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EVALUATION OF ROOTSTOCKS FOR 'TAHITI' ACID LIME IN NORTHERN STATE OF MINAS GERAIS[1]

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ABSTRACT - The aim of this study was to evaluate 12 rootstock varieties on the development and quality of 'Tahiti' acid lime fruits cultivated in the municipality of Jaíba, MG. Seedlings were planted in an experimental orchard in November 2008, using 8 x 5 meters spacing and drip irrigation. The experiment was conducted using a scion cultivar (Tahiti acid lime, IAC-5 cultivar) and the following 12 rootstocks: 'Rangpur' lime, 'Troyer' citrange, 'Carrizo' citrange, 1707 hybrid (Rangpur lime x Swingle trifoliate), 1710 and 1697 citrandarins, 1708citradia, 'Swingle' citrumelo, 'Cleopatra' and 'Sunki' mandarins, 'Volkamer' lemon, and 'Limeira' trifoliate. A randomized block design with five replicates and three trees per plot was used. Trunk diameter of both rootstock and scion, as well as height, diameter, and canopy volume, yield, fruit mass, number of fruits per tree, productivity, production efficiency index, longitudinal diameter, equatorial diameter, total soluble solids, total acidity, and vitamin C content of fruits were evaluated. 'Volkameriano' and 'Cleopatra' rootstocks promoted higher plant vigor and productivity for 'Tahiti' acid lime. However, 'Limeira' trifoliate and 'Troyer' citrange produced less vigor, but increased production efficiency; and can be used as alternative rootstocks for 'Rangpur' lime, as long as adjustments are performed in the planting spacing to increase productivity. In general, no differences in physical and chemical characteristics of fruits for all treatments were found, and fruits remained within commercial standards.
Index terms: *Citrus latifolia* Tan., vegetative growth, fruit quality.

AVALIAÇÃO DE PORTA-ENXERTOS PARA A LIMEIRA ÁCIDA 'TAHITI' NO NORTE DE MINAS GERAIS

RESUMO - O objetivo do trabalho foi avaliar a influência de 12 variedades de porta-enxertos sobre o desenvolvimento e a qualidade dos frutos da limeira-ácida 'Tahiti' cultivadas no município de Jaíba-MG. O plantio do pomar experimental foi realizado em novembro de 2008, em espaçamento de 8 m x 5 m e irrigado usando gotejamento. O experimento foi constituído por uma cultivar copa (lima-ácida Tahiti, cultivar IAC-5) e 12 porta-enxertos: limoeiro 'Cravo', citrangeiro 'Troyer', citrangeiro 'Carrizo', híbrido 1707, citrandarineiro 1710, citrandarineiro 1697, citradia 1708, citrumeleiro 'Swingle', tangerineira 'Cleópatra', tangerineira 'Sunki', limoeiro 'Volkameriano' e trifoliateiro 'Limeira'. Foi utilizado o delineamento em blocos casualizados, com cinco repetições e três plantas por parcela. Foram realizadas avaliações dos diâmetros dos troncos do porta-enxerto e do enxerto, a altura, o diâmetro da copa e o volume médio de copa, produção por planta, massa média dos frutos, número de frutos por planta, produtividade, índice de eficiência de produção, diâmetro longitudinal, diâmetro equatorial, teor dos sólidos solúveis totais, acidez total titulável e teor de vitamina C do fruto. O limoeiro 'Volkameriano' e a tangerineira 'Cleópatra' foram os que induziram maior vigor vegetativo e produtividade ao 'Tahiti'. Por outro lado, o trifoliata 'Limeira' e citrangeiro 'Troyer' induziram menor vigor e maior eficiência de produção, despontando como porta-enxertos alternativos ao limoeiro 'Cravo', desde que sejam feitos ajustes nos espaçamentos de plantio, visando ao aumento da produtividade. Os frutos, em geral, não apresentaram diferenças quanto às características físicas e químicas entre os tratamentos, mantendo-se dentro dos padrões comerciais.
Termos para indexação: *Citrus latifolia* Tan., desenvolvimento vegetativo, qualidade do fruto.

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INTRODUCTION

'Tahiti' acid lime (*Citrus latifolia* Tanaka), popularly known in Brazil as Tahiti lemon, has emerged as an alternative to sweet orange producers due to its good adaptation to tropical climatic conditions and greater economic value (RODRIGUES et al., 2016).

According to data from Agrianual (2014), Brazilian production was 1,165,296 tons of lemons in 2013. The southeastern region is the main national producer, and the State of São Paulo is the largest Brazilian producer, followed by Minas Gerais. The Northern Region of the State of Minas Gerais has increased its participation in this market, with production of 'Tahiti' acid lime exponentially growing in the region. Part of the production is exported, which has increasingly aroused producers' interest in this crop.

Despite the commercial importance of acid lime, there is little research on the fruit in the region of the Irrigated Perimeter of Jaíba and, consequently, little availability of data to assist the producer in the decision making in the time of planting, in order to obtain better returns.

One of the problems in the region refers to the fact that crops are based almost exclusively on the use of plants grafted on 'Rangpur' lime due to the tradition of using this rootstock, the lack of seedlings grafted on other rootstocks and the lack of research that indicates alternative rootstocks. Although 'Rangpur' lime is considered a rootstock suitable for 'Tahiti', it is susceptible to gummosis caused by *Phytophthora citrophthora* and *Phytophthora parasitica*, which reduces plant longevity (CARVALHO et al., 2016). In addition, plants grafted on 'Rangpur' lime tree reach excessive sizes in the climate of northern Minas Gerais, which requires the use of wide spacing or pruning.

