação Experimental da Empresa Mato-Grossense de Pesquisa, Assistência Técnica e Extensão Rural (Empaer-MT), in Sinop-MT. The seedlings were produced in 2.6 L plastic bags, filled with Tecnomax Citros® substrate enriched with thermophosphate at a rate of 7 kg m^{-3} and a slow-release fertilizer (22-04-08 + micronutrients) at a rate of 2.7 kg m^{-3}. The seedlings received the recommended cultural treatments and took about 18 months to be ready for field planting.

Table 1. Chemical and physical properties of the soil in the 0.0 to 0.20 m depth layer of the experimental area in Guarantã do Norte in implantation year (2016).

Soil Properties	Guarantã do Norte
pH (H_2O)	5.5
Organic Matter (g dm^{-3})	20.3
P Mehlich 1 (mg dm^{-3})	5.4
K^+ (cmolc dm^{-3})	0.08
Ca^{2+} (cmolc dm^{-3})	1.52
Mg^{2+} (cmolc dm^{-3})	0.75
Total Acidity (H+Al) (cmolc dm^{-3})	2.60
CTC (cmolc dm^{-3})	4.9
Base Saturation (%)	47.5
B (mg dm^{-3})	0.11
Cu (mg dm^{-3})	2.00
Fe (mg dm^{-3})	203
Mn (mg dm^{-3})	29.4
Zn (mg dm^{-3})	1.8
Sand (g kg^{-1})	575
Silt (g kg^{-1})	85
Clay (g kg^{-1})	340

The area with Brachiaria vegetation was previously desiccated, and on the day of the experiment's installation, minimal soil preparation was carried out with the passage of a forest subsoiler along the planting line. The planting holes were manually dug using a shovel. The fertilization and planting correction were performed with the application of 250 g of dolomitic lime, 150 g of single superphosphate, 10 g of slow-release fertilizer (22-04-08), 50 g of FTE BR 12, and 5 g of boric acid.

The planting spacing was 6.25 m x 2.75 m (582 plants ha^{-1}). The planting was conducted with supplemental localized irrigation via micro-sprinklers during dry periods. Weed management was carried out with herbicide application along the planting lines and tractor mowing between the rows. In the first and second years, periodic chemical control of the citrus leaf miner larva (Phyllocnistis citrella) was required. Formation fertilizations were carried out according to soil analysis and the nutritional requirements of the lime tree 'Tahiti' (Sousa & Lobato, 2004). Other cultural practices followed technical recommendations for the crop, as outlined by Coelho & Mascarenhas (1991). The experimental design was randomized blocks with four replications. The plots were consisted of five plants. The treatments were 13 rootstocks (**Table 2**). The 'Cravo Santa Cruz' lemon tree was considered as a control because it is susceptible to gummosis

The evaluations were conducted with six-month periodicity, the first one occurring six months after planting (MAP) and the last at 36 MAP. At each time point, the following parameters were assessed: plant height (m),

Table 2. Rootstocks evaluated for the Tahiti lemon tree 'CNPMF 02' in the northern region of Mato Grosso.

