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Agronomical performance of citrus scion cultivars grafted on Rangpur lime in north-eastern Brazil

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Abstract

The Brazilian north-eastern states of Bahia and Sergipe account for 10% of national citrus production. In this region, the majority of farmers cultivate the ‘Pera’ sweet orange grafted on Rangpur lime highlighting the need for new scion-rootstock combinations. Here, we evaluated vegetative, productive and phytosanitary parameters of twenty citrus scion cultivars (eight sweet oranges, four hybrids of mandarins and eight clones of ‘Tahiti’ acid limes) grafted on Rangpur lime, grown in the state of Sergipe. The ‘Pera’ scion was considered the control. The following parameters were evaluated in all scion cultivars: canopy volume, vigor, drought tolerance, nutrition, cumulative yield, yield efficiency as well as the number of mined leaves by the leaf miner *Phyllocnistis citrella* and the number of adults of the rust mite *Phylocoptruta oleivora*. The ‘Kona’ scion had the highest annual and cumulative fruit yields among sweet orange cultivars. Among the hybrids of mandarins, ‘Piemonte’ showed higher cumulative yield and similar production efficiency in comparison to ‘Nova’ and ‘Page’. Soil fertility was similar among blocks of the experimental area, however leaf tissue contents of N, P and Mg differed among cultivars. Regarding the influence of pests, our results shown that all cultivars were equally susceptible to the leaf miner and the rust mite. Overall, the scion cultivars ‘Kona’, ‘Piemonte’ and ‘Persian Lime 58’ had higher vegetative and productive efficiency compared to the main cultivar grown in the region, the ‘Pera CNPMF D6’, which emphasizes their potential for orchards diversification in north-eastern Brazil.

Keywords: Sweet orange; mandarin; acid lime; canopy volume; pests; yield.

Abbreviations: CV_canopy volume; CY_cumulative yield; DA_diameter above the graft line; DB_ diameter below the graft line; DP_ canopy diameter perpendicular to the row; DR_ canopy diameter along the row; DT_Drought tolerance; OM_ organic matter; PH_plant height; RBDA_Relationship between rootstock/scions; SO_Sweet orange; VS_visual assement of vigor; YE_ yield efficiency.

Introduction

The Northeast region of Brazil accounts for 10% of national citrus production, the second largest producer in the country with 121,498 ha of harvested area, producing 1,858.781 million tons of fruits, with an average yield of 15.3 tons ha^{-1} (IBGE, 2014). The states of Bahia and Sergipe concentrate 90% of the planted area of the Northeast, i.e. 68,800 and 57,600 ha, respectively. The state of Sergipe is considered the fourth national citrus producer, with 840,000 tons of fruits, mostly sweet oranges [*Citrus sinensis* (L.) Osbeck] (822,000 tons in 56,000 ha), followed by ‘Tahiti’ acid lime [*C. latifolia* (Yu. Tanaka) Tanaka] (11,000 tons in 857 ha) and hybrids of mandarins (6,500 tons in 420 ha) (IBGE, 2014). Citrus orchards are spread over 11,000 farms located predominantly in the South of Sergipe state, within the range of the Coastal Tablelands, in properties with an average of less than 10 ha over an area of 5,400 km^2. The majority of producers are smallholders which usually carry out low-input management practices (Martins et al., 2014). The Coastal Tablelands run along the coastline and is characterized by cohesive soils with low water availability in part of the year, rendering plants nutritionally unbalanced, underdeveloped, with low vegetative growth and yield (average 14 tons ha^{-1}) and longevity (10-12 years of effective production) (Cintra et al., 2000; Souza et al., 2007; Souza et al., 2008; Anjos et al., 2011; Martins et al., 2014). The ‘Pera’ sweet orange is the main scion cultivar being grown in the states of Sergipe and Bahia (Prudente et al., 2004). Historically, the ‘Pera’ sweet orange is considered the most widespread and economically important scion cultivar in Brazil (Salibe et al., 2002; Passos et al., 2013). The cultivation of a single cultivar in a region concentrates management practices and harvest within a given period which contributes to increasing costs apart from varietal monocultures being more vulnerable to pests and diseases (Passos et al., 2007; Moraes Filho et al., 2011). New cultivars of sweet oranges, mandarins and acid limes could be introduced into this region, however few information is available regarding the agronomical performances of such cultivars in comparison to the prevailing ‘Pera’ sweet orange.