Rootstocks influence about 20 horticultural characteristics of citrus, namely: absorption, synthesis and use of nutrients, size, production precocity, maturation, weight and permanence of fruits in the plant, bark and juice color, fruit productivity and quality (POMPEU JÚNIOR et al., 2013). Therefore, it is important to select rootstocks suitable for the production system to be implanted in each region. The selection of alternative rootstocks is essential for the Brazilian citrus industry, as it may make orchards less vulnerable to the appearance of new pests that may affect the few varieties of rootstocks currently used (PETRY et al., 2015).

No studies carried out with rootstocks for 'Tahiti' lime in Minas Gerais have been found in literature. In Brazil, there are few researches carried out with this objective. Figueiredo et al. (2002), working with ten alternative rootstocks to 'Rangpur' lime tree in the region of Bebedouro, recommended 'Orlando' tangelo, 'Morton' citrange, 'Swingle' citrume, 'Volkameriano' lime and 'Limeira' trifoliate. On the other hand, Stenzel and Neves (2004) observed that 'Tahiti' plants grafted on 'Rangpur' lime and 'C-13' citrange presented the highest accumulated yields.

Thus, the aim of this work was to evaluate the influence of 12 rootstocks on the development and quality of 'Tahiti' acid lime fruits grown in the municipality of Jaíba, MG.

MATERIAL AND METHODS

The experimental orchard was planted in November 2008 in the Irrigation District of Mocambinho, municipality of Jaíba, Experimental Farm of Mocambinho, Technological Center of Northern Minas Gerais / EPAMIG. The coordinates are 15º 03'S, 44° 01' W and 452 m asl. The climate of the region is A_w type, according to Köppen classification, and climatic data (average of 10 years) are as follows: average maximum temperature: 34.0 ºC; average minimum temperature: 14.8 ° C; average temperature: 24.2 ° C; relative humidity: 58% to 79%; sunshine: 2,892 hours / year; precipitation: 787 mm / year; wind speed: 35 to 81 km / h.

The predominant soil in the region is the dystrophic Yellow Latosol and the predominant relief is flat. Previous soil physical analysis showed that the soil of the experimental area is of sandy texture, being composed of 76% of sand, 10% of silt and 14% of clay.

Twelve treatments (rootstocks) and five replicates were used, each experimental unit consisting of three useful plants, comprising 60 experimental units, with a total of 180 useful plants. The external border was formed by 'Tahiti' acid limes grafted on 'Rangpur' lime. Plants were arranged in 8m x 5m spacing and irrigated by the drip system. The experimental design was in randomized blocks.

The experiment consisted of a canopy cultivar (Tahiti acid lime, IAC-5 - *Citrus latifolia* Tanaka) and 12 rootstocks. The rootstocks were ''Rangpur' lime [*C. limonia* L. Osbeck]; 'Troyer' citrange [*C. sinensis* (L.) Osbeck x *Poncirus trifoliata* (L.) Rafinesque]; 'Carrizo' citrange [*C. sinensis* (L.) Osbeck x *P. trifoliata* (L.) Rafinesque]; '1707' hybrid (Rangpur lime x Swingle trifoliate); '1710' citrandarin (Changsha x English Small); '1697'

citrandarin (Sunki x Benecke); '1708' citradia (*C. aurantium* x *P. trifoliata*); 'Swingle' citrumelo (*C. paradisi* x *P. trifoliata*); 'Cleópatra' mandarin (*C. reshni* Hort.); 'Sunki' mandarin (*Citrus sunki* Hort.); 'Volkameriano' lemon (*C. volkameriana* Tenn. & Pasq.) and Limeira trifoliate [*P. trifoliata* (L.) Rafinesque].

Vegetative development and yield in the 2009-2015 harvests and fruit quality in the 2011, 2012 and 2013 harvests were evaluated.

Vegetative development was evaluated in the first semester of each year. The following parameters were evaluated from each tree under study: stem diameter of rootstock (DCPE, in mm) and graft (DCE, in mm), measured at 5 cm below and above the grafting point, respectively, plant height (A, in m), measured from the soil to the top of the plant and the canopy diameter (DCO, in m) measured perpendicular to the planting line. The average canopy volume (VMC, in m^3) was determined using the diameter and canopy height measurements using the formula of Mendel: $V = 2/3\ \pi \times R^2 \times A$, where V is the canopy volume (m^3), R is the radius (m), π = 3.141593 and A is the plant height (m).

Fruits were harvested when they were fully developed, but with the green and slightly rough peel, which is the harvest point commercially used in the region. Due to the fact that 'Tahiti' lime tree presents flowering multiplicity, harvests and production weighing were carried out throughout the year and the results of production per plant are summed and presented in the form of a value per year. The following production-associated variables were studied for each canopy / rootstock combination: yield per plant (PP, in kg), mean fruit mass (MMF, in grams), number of fruits per plant (NFP), productivity (PTVD, $t.ha^{-1}$) and production efficiency (EP, in $kg.m^{-3}$ canopy), calculated by dividing the average yield of each canopy / rootstock combination by the respective canopy volume.