Code	Parentage/Species/Cultivar	Scientific Name
HTR 0691	Orange 'Pera' x Citrange 'Rusk' or 'Yuma'	*Citrus ×sinensis* (L.) Osbeck x [*Citrus ×sinensis* x *Poncirus trifoliata* (L.) Raf.]
TSKC x TRFD - 003 (BRS Donadio)	Common Tangerine 'Sunki' x Trifoliata 'Flying Dragon'	*Citrus sunki* [(Hayata) hort. ex Tanaka] x *Poncirus trifoliata*
TSKC x TRFD - 006 (BRS Matta)	Common Tangerine 'Sunki' x Trifoliata 'Flying Dragon'	*Citrus sunki* x *Poncirus trifoliata*
TSKC x CTSW - 028 (BRS Pompeu)	Common Tangerine 'Sunki' x Citrumeelo 'Swingle'	*Citrus sunki* x (*Citrus ×paradisi* Macfad. x *Poncirus trifoliata*)
TSKC x (LCR x TR) - 059 (BRS Bravo)	Common Tangerine 'Sunki' x Citrimonia	*Citrus sunki* x (*Citrus ×limonia* Osbeck x *Poncirus trifoliata*)
LVK x LCR - 038 (BRS Cravinho1)	Lemon 'Volkameriano' x Lemon 'Cravo'	*Citrus ×volkameriana* (Risso) V. Ten. & Pasq. x *Citrus ×limonia*
LRF x (LCR x TR) - 005 (BRS N Gimenes Fernandes)	Lemon 'Rugoso da Flórida' x Citrimonia	*Citrus ×jambhiri* Lush. x (*Citrus ×limonia* x *Poncirus trifoliata*)
LCRSC	Lemon 'Cravo Santa Cruz'	*Citrus ×limonia*
LCR – 03	Lemon 'Cravo CNPMF - 03'	*Citrus ×limonia*
CTSW	Citrumeelo 'Swingle'	*Citrus ×paradisi* x *Poncirus trifoliata*
CTRI	Citrandarin 'Indio'	*Citrus sunki* x *Poncirus trifoliata* 'English'
CTRSD	Citrandarin 'San Diego'	*Citrus sunki* x *Poncirus trifoliata* 'Swingle'
TSKTR	Tangerine 'Sunki BRS Tropical'	*Citrus sunki*

[1] Rootstock in the process of registration in Registro Nacional de Cultivares (RNC) of Ministério da Agricultura, Pecuária e Abastecimento (MAPA); the others, identified with the acronym BRS, have already been registered in RNC/MAPA.

measured with a graduated ruler from the soil surface to the highest point of the plant; trunk diameter of the rootstock (cm) and trunk diameter of the graft (cm), with measurements taken 10 cm below and 10 cm above the graft union using a caliper; graft compatibility ratio, given by the ratio between the trunk diameters of the rootstock and the graft; crown diameter (m), calculated as the average of two equatorial diameters of the crown measured in directions perpendicular to the planting line, using a tape measure; crown volume (m^3), calculated by the formula $V = 2/3 \times [(\pi \times D/4) \times H]$, where V is the crown volume, D is the average crown diameter (m), and H is the plant height (m); Vegetative Vigor Index (IVV), calculated by the formula $IVV = [H + D + (DPE \times 10)]/100$, where H is the plant height (cm), D is the crown diameter (cm), and DPE is the trunk diameter of the rootstock (cm) (Bordignon et al., 2003a; Bordignon et al., 2003b).

The data were tested for normality of distribution using the Kolmogorov-Smirnov test and then submitted to analysis of variance and the F-test. The means were grouped using the Scott-Knott test at a 5% significance level, with the assistance of the SISVAR software.

Results and Discussion

The results of the evaluations of vegetative growth of the 'Tahiti CNPMF 02' lime tree on the rootstocks evaluated in Guarantã do Norte-MT are presented in **Tables 3** and **4**.

The number of mean groupings for plant height varied between two and four, with the hybrids generated by PMG Citros reorganizing into different positions and groups over the six evaluation periods (Table 3). At 36 months after planting (MAP), the commercial rootstocks grouped in the highest plant height class (3.21 m), and the hybrids in the final selection formed three mean classes. Among the new hybrids, TSKC x TRFD - 003 showed the highest average (2.96 m), standing alone in a class, while LRF x (LCR x TR) - 005 induced the lowest plant height (2.35 m). This hybrid was always in the lower height class throughout the evaluations, except for the first evaluation. It is also observed in Table 3 that between the penultimate and last evaluations, the hybrid LRF x (LCR x TR) - 005 was the only rootstock that did not induce growth in crown height, having stabilized height. Costa (2019), evaluating various rootstocks in combination with the 'Valência IAC' orange tree, concluded that TSKC x TRFD - 006 and TSKC x TRFD - 003 determined dwarf and semi-dwarf tree canopy variety, respectively, which disagrees with the results obtained here so far, and this was not observed in relation to the hybrid LRF x (LCR x TR) - 005.