Regarding phytotechnical problems, citrus orchards in north-eastern Brazil are attacked by a complex of pests including the leaf miner *Phyllocnistis citrella* (Lepidoptera: Gracillariidae) and the rust mite *Phyllocoptruta oleivora* (Acari: Eriophyidae) which cause severe yield losses annually (Moraes and Flechtmann, 2008; Mendonça and

Silva, 2009). The leaf miner attacks mainly young leaves decreasing photosynthesis rate and branch development. The rust mite feeds on leaves and on developing fruits, which surface turns silvery in lemons or rust brown in oranges as a result of attack (Moraes and Flechtmann, 2008; Mendonça and Silva, 2009). Therefore, it is important to evaluate how citrus scion cultivars respond to pests since cultivars have distinct genetic characteristics (Vendramim and Guzzo, 2009, 2011).

Diversification of citrus scion and rootstock cultivars are demands of the Brazilian citrus industry and farmers (Silva et al., 2013). New citrus cultivars have proved good adaptability in several regions of the country, including in the Northeast. These cultivars show high quality of fruits and yield for the fresh market and industry (Passos et al., 2007, 2013; Caputo et al., 2012).

Therefore, we aimed at searching for new scion cultivars of sweet oranges, mandarins and acid limes as an alternative to the traditional 'Pera' sweet orange helping farmers to diversify their orchards. To achieve this goal we used an approach combining comprehensive evaluations of vegetative, productive and phytosanitary parameters.

Results and discussion

Soil characteristics and nutritional status of cultivars

Soil fertility results show that all blocks were similar regarding the contents of macro and micronutrients (Table 1), indicating that cultivars were subjected to equal conditions for expressing their genetic potential. Soils of the Coastal Tablelands are generally sandy, with low contents of organic matter and nutrients besides having cohesive layers between 20 and 60 cm depth (Cintra et al., 2000). These pedogenetic cohesive layers are a major constraint to citrus production because such layers alter water and air movement in addition to increasing mechanical resistance to root penetration, resulting in yield problems, reduced fruit quality and plant longevity (Cintra et al., 2000). Interestingly, the foliar contents of K, Ca, Fe, B, Mn, S, Zn, B and Cu were similar among cultivars. However, leaf tissue contents of N, P and Mg differed among cultivars (Table 2). All varietal groups (sweet oranges, hybrids of mandarins and clones of 'Tahiti' acid limes) had cultivars that stood out in terms of N and Mg leaf contents. For cultivars with higher N concentrations, detected values ranged from 28.21 to 31.41 g kg^{-1}. Regarding Mg contents, the highest values ranged from 2.71 to 3.37 g kg^{-1} (Table 2). The highest P contents were found in the group of sweet oranges and clones of 'Tahiti'. The 'Lima', 'Lima Verde' and 'Kona' scions had higher P values compared to the remaining sweet oranges, while the 'IAC-5' had lower P contents than the other clones of 'Tahiti' acid limes. The 'Pera' scion had low foliar contents of N, P and K. Considering the nutritional limits for citrus in the state of Sergipe (Sobral et al., 2007), the average levels of micronutrients and P are within the appropriate range, while N levels are higher, and contents of K, Ca and Mg are lower than recommended. It is noteworthy that citrus plants absorb high quantities of Ca, N and Fe (Mattos Junior et al., 2003; Dias et al., 2013). In general, fruit plants store N mainly in leaves, but also in woody parts, leading to an exaggerated vegetative growth at the expense of production. Fidalski and Auller (2007) reported that the balance between proper nutrition and orange fruit production may be achieved by reducing N input during the rainy season. In our experiment, nitrogen fertilization was carried out in the rainy season following by manual incorporation, which may have contributed to high levels of foliar N in almost all cultivars.