Fruit quality was analyzed close to the main crop of the canopy cultivar, evaluating the physical and chemical characteristics of fruits. All fruit analyses were carried out at the Laboratory of Fruit Analysis, Viçosa, MG, in the years 2011, 2012 and 2013, where the external quality attributes of 20 fruits per treatment were evaluated: diameter in the longitudinal direction (DL, in mm) and diameter in the equatorial direction (DE, in mm).

Later, evaluations of attributes associated to the internal quality of the fruits were carried out: soluble solids content (SS, in ºBrix); titratable acidity (AT, in % citric acid); vitamin C content (TVC, in $mg.100\ mL^{-1}$ of juice) and yield in juice: RS (%).

Data were analyzed using Saeg 9.1 software (SAEG, 2014). Analyses of variance were performed and when there were significant differences, the means of treatments were compared by the Tukey test, adopting 5% of probability level.

RESULTS AND DISCUSSION

Regarding plant height, it was observed that, during the evaluation years, '1708' citradia, 'Cleopatra' mandarin and 'Limeira' trifoliate rootstocks, with emphasis on the latter, induced smaller canopy size. There is a growing interest of researchers and producers for dwarfing rootstocks, which, above all, lead to a reduction in the harvesting cost, which is one of the most costly activities in the citrus production system. Some authors have related reduction of canopy vigor on dwarfing rootstocks to the lower water potential in the canopy, probably due to the difficulty in transporting water from roots to shoots (FORNER-GUINER et al., 2014). In addition, these rootstocks facilitate pest and disease management and increase productivity through planting densification (POMPEU JÚNIOR et al., 2013).

In the last evaluation carried out in 2015 when plants were seven years old, it was observed that the height of 'Tahiti' plants on 'Limeira' trifoliate (mean of 3.66 m) was 28% lower than the height of plants grafted on 'Swingle' citrumelo, which presented the highest mean height (5.08 m) this year. Plants on 'Troyer' citrange, 'Rangpur' lime and '1708' citradia also stood out among the highest ones (TABLE 1).

No significant differences among rootstocks were observed regarding stem diameter and rootstock in the years 2009 and 2010. From 2011, it was observed that rootstocks induced significant differences for these characteristics, with emphasis on 'Rangpur' lime and 'Volkameriano' lemon, which induced higher values, as well as an increase in diameter of the graft stem that exceeded the diameter of the rootstock stem in the last years evaluated (TABLE 1).

In the DCPE / DCE ratio, there was a general trend over the years of evaluations, where plants on 'Rangpur' lime, '1707' hybrid and 'Carrizo' citrange rootstocks had the lowest values. The greatest difference between rootstock and canopy diameters occurred in plants on 'Limeira' trifoliate and '1708' citradia. This characteristic is commonly observed when rootstocks of the genus Poncirus trifoliate or their hybrids are used. For the other rootstocks studied, the ratio remained close to 1, indicating similar diameters (TABLE 1).

Plants on '1707' hybrid, '1710' citrandarin, 'Rangpur' lime and 'Swingle' citrumelo showed larger canopy diameters compared to the others (5.87 m, 5.27 m, 5.68 m 5.67 m, respectively, in 2015) in the last three years of evaluation, differing from 'Limeira' trifoliate rootstock, which presented the lowest values in the last three years (3.05 m, 4.13 m and 4.54 m, In 2013, 2014 and 2015, respectively) (TABLE 1). Considering that 'Tahiti' acid lime can reach up to 4.5 m in height, impairing crop and harvest management (AZEVEDO et al., 2015), a dwarfing rootstock such as 'Limeira' trifoliate emerges as promising for the northern region of Minas Gerais, where favorable climatic and management conditions enhance the vegetative development of 'Tahiti' acid lime tree.

For the average canopy volume, in all evaluated years, there were significant differences among rootstocks. In the initial growth phase, 'Carrizo' citrange, 'Rangpur' lime, 'Swingle' citrumelo and 'Troyer' citrange, induced greater growth in canopy volume in 'Tahiti' acid lime (TABLE 1); however, in the last evaluation year, in 2015, '1707' hybrid, 'Swingle' citrumelo, '1708' citradia and 'Carrizo' citrange stood out, with average canopy volumes of 87.56 m^3, 85.82 m^3, 81.89 m^3 and 79.52 m^3, respectively.

In studies conducted by Figueiredo et al. (2002), in Bebedouro-SP, the authors found that 'Volkameriano' 'Catania 2' lemon and 'Orlando' tangelo promoted greater development of the 'Tahiti' canopy, with maximum value of 123.83 m^3 of average canopy volume in plants with nine years of age, and most values were close to those reported in this work in plants still at seven years of age. It is important the selection of rootstocks that induce the formation of smaller canopies, with high productive efficiency in relation to their volume, so as to allow the formation of more dense plants and to obtain greater production by area (SANTOS et al., 2015) .

In this aspect, 'Limeira' trifoliate and '1708' citradia, despite having induced the formation of smaller 'Tahiti' canopy volumes in almost every year evaluated, in 2015, they induced higher production efficiency (1.29 $kg.m^{-3}$ and 1.77 $kg.m^{-3}$, respectively) when compared to 'Volkameriano' lime (0.95 $kg.m^{-3}$) and 'Rangpur' lime (1.15 $kg.m^{-3}$) (TABLE 2), which indicates the possibility of being used in more densified plantations, providing greater production per area. These results corroborate Portella et al. (2016), who observed that 'Limeira' trifoliate reduced height, vegetative vigor index, coverage rates in the row and inter-rows, and canopy volume of 'Tahiti' acid lime in irrigated cultivation under the climatic conditions of northern Rio de Janeiro. Lima, et al. (2014) also observed in northern Rio de Janeiro that the size of 'Lima' orange tree was reduced by 56% when grafted on 'Limeira' trifoliate, having 'Rangpur' lime as reference in irrigated cultivation.