The mean trunk diameters of the rootstocks formed three groupings over the six semiannual evaluations, except for the evaluation at 18 MAP, where five classes were formed, and the evaluation at 30 MAP, which resulted in two groupings (Table 3). At 36 MAP, similarly to what was observed for plant height, the commercial rootstocks formed the class of means with the largest trunk diameters. The 'Swingle' citrumelo, due to its characteristics, was the only one with a mean diameter greater than 10 cm. The hybrids created by PMG Citrus grouped into two classes: the lower class included HTR - 069, LRF x (LCR x TR) - 005, and TSKC x (LCR x TR) – 059, while the intermediate class included the hybrids TSKC x CTSW - 028, LVK x LCR - 038, TSKC x TRFD - 003, and TSKC x TRFD - 006.

Table 3. Plant height, rootstock and scion trunk diameters, compatibility ratio between rootstock/scion of 'Tahiti' acid lime tree [Citrus ×latifolia (Yu. Tanaka) Tanaka] clone 'CNPMF 02', combined with 13 rootstocks during the vegetative phase, up to 36 months after planting (MAP). 2017, 2018, 2019, Guarantã do Norte, MT.

	Plants height (m)											
Rootstock1	6 MAP		12 MAP		18 MAP		24 MAP		30 MAP		36 MAP	
'Cravo Santa Cruz' lemon tree	0,77	b	1,07	b	1,80	b	2,07	a	2,74	a	3,28	a
'Cravo CNPMF - 03'lemon tree	0,69	b	1,00	b	1,75	b	2,07	a	2,58	a	3,25	a
Cintrandarin 'Indio'	0,86	a	1,17	a	1,89	a	2,10	a	2,67	a	3,25	a
Citrandarin 'San Diego'	0,82	a	1,10	b	1,76	b	1,98	a	2,65	a	3,15	a
Citrumelo 'Swingle'	0,76	b	1,03	b	1,76	b	1,98	a	2,60	a	3,15	a
'Sunki Tropical' Tangerine	0,74	b	1,16	a	1,93	a	2,13	a	2,75	a	3,18	a
TSKC x CTSW - 028	0,38	d	0,72	d	1,38	d	1,84	b	2,46	b	2,84	c
HTR - 069	0,57	c	0,93	c	1,53	c	1,81	b	2,45	b	2,62	c
LVK x LCR - 038	0,92	a	1,18	a	1,58	c	1,81	b	2,57	a	2,70	c
TSKC x TRFD - 003	0,71	b	1,07	b	1,66	b	2,01	a	2,62	a	2,96	b
TSKC x TRFD - 006	0,70	b	1,01	b	1,59	c	1,87	b	2,46	b	2,79	c
LRF x (LCR x TR) - 005	0,50	c	0,88	c	1,38	d	1,62	c	2,39	b	2,35	d
TSKC x (LCR x TR) - 059	0,63	c	0,92	c	1,50	c	1,79	b	2,44	b	2,82	c
CV (%)	10,72		17,56		11,70		11,61		10,36		9,61	
	Rootstock Trunk Diameter (cm)											
Rootstock	6 MAP		12 MAP		18 MAP		24 MAP		30 MAP		36 MAP	
'Cravo Santa Cruz' Lemon tree	1,35	b	2,41	a	4,92	b	6,37	b	8,94	a	9,96	a
'Cravo CNPMF - 03' Lemon tree	1,54	a	2,56	a	5,24	b	6,85	a	9,21	a	9,82	a
Cintrandarin 'Indio'	1,49	a	2,59	a	5,21	b	6,60	b	9,08	a	9,66	a
Citrandarin 'San Diego'	1,63	a	2,53	a	5,23	b	6,60	b	8,89	a	9,51	a
Citrumelo 'Swingle'	1,74	a	2,61	a	5,71	a	7,20	a	9,33	a	10,17	a