Vegetative performance

Citrus plants showing water deficiency symptoms are commonly observed throughout the Brazilian Coastal Tablelands during the dry season (Cintra et al., 2000; Cerqueira et al., 2004; Souza et al., 2008), even when cultivars are grafted on Rangpur lime, which is known to induce drought tolerance (Donato et al., 2007; Cunha Sobrinho et al., 2013). The most critical period to water stress in citrus occurs between flowering and fruit set (Pérez-Pérez et al., 2008). Overall, scion cultivars grafted on Rangpur lime showed moderate to high tolerance to drought (Fig. 1). The sweet oranges 'Kona', 'Rubi' and 'Pera CNPMF-D6' had a low tolerance to drought (Fig. 1) as observed by leaf wilting and slightly yellowing, but no leaf drop. However, susceptibility to drought presented by these cultivars was apparently not enough to affect vegetative development and yield. The marked dry season starts in November and lasts until March (Fig. 2), which coincides with the rainfall time series for 1971-2005 (Souza et al., 2008). The 'Pera CNPMF D6' sweet orange had the highest values of trunk diameter below (DB) and above (DA) the grafting line over the period 2011-2013 (Table 3). The sweet orange cultivars 'Rubi', 'Kona', 'Valencia Montemorelos', 'Sucorry Acidless' and the 'Piemonte' also presented high DB and DA values. Conversely, the sweet oranges 'Lima Verde', 'Natal CNPMF-112' and 'Lima' together with the mandarin 'Nova' had the lowest values of DB and DA. No differences in the relationship between rootstock/scions were found among cultivars (Table 3). The difference between trunk diameters at grafting line may be an indicative of incompatibility of a given scion-rootstock combination (Stenzel et al., 2005). However, no incompatibility problems were observed in our study since values were close to 1 (Stenzel et al., 2005), demonstrating the plant canopy development trend (Lima et al., 2014). The scions 'Pera CNPMF D6', 'Rubi' and 'Murcott' had the highest heights (PH) followed by 'Kona', 'Succory Acidless' and 'Piemonte'. In contrast, the cultivars 'Valencia Montemorelos', 'Lima Verde' and tangerine-tangelo 'Page', followed by 'Natal CNPMF 112', 'Lima' and mandarin 'Nova' presented the lowest height values. These results are in line with visual assessment of vigor (VS), indicating that 'Pera CNPMF D6', 'Rubi', 'Kona', 'Valencia Montemorelos' and 'Piemonte' showed greater vegetative growth of branches and shoots contrasting with 'Succory Acidless', 'Lima Verde', 'Natal CNPMF 112', 'Lima', 'Page' and 'Nova'. The vigor of scion cultivars is affected by the rootstock, being directly related to the genotype and their relationships (Auler et al., 2008). The sweet oranges 'Rubi' and 'Pera CNPMF-D6', followed by 'Kona', 'Valencia Montemorelos', 'Succory Acidless', 'Piemonte', 'Murcott' and 'Page' had the highest canopy volumes (CV) . On the other hand, 'Lima Verde', 'Natal CNPMF-112', 'Lima' and 'Nova' had the smallest CV values (Table 3). Shading of the inner canopy can lead to decreased yield efficiency since the productive range of the canopy, which captures 90% of solar radiation, is located within an outer layer of 1 meter deep (Nunez et al., 2007). Thus, small plant size is a desirable feature for facilitating management and harvest apart from allowing increasing planting density and higher yield efficiency (Silva et al., 2013; Lima et al., 2014).

Table 1. Soil chemical characteristics of the experimental site.

*Depth (cm)	OM ($g.kg^{-1}$)	pH in H_2O	Ca	Mg	H+Al	Al	P	K	Na	Fe	Cu	Mn	Zn
			--------($mmol_c.dm^{-3}$)---------				---------------------------($mg.dm^{-3}$)--------------------------						
0-20	11.23	5.12	26.71	3.68	24.50	0.20	50.88	63.20	2.97	62.32	0.12	1.51	0.43
20-40	12.86	5.43	25.67	2.78	30.33	0.00	16.02	99.03	3.27	77.34	0.08	1.32	0.32
Means	12.04	5.27	26.19	3.23	27.42	0.10	33.45	81.12	3.12	68.33	0.10	1.43	0.39

*Soil samples were collected along rows at depths of 0 to 20 cm and 20 to 40 cm.