In the accumulated of the six harvests, 'Rangpur' lime was the most productive, with production of 90.73 $kg.plant^{-1}$ in the last evaluation, in 2015, which represented production 98% above the rootstock that induced the lowest production, which was 'Cleopatra' mandarin (TABLE 2). 'Volkameriano' lemon and 'Carrizo' citrange rootstocks, despite being little used in the region, were among the two that induced higher yields, indicating good adaptation to the edaphoclimatic conditions of Jaíba. Another aspect to consider is that, although 'Limeira' trifoliate and '1708' citradia rootstocks are not among the most productive in this work, they have reduced the vigor of plants and will probably require adjustments in the spacings in order to optimize soil utilization and increase productivity.

All production variables presented significant differences in the F test at 5% probability level in at least one year of evaluations (TABLE 2). Regarding the annual production per plant, differences in rootstocks were observed from 2010. In 2013, production ranged from 52.08 to 70.76 $kg.plant^{-1}$ for the 'Troyer' citrange and 'Volkameriano' lemon, respectively (TABLE 2). Plants grafted on 'Rangpur' lime showed production in 2015 of 90.73 $kg.plant^{-1}$ and those on 'Swingle' citrumelo, 70.00 $kg.plant^{-1}$. The latter is a well-known and widely used rootstock for citrus growers in the region and occupied an intermediate position in this experiment.

Analyzing the mean mass of fruits, the first evaluation showing significant differences was in 2011. In this evaluation, 'Cleopatra' mandarin rootstock induced the highest value (82.12 g), but this trend was not confirmed in evaluations in the following years (TABLE 2). The fresh fruit mass values were lower than those reported by Stuchi et al. (2009), who obtained average values of 91 g, while in the present study, the mass values ranged from 71.17 to 82.12 g.

Table 2 shows significant differences among treatments in relation to the number of fruits per plant in all evaluation years. There is also an increase in the production of fruits per plant over the years. This is because 'Tahiti' produces flowers and fruits in new growing branches, so production is directly associated with the vegetative development of plants. The highest NFP (910) was obtained in 'Tahiti' lime trees grafted on 'Rangpur' lime in the year 2015. In the same year, the lowest NPF was induced by

'Limeira' trifoliate (496) (TABLE 2).

In relation to PTVD, significant differences among rootstocks were observed from the second year of production. The highest yields were obtained on 'Rangpur' lime rootstocks (mean of 22.68 $t.ha^{-1}$ per harvest in 2015), 'Volkameriano' lemon (mean of 20.80 $t.ha^{-1}$ per harvest In 2015) and 'Carrizo' citrange (average of 20.87 $t.ha^{-1}$ per harvest in 2015), in contrast to 'Sunki' and 'Cleopatra' mandarin, which showed the lowest yields throughout harvests (TABLE 2). In general, these data are in agreement with the initial results obtained by Pompeu Júnior et al. (2013), working with most rootstocks studied in this research.

Significant differences were observed for the production efficiency from 2011 to 2015. The highest index, of 4.17 $kg.m^{-3}$, reached in the 2012 evaluation in plants grafted on 1710 citrandarin and the lowest in plants on 'Cleopatra' rootstock, with average values of 0.72 $kg.m^{-3}$ in 2015. The highest EP values occurred due to the lower vegetative growth, which resulted in higher production per canopy area. In 2015, with seven-year-old plants, EP values ranged from 0.72 in plants on 'Cleopatra' to 1.77 $kg.m^{-3}$ in plants grafted on '1708' citradia, a hybrid of trifoliate with sour orange (TABLE 2). These results evidenced the ability of trifoliate to increase the productivity of acid lime in the region, provided that adjustments are made to the crop spacing. These values are lower than those reported by Stenzel and Neves (2004), who observed for a period of eight harvests in the state of Paraná in 'Tahiti' IAC-5 plants grafted on 'Rangpur' lime tree, yield of 6.54 kg m^{-3}. Aranguren et al. (2004) observed EP values for 'Tahiti' plants grafted on *C. macrophylla* ranging from 1.0 to 1.7 kg m^{-3} under Cuban conditions.

Regarding juice yield, there were no significant differences induced by rootstocks in the three-year study period (TABLE 3). These results differ from those obtained by Stenzel and Neves (2004), who observed higher RS in 'Tahiti' lime tree grafted on 'Rangpur' lime. However, it is noteworthy that all rootstocks induced RS above 42%, which according to Hortibrasil (2000) classification is the minimum RS required for fruits for export. The RS results obtained are higher than those found by Stenzel and Neves (2004), who reported values between 36.7 and 47.3% for 'Tahiti' acid lime and Dubey and Sharma (2016), who evaluated eight different rootstocks for lemon (*Citrus limon*) cv. 'Kagzi Kalan' in India and observed values between 38.1 and 45.8%, and in this study, 'Troyer' rootstock induced the lowest RS among evaluated rootstocks.