'Sunki Tropical' Tangerine tree	1,32	b	2,20	b	4,72	c	6,47	b	8,84	a	9,74	a
TSKC x CTSW - 028	0,84	c	1,78	c	3,91	e	5,86	c	7,98	b	9,17	b
HTR - 069	1,19	b	2,00	b	4,29	d	5,66	c	7,82	b	8,39	c
LVK x LCR - 038	1,84	a	2,58	a	5,00	b	5,96	c	7,92	b	8,96	b
TSKC x TRFD - 003	1,33	b	2,32	a	4,78	c	5,96	c	7,97	b	8,85	b
TSKC x TRFD - 006	1,38	b	2,26	b	4,52	c	6,17	c	8,32	b	8,91	b
LRF x (LCR x TR) - 005	1,04	c	2,11	b	4,60	c	5,86	c	8,09	b	8,59	c
TSKC x (LCR x TR) - 059	1,03	c	2,04	b	4,52	c	5,60	c	7,72	b	8,65	c
CV (%)	13,40		15,60		9,85		9,92		9,80		8,05	
	Scion Trunk Diameter (cm)											
Rootstock	6 MAP		12 MAP		18 MAP		24 MAP		30 MAP		36 MAP	
'Cravo Santa Cruz' Lemon tree	1,23	b	2,29	a	4,82	a	6,61	a	9,02	a	9,98	a
'Cravo CNPMF - 03' Lemon tree	1,33	b	2,41	a	5,02	a	6,81	a	9,20	a	9,80	a
Cintrandarin 'Indio'	1,33	b	2,40	a	5,09	a	6,74	a	9,12	a	9,79	a
Citrandarin 'San Diego'	1,38	b	2,28	a	4,77	a	6,63	a	8,99	a	9,51	b
Citrumelo 'Swingle'	1,32	b	2,25	a	4,83	a	6,74	a	8,69	a	9,44	b
'Sunki Tropical' Tangerine tree	1,23	b	2,36	a	5,00	a	6,81	a	9,27	a	10,17	a
TSKC x CTSW - 028	0,60	d	1,55	c	3,60	d	5,83	b	8,17	b	8,93	c
HTR - 069	0,95	c	1,82	b	3,77	d	5,51	b	7,98	b	8,13	d
LVK x LCR - 038	1,61	a	2,45	a	4,53	b	5,80	b	8,12	b	9,01	c
TSKC x TRFD - 003	1,07	c	2,02	b	4,39	b	5,74	b	7,80	b	8,54	d
TSKC x TRFD - 006	1,20	b	2,22	a	4,49	b	6,43	a	8,49	b	8,92	c
LRF x (LCR x TR) - 005	0,82	c	2,02	b	4,22	c	6,07	b	8,03	b	8,51	d
TSKC x (LCR x TR) - 059	0,92	c	1,96	b	4,55	b	5,83	b	8,17	b	8,99	c
CV (%)	14,58		16,02		13,16		10,57		9,79		7,67	
	Rootstock/Scion Incompatibility Ratio											
Porta-Enxerto	6 MAP		12 MAP		18 MAP		24 MAP		30 MAP		36 MAP	
'Cravo Santa Cruz' Lemon tree	1,10	b	1,06	b	1,03	c	0,96	c	0,99	b	1,00	c
'Cravo CNPMF - 03'Lemon tree	1,16	b	1,06	b	1,05	c	1,01	b	1,01	b	1,00	c
Cintrandarin 'Indio'	1,12	b	1,09	b	1,03	c	0,98	c	1,00	b	0,99	c
Citrandarin 'San Diego'	1,19	b	1,12	a	1,10	b	0,99	c	0,99	b	1,00	c
Citrumelo 'Swingle'	1,33	a	1,19	a	1,20	a	1,07	a	1,09	a	1,08	a
'Sunki Tropical' Tangerine Tree	1,07	b	0,94	b	0,95	c	0,95	c	0,96	b	0,96	d
TSKC x CTSW - 028	1,46	a	1,19	a	1,09	b	1,01	b	0,98	b	1,03	b
HTR - 069	1,26	a	1,12	a	1,16	a	1,04	b	0,99	b	1,03	b
LVK x LCR - 038	1,14	b	1,05	b	1,11	b	1,03	b	0,98	b	1,00	c
TSKC x TRFD - 003	1,24	a	1,16	a	1,10	b	1,02	b	1,03	b	1,04	b
TSKC x TRFD - 006	1,16	b	1,03	b	1,03	c	0,96	c	0,98	b	1,00	c
LRF x (LCR x TR) - 005	1,30	a	1,06	b	1,10	b	0,98	c	1,01	b	1,01	c
TSKC x (LCR x TR) - 059	1,12	b	1,05	b	1,00	c	0,96	c	0,95	b	0,96	d
CV (%)	9,89		13,97		11,31		6,57		8,01		5,71	