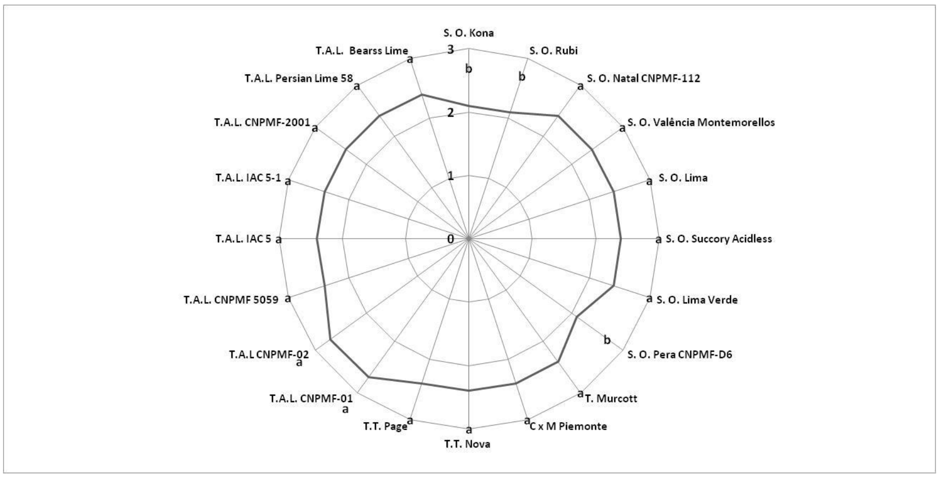

Fig 1. Drought tolerance (DT) of scion cultivars of sweet oranges (S.O.) (*Citrus sinensis*), hybrids of mandarins (T, TT and C x M) and 'Tahiti' acid lime (T.A.L.) clones (*C. latifolia*). Same letters indicate that DT values are not significantly different based on Scott-Knott tests (P ≤0.05). DT values ranged from 1 (susceptible to drought) to 3 (tolerant to drought).

Yield and phytosanitary parameters

Regarding production, the scion 'Kona' stood out throughout the evaluating period (2011 to 2013) together with 'Rubi' (2012), 'Piemonte' and 'Persian lime 58' (2013). 'Kona' had the highest cumulative yield (74 tons ha^{-1}) among scion cultivars over the period 2011 to 2013 contrasting with only 51 tons ha^{-1} of 'Pera' (Table 4). 'Rubi' (59 tons ha^{-1}), 'Piemonte' (59 tons ha^{-1}) and 'Persian lime 58' (65 tons ha^{-1}) also had high cumulative yields, while 'Lima Verde', 'Lima' and 'CNPMF-2001' had low cumulative yields over the 3-year evaluation period. With respect to the clones of 'Tahiti' acid limes, 'Persian Lime 58' stands out in production. Also, the 'Bearss' cultivar could be highlighted by attaining higher yields than the 'IAC 5' which is traditionally cultivated by farmers in this region. It is noteworthy that the clones 'CNPMF-01', 'Persian Lime 58', 'Bearss Lime' and 'IAC 5-1' precociously entered production although 'CNPMF-01' and 'IAC 5-1' had reduced yields over the evaluation period in comparison to the first harvest. In Brazil, plantations of 'Tahiti' acid limes mainly consist of the clones 'IAC 5' and 'Quebra-galho'. In combination with Rangpur lime, yields and lifespan of scion citrus cultivars are reduced mainly due its susceptibility to gummosis *Phytophthora* spp., which is a widespread fungal disease in Brazil (Stuchi et al., 2009). Additionally, the vigorous scion growth, which interferes in management practices, discourages Brazilian farmers to cultivate 'Tahiti' acid limes. The production performance achieved by 'Kona', 'Rubi', 'Piemonte', and 'Tahiti Persian lime 58' under the conditions of the Coastal Tablelands of Sergipe state is in agreement with other results highlighting their potential for varietal orchard diversification purposes (Caputo et al., 2012; Passos et al., 2013; Cunha Sobrinho et al., 2013; Martins et al., 2014). The cultivars were grouped into two categories of yield efficiency (YE): i) 'Kona', 'Natal CNPMF-112', 'Valencia Montemorelos', 'Succory Acidless', 'Lima', 'Lima Verde', 'Piemonte', 'Nova' and 'Page', which presented high YE values (3.62 to 5.5 fruits m^{-3}), and ii) 'Ruby', 'Pera CNPMF-D6', 'Murcott', 'CNPMF-01', 'CNPMF-02', '5059', 'IAC 5', 'IAC 5-1', 'CNPMF-2001', 'Persian lime 58' and 'Bearss lime', which had low YE values (1.17 to 3.18 fruits m^{-3}) (Table 4). These values are inversely related to those obtained in vegetative growth (PH and CV). The yield efficiency measured by the mass of fruits per CV reflects the need for plant size reduction enabling higher yield per acreage (Cantuarias-Avilés et al., 2011, 2012). Reducing plant size has the additional advantage of facilitating management, labor economy, and greater plant density (Lima et al., 2014). Plant resistance is considered a key strategy of integrated pest management programs (Gallo et al., 2002; Chacón et al., 2012) contributing for keeping pests below economic levels besides being nontoxic to the environment and humans and acting continuously against pests (Gallo et al., 2002; Vendramim and Guzzo, 2009, 2011). Resistant cultivars are less damaged by pests in comparison to other cultivars in equal conditions owed to their genotype constitution (Vendramim and Guzzo, 2009, 2011). However, our results demonstrate that the scion cultivars neither influenced the number of mined leaves by *P. citrella* ($F_{19,40}$=1.188; P=0.313) nor densities of *P. oleivora* ($F_{19,40}$=1.324; P=0.222) indicating that both pests equally attacked all 20 cultivars (Fig. 3).