Several rootstocks have stood out for SS content in the three years of evaluations, such as 'Carrizo' citrange, 'Limeira' trifoliate, 'Swingle' citrumelo, '1708 citradia' and 'Troyer' citrange (TABLE 3). 'Rangpur' lime and 'Volkameriano' lemon trees induced the lowest SS levels, this fact is also observed in orange trees grafted on these two rootstocks, which can be caused by the greater dilution of fruit juice due to the greater vigor induced by these rootstocks, promoting greater growth and consequent SS dilution. In general, the observed SS values were close to the mean values described by Yeşiloğlu et al. (2014), about 9 ° Brix, in a work with rootstocks for 'Handerson' grapefruit in Turkey. These values were within the acceptable range for the domestic and export markets.

The rootstocks evaluated did not cause significant differences in the acidity of 'Tahiti' acid lime fruits (TABLE 3). The averages found were higher than those obtained by Stenzel and Neves (2004), who reported values between 5.0 and 5.8%, whereas in the present study, titratable acidity ranged from 6.00 to 7.52%, considering the three evaluations. These acidity levels are similar to those described by Stuchi et al. (2009) from 6 to 8%, which according to the authors, are close to the commercial standards demanded by the market, which is 7-8%.

Rootstocks induced significant variations in vitamin C levels (TABLE 3) in the 2011 and 2012 evaluations. In 2013, there were no differences in values found. '1697' hybrid presented the lowest values in 2011 and 2012 (27.56 and 28.60 mg ascorbic acid.100 mL^{-1} of juice, respectively). On the other hand, 'Volkameriano' lemon, 'Limeira' trifoliate, 'Carrizo' citrange and 'Sunki' mandarin rootstocks showed the highest values, ranging from 31.54 to 34.89 mg ascorbic acid.100 mL^{-1} juice. On average, the results for vitamin C (TVC) found in the study were higher than those observed by Miranda and Campelo Júnior (2010), who found average levels of 27.97 mg ascorbic acid.100 mL^{-1} of juice in 'Tahiti' lime fruits from Colorado do Oeste, RO. The high TVC found in 'Tahiti' lime fruits are interesting, since marketing strategies can be adopted, emphasizing the importance of the consumption of nutraceutical foods.

TABLE 1 - Mean values of plant height (A) (m), diameters of rootstock stem (DCPE) and grafts (DCE) (mm), DCPE / DCE ratio, canopy diameter (DCO) (m) and mean canopy volume (VMC) (m³) from 2009 to 2015 of 'Tahiti' acid lime grafted on 12 rootstocks. Jaíba, Minas Gerais.