[1]Clones of 'Cravo' lemon tree (Citrus ×limonia Osbeck); 'Indio' and 'San Diego' citrandarins [C. sunki (Hayata) hort. ex Tanaka x Poncirus trifoliata (L.) Raf]; 'Swingle' citrumelo (C. ×paradisi Macfad. x P. trifoliata); 'Sunki' tangerine tree (C. sunki) Tropical selection; TSKC: common 'Sunki' tangerine tree; CTSW: 'Swingle' citrumelo; HTR: trifoliated hybrid; LVK: 'Volkameriano' lemon tree [C. ×volkameriana (Risso) V. Ten. & Pasq.]; LCR: 'Cravo' lemon tree; TRFD: 'Flying Dragon' P. trifoliata selection; LRF: 'Rugoso da Flórida' lemon tree (C. ×jambhiri Lush.); TR: P. trifoliata.

[2] Means followed by the same letter in the column do not differ by the Scott-Knott test ($p < 0.05$).

CV: Coefficient of Variation

Table 4. Canopy diameter, canopy volume, and vegetative vigor index of 'Tahiti' acid lime tree [Citrus ×latifolia (Yu. Tanaka) Tanaka] clone 'CNPMF 02', combined with 13 rootstocks during the vegetative phase, up to 36 months after planting (MAP). 2017, 2018, 2019, Guarantã do Norte, MT.