Materials and Methods

Experimental site description

The experiment was installed in 2008 in an Ultisol soil at the Experimental Station of Embrapa Coastal Tablelands located in the municipality of Umbaúba (11°22'37'' S, 37° 40' 26'' W; 109 m above sea level), Sergipe state, Brazil. The climate, according to Köppen classification, is type As', rainy tropical

Table 2. Contents of N, P, K, Ca, Mg, Fe, Mn, Zn and B in the foliar tissues of citrus scion cultivars after five years of experiment set up.

Scion cultivars	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu
	$g.kg^{-1}$						$mg.kg^{-1}$				
Sweet oranges											
Lima	31.41a	1.53a	8.62a	27.63a	1.67b	3.85a	77.88a	61.21a	29.97a	76.65a	7.57a
Succory Acidless	29.69a	1.17b	6.25a	20.45a	1.99b	3.30a	63.61a	51.15a	16.44a	65.25a	7.15a
Lima Verde	28.84a	1.36a	5.75a	27.73a	2.71a	3.69a	75.25a	77.93a	30.12a	77.50a	7.99a
Natal CNPMF-112	28.21a	0.96b	6.29a	29.03a	1.76b	3.39a	59.92a	47.18a	20.93a	57.70a	6.38a
Kona	27.74b	1.36a	7.33a	33.5a	2.16b	4.26a	106.26a	66.64a	21.81a	96.58a	5.16a
Rubi	27.42b	1.20b	5.27a	22.76a	2.00b	3.25a	44.94a	53.82a	27.29a	65.04a	5.43a
Pera CNPMF-D6	27.38b	1.07b	6.92a	29.75a	1.66b	3.15a	96.28a	51.69a	34.10a	77.18a	7.06a
Valencia Montemorellos	26.36b	1.19b	6.79a	36.64a	2.41b	3.71a	75.73a	56.75a	21.14a	95.88a	7.23a
Hybrids of mandarins											
Piemonte	29.95a	0.90b	5.54a	23.52a	2.19b	2.69a	32.12a	28.18a	10.35a	47.13a	6.25a
Page	29.70a	1.10b	5.89a	21.45a	2.03b	3.11a	40.15a	48.14a	17.80a	68.39a	6.82a
Murcott	29.38a	1.22b	7.05a	40.04a	3.44a	3.81a	71.54a	90.22a	37.44a	94.77a	6.77a
Nova	27.43b	1.12b	7.09a	19.11a	2.18b	3.24a	54.41a	65.90a	35.57a	71.62a	7.35a
Tahiti acid lime clones											
5059	29.63a	1.54a	5.39a	33.64a	3.02a	3.67a	85.44a	48.76a	21.71a	91.16a	6.71a
CNPMF-2001	28.26a	1.48a	7.09a	26.55a	2.31b	3.39a	40.10a	48.49a	37.70a	48.58a	6.79a
IAC 5-1	27.54b	1.63a	6.28a	32.35a	2.53b	3.94a	69.42a	53.88a	53.60a	76.91a	7.37a
IAC 5	27.20b	1.12b	7.30a	24.10a	2.24b	3.31a	35.49a	53.11a	23.37a	42.87a	6.39a
CNPMF-02	26.30b	1.52a	5.20a	20.66a	3.10a	3.89a	46.95a	51.48a	18.66a	59.66a	7.58a
Persian lime 58	26.29b	1.35a	7.61a	19.41a	2.88a	3.04a	34.92a	47.15a	17.91a	38.53a	6.77a
Bearss lime	25.74b	1.46a	5.65a	29.04a	2.84a	3.83a	52.94a	53.63a	50.58a	62.54a	7.15a
CNPMF-01	24.25b	1.53a	5.69a	33.02a	3.37a	4.18a	57.69a	69.21a	32.24a	68.92a	6.40a
Means	27.9	1.3	6.4	27.5	2.4	3.5	61.0	56.2	27.9	69.1	6.8
C.V.* (%)	5.6	20.2	35.3	30.0	23.6	18.0	50.4	29.5	59.4	32.6	17.7

Means followed by the same letter within columns are not significantly different based on Scott-Knott tests (P ≤0.05). *Coefficient of variation.