Rootstock	A	DCPE	DCE	DCPE/ DCE	DCO	VMC
			2009			
'Rangpur' lime	1.02 a	15.07 a	13.60 a	1.11 c	1.21 a	1.78 a
'Troyer' citrange	0.91 a	14.40 a	11.33 a	1.27 b	1.22 a	1.79 a
'Carrizo' citrange	0.88 a	14.53 a	10.67 a	1.36 ab	1.24 a	1.82 a
1707 Hybrid	0.89 a	14.40 a	11.53 a	1.25 b	1.08 a	1.53 b
1710 citrandarin	0.81 a	13.60 a	10.60 a	1.28 b	1.19 a	1.65 b
1697 citrandarin	0.86 a	14.41 a	11.00 a	1.31 b	1.20 a	1.68 b
1708 citradia	0.88 a	15.27 a	10.73 a	1.42 a	1.17 a	1.59 b
'Swingle' citrumelo	0.85 a	16.13 a	11.33 a	1.42 a	1.23 a	1.80 a
'Cleópatra' mandarin	0.92 a	12.53 a	11.07 a	1.13 c	1.19 a	1.65 b
'Sunki' mandarin	0.82 a	13.07 a	10.80 a	1.21 bc	1.03 a	1.32 c
'Volkameriano' lemon	1.04 a	15.28 a	13.33 a	1.15 c	1.19 a	1.65 b
'Limeira' trifoliate	0.85 a	14.73 a	10.32 a	1.43 a	0.95 a	1.02 d
VC (%)	12.17	9.13	7.16	16.66	14.32	11.49
			2010			
'Rangpur' lime	2.35 a	68.52 a	61.42 a	1.12 c	2.65 a	13.75 a
'Troyer' citrange	2.38 a	76.54 a	62.51 a	1.22 b	2.72 a	13.92 a
'Carrizo' citrange	2.48 a	77.93 a	63.35 a	1.23 b	2.54 a	13.31 a
1707 Hybrid	2.19 a	62.93 a	51.28 a	1.23 b	2.23 a	12.91 a
1710 citrandarin	2.23 a	66.12 a	51.53 a	1.28 ab	2.19 a	12.17 ab
1697 citrandarin	2.33 a	72.50 a	57.52 a	1.26 b	2.70 a	13.85 a
1708 citradia	2.25 a	70.29 a	53.72 a	1.31 a	2.17 a	12.05 b
'Swingle' citrumelo	2.21 a	76.88 a	55.60 a	1.38 a	2.53 a	13.28 a
'Cleópatra' mandarin	2.26 a	65.64 a	64.81 a	1.01 cd	2.41 a	13.18 a
'Sunki' mandarin	2.31 a	68.55 a	61.43 a	1.12 c	2.11 a	12.02 b
'Volkameriano' lemon	2.59 a	74.18 a	62.82 a	1.18 bc	2.78 a	13.98 a
'Limeira' trifoliate	2.05 a	65.91 a	47.29 a	1.39 a	2.09 a	11.96 b
VC (%)	13.43	10.02	7.71	19.04	11.32	9.23
			2011			
'Rangpur' lime	3.09 ab	96.04 a	103.43 ab	0.93 c	3.10 b	16.95 b
'Troyer' citrange	3.17 a	106.37 a	89.32 bc	1.19 b	3.17 ab	17.28 b
'Carrizo' citrange	3.19 a	110.31 a	94.47 b	1.17 ab	3.19 ab	18.61 ab
1707 Hybrid	2.94 b	94.12 a	78.38 c	1.20 ab	2.94 bc	13.85 c
1710 citrandarin	2.89 bc	92.11 a	77.66 c	1.19 b	2.89 c	13.27 c
1697 citrandarin	3.20 a	102.55 a	86.71 bc	1.18 b	3.20 ab	20.23 a
1708 citradia	2.97 b	102.66 a	78.92 b	1.30 a	2.67 d	13.88 c
'Swingle' citrumelo	3.03 ab	107.31 a	79.49 b	1.35 a	3.03 b	16.57 b
'Cleópatra' mandarin	2.85 bc	95.42 a	91.76 b	1.04 bc	2.85 c	16.10 b
'Sunki' mandarin	2.98 b	99.30 a	102.92 ab	0.96 c	2.99 bc	19.52 a
'Volkameriano' lemon	3.31 a	108.35 a	108.14 a	1.00 bc	3.31 a	19.47 a
'Limeira' trifoliate	2.71 c	93.33 a	68.67 c	1.36 a	2.71 d	12.10 c
VC (%)	15.31	11.02	13.28	14.41	11.16	12.01
			2012			
'Rangpur' lime	3.42 a	115.17 b	122.40 a	0.94 d	3.42 b	20.56 c
'Troyer' citrange	3.46 a	128.22 a	105.78 b	1.21 b	3.46 b	23.65 ab
'Carrizo' citrange	3.58 ab	129.91 a	104.33 b	1.25 a	3.58 ab	24.45 a
1707 Hybrid	3.22 b	111.13 b	95.54 bc	1.16 bc	3.22 c	17.63 d
1710 citrandarin	3.20 b	113.74 b	92.66 bc	1.23 ab	3.20 c	16.85 d
1697 citrandarin	3.37 ab	118.22 ab	99.17 b	1.19 bc	3.37 b	23.27 ab
1708 citradia	2.87 c	110.29 b	88.93 c	1.24 ab	2.87 cd	15.76 d
'Swingle' citrumelo	3.34 ab	130.10 a	99.35 b	1.31 a	3.34 b	20.78 c
'Cleópatra' mandarin	3.15 b	113.35 b	101.72 b	1.11 c	3.15 c	19.82 c
'Sunki' mandarin	3.45 a	113.92 b	121.61 a	0.94 cd	3.45 b	24.58 a

continued Table 1...