	Canopy Diameter (m)											
Rootstock	6 MAP		12 MAP		18 MAP		24 MAP		30 MAP		36 MAP	
'Cravo Santa Cruz' Lemon tree	0,54	a	1,08	a	2,14	a	2,67	a	2,82	a	3,36	b
'Cravo CNPMF - 03' Lemon tree	0,55	a	1,05	a	2,09	a	2,60	a	2,80	a	3,47	a
Cintrandarin 'Indio'	0,55	a	1,14	a	2,23	a	2,81	a	2,81	a	3,60	a
Citrandarin 'San Diego'	0,54	a	1,11	a	2,04	b	2,61	a	2,70	a	3,33	b
Citrumelo 'Swingle'	0,52	a	1,00	a	2,11	a	2,58	a	2,72	a	3,48	a
'Sunki Tropical' Tangerine tree	0,46	b	0,98	a	2,22	a	2,75	a	2,77	a	3,43	a
TSKC x CTSW - 028	0,18	c	0,49	c	1,56	d	2,28	b	2,74	a	3,04	c
HTR - 069	0,39	b	0,94	b	1,83	c	2,33	b	2,52	b	2,98	c
LVK x LCR - 038	0,54	a	1,01	a	1,76	c	2,33	b	2,60	b	3,07	c
TSKC x TRFD - 003	0,48	b	1,01	a	1,95	b	2,57	a	2,72	a	3,32	b
TSKC x TRFD - 006	0,45	b	0,98	a	1,94	b	2,49	b	2,71	a	3,29	b
LRF x (LCR x TR) - 005	0,26	c	0,82	b	1,64	d	2,29	b	2,53	b	2,95	c
TSKC x (LCR x TR) - 059	0,30	c	0,90	b	1,93	b	2,44	b	2,61	b	3,24	b
CV (%)	17,3		21,67		12,17		11,24		8,23		8,65	
	Canopy volume (m^3)											
Rootstock	6 MAP		12 MAP		18 MAP		24 MAP		30 MAP		36 MAP	
'Cravo Santa Cruz' Lemon tree	0,12	a	0,69	b	4,37	b	7,80	b	11,56	a	19,54	a
'Cravo CNPMF - 03' Lemon tree	0,12	a	0,61	b	4,15	b	7,27	b	10,75	a	20,89	a
Cintrandarin 'Indio'	0,14	a	0,86	a	5,03	a	8,91	a	11,20	a	22,28	a
Citrandarin 'San Diego'	0,13	a	0,77	a	3,89	b	7,24	b	10,17	a	18,39	b
Citrumelo 'Swingle'	0,11	a	0,60	b	4,19	b	7,11	b	10,30	a	20,28	a
Tangerineira 'Sunki Tropical'	0,09	a	0,64	b	5,04	a	8,63	a	11,18	a	19,68	a
TSKC x CTSW - 028	0,01	b	0,10	d	1,87	d	5,06	c	9,89	a	14,19	c
HTR - 069	0,05	b	0,47	c	2,77	c	5,30	c	8,27	b	12,35	d
LVK x LCR - 038	0,15	a	0,68	b	2,59	c	5,20	c	9,18	b	13,36	d
TSKC x TRFD - 003	0,09	a	0,61	b	3,32	c	7,02	b	10,15	a	17,32	b
TSKC x TRFD - 006	0,08	a	0,53	b	3,26	c	6,34	c	9,47	b	15,97	c
LRF x (LCR x TR) - 005	0,02	b	0,27	d	1,95	d	4,54	c	8,08	b	10,92	d
TSKC x (LCR x TR) - 059	0,03	b	0,42	c	2,94	c	5,61	c	8,83	b	15,63	c
CV (%)	44,26		51,79		29,81		28,52		21,73		21,75	
	Vegetative Vigor Index											
Rootstock	6 MAP		12 MAP		18 MAP		24 MAP		30 MAP		36 MAP	
'Cravo Santa Cruz'Lemon Tree	1,44	b	2,39	a	4,43	b	5,37	a	6,45	a	7,64	a
'Cravo CNPMF - 03' Lemon Tree	1,39	b	2,30	a	4,37	b	5,26	a	6,31	a	7,70	a
Cintrandarin 'Indio'	1,56	a	2,56	a	4,64	a	5,57	a	6,38	a	7,82	a
Citrandarin 'San Diego'	1,52	a	2,46	a	4,32	b	5,26	a	6,23	a	7,43	b
Citrumelo 'Swingle'	1,46	b	2,29	a	4,44	b	5,28	a	6,26	a	7,66	a
'Sunki Tropical' Tangerine Tree	1,34	b	2,36	a	4,62	a	5,53	a	6,40	a	7,58	a
TSKC x CTSW - 028	0,65	e	1,39	c	3,33	d	4,71	b	6,00	b	6,80	c
HTR - 069	1,08	c	2,06	b	3,78	c	4,70	b	5,76	b	6,43	d
LVK x LCR - 038	1,65	a	2,45	a	3,83	c	4,73	b	5,95	b	6,66	c
TSKC x TRFD - 003	1,32	b	2,31	a	4,08	c	5,16	a	6,13	a	7,17	b
TSKC x TRFD - 006	1,29	b	2,21	a	3,98	c	4,97	b	5,99	b	6,98	c
LRF x (LCR x TR) - 005	0,87	d	1,91	b	3,47	d	4,50	b	5,73	b	6,16	d
TSKC x (LCR x TR) - 059	1,04	c	2,03	b	3,88	c	4,79	b	5,82	b	6,92	c
CV (%)	10,97		16,07		9,44		9,32		7,11		6,88	