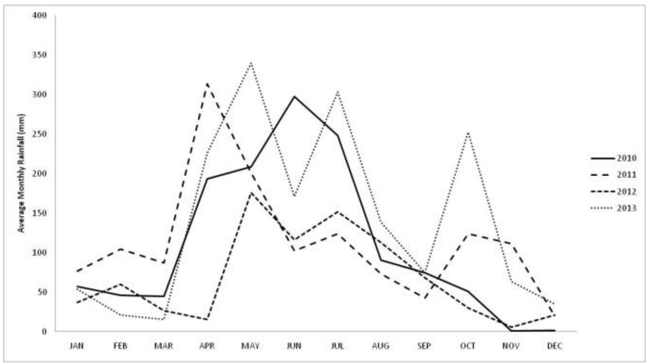

Fig 2. Average monthly rainfall (mm) from 2010 to 2014 at the experimental site.

with dry summer and annual rainfall of 1,317mm (Anjos et al., 2011). During the experiment the average annual temperature was 24.6°C, relative humidity of 83% and rainfall of 1,315.74 mm. Plants were spaced 5.0 m x 3.0 m (660 plants ha^{-1}) and conventionally managed without irrigation (except for the driest months, from November to March 2008-2010, where plants received salvation irrigation with 3 l per plant weekly. Management practices included fertilization, control of pests, diseases and weeds as well as pruning (Azevedo et al., 2006).

Plant material and experimental design

The experiment consisted of twenty citrus scion cultivars (sweet oranges, hybrids of mandarins and clones of 'Tahiti' acid limes) grafted on Rangpur lime (*Citrus limonia* Osbeck), which is the main rootstock cultivar grown throughout the region. The scion cultivars were the sweet oranges 'Pera CNPMF-D6', 'Kona', 'Rubi', 'Natal CNPMF-112', 'Valencia Montemorelos', 'Lima', 'Succory Acidless', 'Lima Verde'; the hybrids of mandarins 'Piemonte' ['Clementina' mandarin (*C. clementina* hort. ex Tanaka) x 'Murcott' (hybrid of unknown origin, possibly resulting from the crossing between tangerine and sweet orange, according to Hodgson, 1967)], Murcott, and the mandarins 'Nova' and 'Page' [*C. clementina* x (*C. paradisi* Macfad. x *C. tangerina* hort. ex Tanaka)]; the clones of Tahiti acid lime 'CNPMF-01', 'CNPMF-02', '5059', 'IAC 5', 'IAC 5-1', 'CNPMF-2001', 'Persian lime 58' and 'Bearss lime'. The sweet orange 'Pera CNPMF-D6' was included as it is the main scion cultivar grown in the region and considered the control. The experiment consisted of a completely randomized block design with three replications and three plants per plot.

Parameters measured

The following parameters were evaluated in each of the three plants per plot, totaling nine plants per scion cultivar (treatments): plant growth by measuring trunk diameter below (DB) and above (DA) the grafting line, the relationship

Table 3. Diameters of trunk above (DA) and bellow (DB) grafting line, relationship between rootstock/scions (RDBDA), plant height (PH), vigor index and canopy volume (CV) of scion cultivars of sweet oranges and tangerines after four years of experiment set up.

Scion cultivars	DA	DB	RDBDA	PH	Vigor	CV
	-------cm-----			m		m^3
Sweet oranges						
Rubi	90b	80b	1.13a	2.37a	2.70a	9.41a
Pera CNPMF-D6	98a	89[a]	1.11a	2.44a	2.89a	8.88a
Kona	92b	82b	1.13a	2.26b	2.72a	7.86b
Valencia Montemorelos	90b	82b	1.10a	2.09c	2.70a	7.40b
Succory Acidless	86b	77b	1.13a	2.24b	2.48b	7.63b
Lima Verde	80c	73c	1.11a	2.13c	2.19b	5.13c
Natal CNPMF-112	75c	68c	1.10a	1.84d	2.28b	4.22c
Lima	79c	69c	1.15a	1.93d	2.30b	3.86c
Means	86,25	77.5	1.13	2.16	2.53	6.43
Hybrids of mandarins						
Piemonte	86b	80b	1.09a	2.28b	2.75a	8.00b
Page	81c	77b	1.06a	2.54a	2.70a	7.49b
Murcott	89b	75c	1.23a	2.10c	2.48b	7.41b
Nova	78c	69c	1.12a	1.90d	2.37b	4.56c
Means	83.5	75.25	1.12	2.2	2.57	6.86

Means followed by the same letter within columns are not significantly different based on Scott-Knott tests ($P \leq 0.05$).