'Volkameriano' lemon	3.66 a	115.52 b	127.91 a	0.90 d	3.66 a	26.24 a
'Limeira' trifoliate	2.80 c	108.78 b	86.19 c	1.26 a	2.80 d	12.80 e
VC (%)	13.33	14.67	9.18	18.29	8.86	10.11
			2013			
'Rangpur' lime	4.48 ab	121.14 b	144.23 a	0.84 d	3.74 b	28.59 b
'Troyer' citrange	4.53 ab	136.23 a	121.82 b	1.12 b	3.69 bc	28.36 b
'Carrizo' citrange	4.32 b	134.44 a	119.14 b	1.13 b	3.55 c	26.73 b
1707 Hybrid	3.85 c	123.45 b	110.16 bc	1.12 b	3.58 c	27.24 b
1710 citrandarin	3.92 c	116.08 bc	105.15 c	1.10 b	3.85 a	32.74 a
1697 citrandarin	4.55 a	125.57 ab	105.13 c	1.19 ab	3.67 bc	28.65 b
1708 citradia	3.76 c	117.25 bc	102.24 c	1.15 b	3.84 a	31.86 a
'Swingle' citrumelo	4.30 b	135.56 a	108.35 c	1.25 a	3.68 bc	28.97 b
'Cleópatra' mandarin	3.56 c	119.91 bc	107.57 c	1.11 b	3.91 a	32.90 a
'Sunki' mandarin	4.20 b	116.12 bc	142.68 a	0.81 d	3.62 bc	27.10 b
'Volkameriano' lemon	4.72 a	130.01 a	150.00 a	0.87 d	3.80 ab	30.29 a
'Limeira' trifoliate	2.98 d	112.14 c	89.29 d	1.26 a	3.05 d	19.24 c
VC (%)	17.91	12.33	7.35	17.23	13.07	17.33
			2014			
'Rangpur' lime	4.67 a	194.12 abc	170.66 a	1.14 de	5.27 ab	58.10 a
'Troyer' citrange	4.54 abc	210.26 a	143.38 abcd	1.47 a	5.05 ab	50.85 abc
'Carrizo' citrange	4.53 abc	177.06 bcd	154.60 abc	1.15 de	5.19 ab	55.41 ab
1707 Hybrid	4.85 a	184.12 abcd	164.58 ab	1.12 e	5.34 a	60.51 a
1710 citrandarin	3.99 bcd	172.20 cd	146.80 abcd	1.20 cde	4.87 abc	46.03 abcd
1697 citrandarin	3.89 cd	162.20 d	118.74 de	1.37 abc	4.33 cd	32.22 cd
1708 citradia	4.87 a	195.48 abc	163.66 ab	1.20 cde	5.12 ab	52.83 ab
'Swingle' citrumelo	4.99 a	200.46 ab	161.92 ab	1.24 bcde	5.32 d	59.24 a
'Cleópatra' mandarin	4.58 ab	183.88 abcd	138.12 bcde	1.33 abcd	4.91 abc	47.09 abcd
'Sunki' mandarin	4.33 abc	174.52 abc	131.14 cde	1.33 abcd	4.91 abc	47.09 abcd
'Volkameriano' lemon	4.53 abc	177.12 abc	140.26 bcd	1.26 bcde	4.57 bcd	38.17 bcd
'Limeira' trifoliate	3.55 d	159.06 d	111.26 e	1.43 ab	4.13 d	27.89 d
VC (%)	6.98	6.86	9.13	7.32	6.61	19.39
			2015			
'Rangpur' lime	4.80 ab	206.16 ab	178.66 a	1.15 cde	5.68 ab	77.55 ab
'Troyer' citrange	4.76 ab	220.88 a	143.38 de	1.55 e	5.49 ab	75.33 ab
'Carrizo' citrange	4.89 ab	185.42 bc	159.40 bcde	1.17 bcde	5.57 ab	79.52 a
1707 Hybrid	4.85 ab	193.68 abc	172.26 cde	1.12 de	5.87 a	87.56 a
1710 citrandarin	4.28 bcd	188.20 bc	163.86 bcde	1.15 cde	5.27 abc	62.45 abc
1697 citrandarin	4.04 cd	175.12 c	172.26 cde	1.02 e	4.81 bc	49.86 bc
1708 citradia	5.06 a	206.48 ab	174.74 de	1.18 bcde	5.69 ab	81.89 a
'Swingle' citrumelo	5.08 a	210.34 bc	152.68 bcde	1.39 ab	5.67 ab	85.82 a
'Cleópatra' mandarin	4.78 cd	196.32 abc	148.06 bcde	1.33 bcde	5.30 abc	71.41 ab
'Sunki' mandarin	4.54 abc	185.32 bc	150.06 bcde	1.24 bcde	5.08 abc	62.33 abc
'Volkameriano' lemon	4.52 abc	182.80 bc	145.86 cde	1.25 cde	5.37 abc	68.04 ab
'Limeira' trifoliate	3.66 d	167.40 c	124.08 e	1.36 abc	4.54 c	40.00 c
VC (%)	6.18	6.98	8.81	8.28	7.59	6.93

Means followed by the same letter in the column for each year do not differ by the Tukey test at 5% probability level.

TABLE 2 - Mean values of production per plant (PP) (kg.plant^{-1}), mean fruit mass (MMF) (g), number of fruits per plant (NFP) (un), productivity (PTVD) (t.ha^{-1}) and production efficiency (PE) (kg.m^{-3}) in 2010 to 2015 of 'Tahiti' acid lime grafted on 12 rootstocks. Jaíba, Minas Gerais.