1Clones of 'Cravo' Lemon Tree (Citrus ×limonia Osbeck); Citrandarin 'Indio' and 'San Diego' [C. sunki (Hayata) hort. ex Tanaka × Poncirus trifoliata (L.) Raf]; Citrumelo 'Swingle' (C. ×paradisi Macfad. × P. trifoliata); Tangerine Tree'Sunki' (C. sunki) 'Tropical' selection; TSKC: Common Tangerine Tree 'Sunki'; CTSW: Citrumelo 'Swingle'; HTR: Trifoliate hybrid; LVK: 'Volkamerian' Lemon Tree [C. ×volkameriana (Risso) V. Ten. & Pasq.]; LCR: 'Cravo' Lime Tree; TRFD: P. trifoliata 'Flying Dragon' selection; LRF: 'Rugoso da Flórida' Lemon Tree (C. ×jambhiri Lush.); TR: P. trifoliata.

Note: Averages followed by the same letter in the column do not differ according to the Scott-Knott test (p<0.05).

CV: Coefficient of variation.

Among four classes of means, the extremes were composed of only one rootstock: LVK x LCR - 038 with the highest mean and TSKC x CTSW - 028 with the lowest, with a 63% difference between them. At 36 MAP, the means grouped into four classes, two of them contained the commercial rootstocks, and two contained the hybrids in pre-release. The 'Sunki Tropical' tangerine tree was the only rootstock that resulted in a trunk diameter of the graft with a mean greater than 10 cm. The 'San Diego' citrandarin and the 'Swingle' citrumelo formed the second mean class, in descending order. The hybrids HTR - 069, TSKC x TRFD - 003, and LRF x (LCR x TR) - 005 formed

the lower class of mean trunk diameters of the graft. The difference between the means of the upper and lower classes was 15.6%.

The means for the rootstock trunk diameter/graft trunk diameter ratio showed a downward trend in all combinations of scion/rootstock up to 24 MAP, staying close to perfect balance (1.00) until the end of the evaluations at 36 MAP (Table 3). This is a good indication of the compatibility of all scion/rootstock combinations in the study. At 36 MAP, the 'Swingle' citrumelo stood out in the upper class of the diameter ratio discussed here, while the 'Sunki Tropical' tangerine tree and the hybrid TSKC x (LCR x TR) - 059 stabilized with the lowest mean, forming the lower class (Table 3).

The crown diameter increased seven times during the vegetative development period of the 'Tahiti CNPMF' lime tree (Table 4). At 36 MAP, the mean of crown diameters formed three groupings, with a small difference between the upper, intermediate, and lower classes. Unlike the previously analyzed characteristics, the intermediate class was formed by commercial rootstocks (LCRSC and CTRSD) and by non-commercial hybrids of tangerine 'Sunki' tree with trifoliata: TSKC x TRFD - 003, TSKC x TRFD - 006, and TSKC x (LCR x TR) - 059.

The overall mean crown volume of the thirteen rootstocks combined with the 'Tahiti CNPMF 02' lime tree was only 0.1 m³ at 6 MAP (Table 4). From 6 MAP onwards, the crown volume showed greater growth. Between the last two evaluations, there was a 41.8% increase in crown volume. At 36 MAP, the means of the treatments formed four groupings. The upper mean class included all commercial rootstocks, except for the 'San Diego' citrandarin, which, along with the hybrid TSKC x TRFD - 003, formed the second class with the highest means. HTR - 069, LVK x LCR - 038, and LRF x (LCR x TR) - 005 formed the lower mean class for crown volume. LRF x (LCR x TR) - 005 induced 50% less volume than the 'Indio' citrandarin, the two extremes observed in the study. LVK x LCR - 038 grouped in the upper crown volume class at 6 MAP and in the lower crown volume class at 36 MAP.