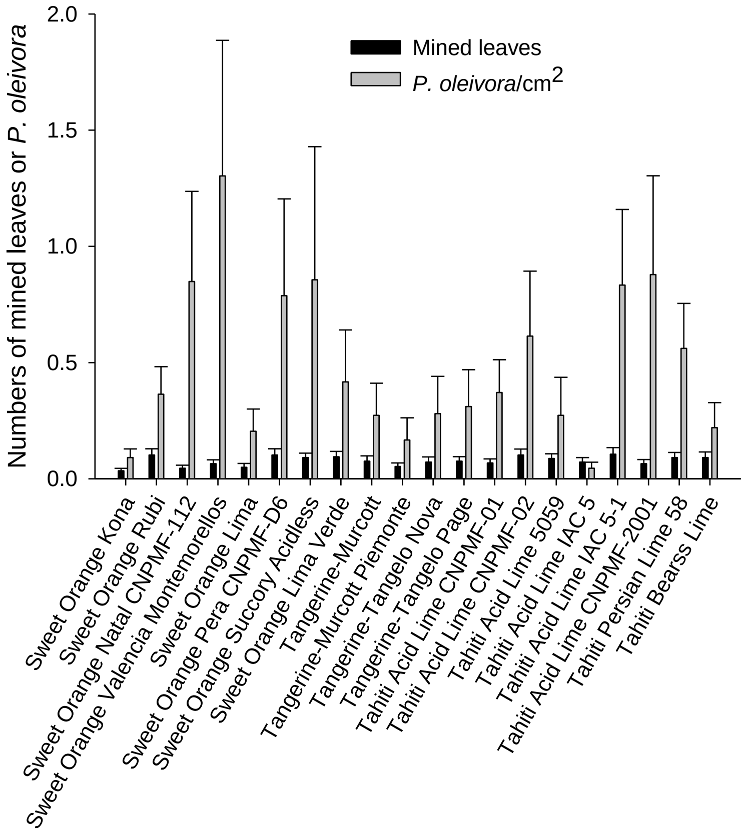

Fig 3. Numbers of mined leaves by the leaf miner *Phyllocnistis citrella* (Lepidoptera: Gracillariidae) and of the rust mite *Phyllocoptruta oleivora* (Acari: Eriophyidae) on fruits in relation to scion cultivars of sweet oranges (*Citrus sinensis*), hybrids of mandarins and 'Tahiti' acid lime clones (*C. latifolia*). Means + standard error of log x+1 transformed data are shown.

Table 4. Annual and cumulative (CY) yields and yield efficiency (YE) of scion cultivars of sweet oranges, mandarins and acid limes after four years of experiment set up.

Scion cultivars	Yield (kg ha^{-1}) 2011	2012	2013	CY Kg ha^{-1}	YE Kg m^{-3}
Sweet oranges					
Kona	24773a	27693a	25957a	74887a	4.84a
Valencia Montemorelos	19067b	14293c	17773b	51133c	4.15a
Rubi	14377c	27367a	17273b	59217b	3.18b
Succory Acidless	9487d	20107b	16960b	46553c	3.76a
Pera CNPMF-D6	12407c	22030b	16687b	51123c	2.98b
Lima Verde	6857d	6523d	13920c	27300e	4.42a
Natal CNPMF-112	12253c	10723d	12163c	38517d	4.64a
Lima	7187d	9523d	10223c	26933e	5.39a
Means	13301	17282.38	16369.5	46957.88	4.17
Hybrids of mandarins					
Piemonte	18063b	14137c	27093a	59293b	5.02a
Page	6330d	18680b	15333b	40343d	3.62a
Murcott	8670d	16203c	13000c	37713d	2.69b
Nova	8893d	13000c	12840c	34893d	5.50a
Means	10489	15505	17066.5	43060.5	4.21
Acid limes					
Persian lime 58	18610b	23207b	23877a	65693b	2.26b
Bearss lime	17127b	16833c	19230b	53190c	2.21b
5059	15817b	13900c	17340b	47057c	2.6b
IAC-5	11777c	10277d	15393b	37447d	1.95b
IAC-5-1	17323b	14840c	15327b	51490c	1.75b
CNPMF-02	12820c	8742d	14137c	35699d	1.60b
CNPMF-01	20033b	18607b	11950c	50590c	1.38b
CNPMF-2001	8280d	8170d	10783c	27233e	1.17b
Means	15723	14322	16005	46050	1.9