For IVV, there were between two and five groupings over the six evaluations. Between 6 and 18 MAP, the rootstocks showed considerable variation in ranking position and class participation (Table 4). In the following two evaluations, only two groupings were formed, with no variation in the class composition. In these periods, the hybrid TSKC x TRFD - 003 formed the upper mean class along with the commercial rootstocks in the study. This same hybrid participated in the upper IVV grouping in three of the six evaluations. The LVK x LCR - 038 showed the lowest increase in IVV between the first and last evaluation. At 36 MAP, the IVV means were divided into four groupings, very similarly to what was observed for the crown volume variable (Table 4). The only difference was that LVK x LCR - 038 ascended one class in IVV compared to its crown volume grouping. The mean of the upper class was 7.68, and the most vigorous combination was that with the 'Indio' citrandarin. Bettini (2019), in the evaluation of IVV of 'Tahiti' lime tree combinations with 16 rootstocks, being 13 new citrandarins, at four years after planting, obtained an index of 7.83 for the standard 'Cravo' lemon tree rootstock and 7.40 for the most vigorous of the citrandarins. These results show how favorable the edaphoclimatic conditions of Guarantã do Norte are for the vegetative growth of 'Tahiti' lime tree, as these indices are comparable to plants that are three years old in this study (Table 4). The lower IVV mean class grouped two rootstocks: HTR - 069 and LRF x (LCR x TR) - 005. This hybrid of 'Rugoso da Flórida' lime tree (C. ×jambhiri Lush.) induced the lowest vegetative vigor among the rootstocks of the trial, at 36 MAP.

According to Costa et al. (2020a), Costa et al. (2020b), and Costa et al. (2021), applying non-parametric indices as criteria for rootstock selection, ranked LRF x (LCR x TR) - 005 in 8th position in the multiplicative index, among 46 rootstocks combined with the 'Valência IAC' orange tree, outperforming even the standard 'Cravo Santa Cruz' lemon tree. These results in the state of Mato Grosso are consistent with what was observed in São Paulo (Ramos et al., 2015). Marques (2018), in temperate climate conditions, observed high growth vigor of this rootstock in the nursery, between sowing and the grafting point. On the other hand, HTR - 069 is a rootstock that stood out for its low growth vigor in the nursery stage (Parolin et al. 2017). Therefore, rootstocks play an important role in the agronomic performance of citrus. The rootstock clearly impacts productivity estimation indices for citrus, indirectly through greater plant growth and by reducing individual mortality due to disease (Sau et al., 2018; Albrecht & Bowman, 2019; Khankahdani et al., 2019; Santos et al., 2019; Carvalho et al., 2021a; Carvalho et al., 2021b).

Conclusions

The vegetative growth characteristics of the 'Tahiti CNPMF 02' lime tree are determined by the rootstock in the Amazon biome of north of Mato Grosso. The new non-commercial rootstock hybrids LRF x (LCR x TR) - 005, TSKC x (LCR x TR) - 0059, HTR-069, LVK x LCR - 038, TSKC x CTSW - 028, TSKC x TRFD - 006, and 003 are promising for using in high-density 'Tahiti' lime tree orchards in north

of Mato Grosso, as they exhibit less growth compared to the 'Cravo Santa Cruz' lemon tree rootstock, which is the standard rootstock used in conventional cultivation systems.

Acknowledgments

Our recognition and thanks to the institutions CNPMF, CPAMT, IFMT Campus Sorriso, Research Group of Agricultural Production Systems in the Cerrado, IFMT Campus Guarantã do Norte, Guarantã do Norte City Hall, Empaer-MT, and CNPq, without them, this work would not have been possible.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.