Means followed by the same letter within columns are not significantly different based on Scott-Knott tests ($P \leq 0.05$).

between rootstock/scions (RDBDA), plant height (PH) and canopy volume (CV). Plants were also visually evaluated for drought tolerance (DT) and vigor. Annual yield, cumulative yield (CY) as well as yield efficiency (YE) were evaluated for all cultivars during the period 2010-2013. PH was measured from the base of the trunk close to the soil up to the top of the plant using a ruler. CV was calculated by the equation $V = (\pi/6) \times H \times DR \times DP$, where V is the volume (m^3), H is the height of the plant (m), DR is the canopy diameter along the row and DP stands for the canopy diameter in the direction perpendicular to the row (Cantuarias-Avilés et al., 2011). DB and DA were measured using a caliper rule placed 10 cm above and below the grafting point and used to obtain RDBDA by the quotient between DB and DA. Vigor was estimated based on a visual grading scale: 0 (low vigor - plants with few shoots and leaves) to 3 (high vigor - plants with abundance of leaves and great vegetative shoot growth). Drought tolerance (DT) was measured by eye during the driest months (December to April 2011, 2012, 2013 and 2014) and varied from 1 (susceptible to drought - wilt, yellowing and drop of leaves), 2 (moderate drought tolerance - intermediate wilt, yellowing and no leaf drop) to 3 (tolerant to drought - no visual symptoms) (Figueiredo et al., 2002). Plant nutrition was evaluated in the harvest 2013 by soil and leaf analyses. Soil samples were taken in the projection of the canopy in each plot, comprising one sample per block, irrespective of cultivars. Forty leaves were collected per cultivar, being five leaves taken from vegetative shoots of each plot from south and north quadrats. The samples were immediately brought to the laboratory to determine macro and micronutrients.Fruits from all plants were counted and weighed in each harvest. With the data of yield and planting density, productivity for each cultivar was estimated in tons ha^{-1}. Cumulative yield comprised the period from 2011 to 2013. Yield efficiency was estimated as quotient between the number of fruits per plant and the canopy volume. In addition to vegetative and reproductive parameters, we evaluated the influence of scion cultivars on two key pests of citrus in this region, the leaf miner *P. citrella* and the rust mite *P. oleivora*. The number of leaves mined by *P. citrella* and the number of adults of the rust mite were monthly counted from April 2011 to February 2013 (with the exception of data from September 2011 which was not included in the analyses). For *P. oleivora*, two randomly-chosen fruits were evaluated per plant totaling six fruits per scion cultivar in each evaluation and the mites counted in 1 cm^2 area. Care was taken to select only fruits located in the external part of the plant since this region is the most attacked by *P. oleivora* (Mendonça and Silva, 2009). The number of mined leaves by *P. citrella* was recorded in four randomly-collected leaves per plant totaling 12 leaves per treatment in each evaluation.

Statistical analyses

Data from contents of nutrients in foliar tissues, diameters of trunk above and below grafting line, relationship between rootstock and scions, plant height, vigor, canopy volume, annual and cumulative yields, yield efficiency, and drought tolerance among scion cultivars were subjected to ANOVAs followed by Scott-Knott tests ($P \leq 0.05$). Repeated Measures ANOVAs followed by post hoc Fisher LSD tests were conducted to evaluate the influence of scion cultivars on the number of mined leaves by *P. citrella* as well as on densities of *P. oleivora*, removing variance explained by time as evaluations were carried out monthly.

Conclusion

The sweet orange 'Kona', the mandarin 'Piemonte' and the acid lime 'Persian Lime 58' had higher vegetative and productive efficiency compared to the main cultivar grown in the region, the 'Pera CNPMF D6', emphasizing their potential for orchards diversification in the Brazilian northeast.

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