Rootstock	PP	MMF	NFP	PTVD	EP
			2010		
'Rangpur' lime	12.48 a	76.24 a	164 b	3.12 a	0.91 a
'Troyer' citrange	13.68 a	75.12 a	182 ab	3.42 a	0.98 a
'Carrizo' citrange	12.04 a	74.96 a	161 b	3.01 a	0.90 a
1707 Hybrid	11.88 a	74.16 a	160 b	2.97 a	0.92 a
1710 citrandarin	11.56 a	75.08 a	154 bc	2.89 a	0.95 a
1697 citrandarin	11.12 a	75.44 a	147 bc	2.78 a	0.80 a
1708 citradia	12.20 a	74.89 a	163 b	3.05 a	1.01 a
'Swingle' citrumelo	13.60 a	76.76 a	177 ab	3.40 a	1.02 a
'Cleópatra' mandarin	12.72 a	75.24 a	169 b	3.18 a	0.97 a
'Sunki' mandarin	14.84 a	75.19 a	197 a	3.71 a	1.23 a
'Volkameriano' lemon	13.08 a	75.93 a	172 b	3.27 a	0.94 a
'Limeira' trifoliate	13.68 a	75.00 a	182 ab	3.42 a	1.14 a
VC (%)	11.14	10.76	14.45	6.18	8.34
			2011		
'Rangpur' lime	32.40 b	76.34 b	424 a	8.10 ab	1.91 a
'Troyer' citrange	26.44 bc	75.33 b	351 b	6.61 b	1.53 b
'Carrizo' citrange	24.48 c	73.54 bc	333 b	6.12 b	1.32 bc
1707 Hybrid	21.08 cd	75.05 b	281 c	5.27 c	1.52 b
1710 citrandarin	25.52 c	72.88 c	350 b	6.38 b	1.92 a
1697 citrandarin	27.88 bc	74.72 b	373 b	6.97 b	1.38 bc
1708 citradia	24.32 c	72.96 c	333 b	6.08 bc	1.75 ab
'Swingle' citrumelo	22.20 c	72.94 c	304 bc	5.55 c	1.34 b
'Cleópatra' mandarin	33.68 ab	82.12 a	410 ab	8.42 a	2.09 a
'Sunki' mandarin	18.76 d	71.17 c	264 c	4.69 c	0.96 c
'Volkameriano' lemon	41.08 a	75.56 b	544 a	10.27 a	2.11 a
'Limeira' trifoliate	24.04 c	73.17 bc	329 b	6.01 bc	1.99 a
VC (%)	10.92	12.09	16.78	11.17	12.23
			2012		
'Rangpur' lime	52.88 bc	81.63 a	648 c	13.22 c	2.57 c
'Troyer' citrange	53.72 bc	80.85 a	664 c	13.43 c	2.27 c
'Carrizo' citrange	61.40 b	80.05 a	767 bc	15.35 b	2.51 c
1707 Hybrid	49.48 c	79.30 a	624 c	12.37 cd	2.81 bc
1710 citrandarin	70.32 a	82.54 a	852 b	17.58 a	4.17 a
1697 citrandarin	61.84 b	80.30 a	770 bc	15.46 b	2.66 c
1708 citradia	58.00 bc	80.85 a	717 c	14.50 bc	3.68 a
'Swingle' citrumelo	41.72 d	76.86 a	543 d	10.43 d	2.01 c
'Cleópatra' mandarin	75.12 a	80.21 a	937 a	18.78 a	3.79 a
'Sunki' mandarin	50.16 c	79.53 a	631 cd	12.54 cd	2.04 c
'Volkameriano' lemon	69.20 a	81.65 a	848 ab	17.30 a	2.64 c
'Limeira' trifoliate	45.01 cd	79.22 a	568 d	11.25 d	3.52 ab
VC (%)	12.89	13.76	17.34	8.56	13.45
			2013		
'Rangpur' lime	59.52 bc	78.17 a	761 c	14.88 b	2.08 b
'Troyer' citrange	52.08 c	79.16 a	658 d	13.02 c	1.84 b
'Carrizo' citrange	56.52 bc	80.11 a	706 cd	14.13 bc	2.11 b
1707 Hybrid	58.16 bc	82.16 a	708 cd	14.54 b	2.14 b
1710 citrandarin	68.28 a	79.32 a	861 ab	17.07 a	2.09 b
1697 citrandarin	60.48 b	78.91 a	766 bc	15.12 b	2.11 b
1708 citradia	61.52 b	76.16 a	808 ab	15.38 b	1.93 b
'Swingle' citrumelo	61.32 b	79.19 a	774 ab	15.33 b	2.12 b
'Cleópatra' mandarin	65.92 ab	81.20 a	812 a	16.48 a	2.00 b
'Sunki' mandarin	55.40 c	79.44 a	697 c	13.85 c	2.04 b

continued Table 2...

'Volkameriano' lemon	70.76 a	81.52 a	868 a	17.69 a	2.34 ab
'Limeira' trifoliate	58.28 bc	77.15 a	755 cd	14.57 b	3.03 a
VC (%)	9.61	12.90	16.69	9.16	14.05
			2014		
'Rangpur' lime	68.13 ab	110.44 a	617 b	17.53 ab	1.17 b
'Troyer' citrange	61.71 c	103.40 a	597 bc	15.40 bc	1.21 b
'Carrizo' citrange	68.51 ab	112.91 a	607 b	17.10 b	1.24 b
1707 Hybrid	64.47 bc	113.18 a	570 b	16.10 b	1.07 b
1710 citrandarin	65.09 b	101.00 a	645 a	16.27 ab	1.41 b
1697 citrandarin	75.94 a	114.29 a	664 a	18.99 a	2.35 a
1708 citradia	64.62 b	126.36 a	511 c	16.16 b	1.22 a
'Swingle' citrumelo	60.21 b	114.16 a	527 c	15.05 c	1.02 b
'Cleópatra' mandarin	58.82 c	125.40 a	469 d	14.70 c	1.25 b
'Sunki' mandarin	63.42 bc	125.26 a	506 c	15.86 bc	1.35 b
'Volkameriano' lemon	65.90 bc	98.22 a	671 a	16.48 b	1.73 b
'Limeira' trifoliate	59.36 bc	105.91 a	560 cd	14.84 c	2.13 ab
VC (%)	12.45	14.22	13.33	13.26	9.12
			2015		
'Rangpur' lime	90.73 a	99.80 a	910 a	22.68 a	1.15 b
'Troyer' citrange	67.66 abcd	91.28 a	739 abc	16.91 abcd	0.86 b
'Carrizo' citrange	83.47 ab	97.42 a	862 a	20.87 ab	0.98 b
1707 Hybrid	55.87 bcd	89.03 a	628 abc	13.97 bcd	0.82 b
1710 citrandarin	53.33 cd	99.86 a	563 abcd	13.33 cd	0.90 b
1697 citrandarin	80.45 abc	91.27 a	888 a	20.11 abc	1.18 b
1708 citradia	67.67 abcd	90.89 a	746 abcd	16.92 abcd	1.77 a
'Swingle' citrumelo	70.00 abcd	88.71 a	793 abc	17.50 abcd	0.96 b
'Cleópatra' mandarin	45.86 d	83.84 a	535 cd	11.47 d	0.72 b
'Sunki' mandarin	79.60 abc	104.56 a	764 abcd	19.90 abc	1.07 b
'Volkameriano' lemon	83.20 ab	99.75 a	834 ab	20.80 ab	0.95 b
'Limeira' trifoliate	52.33 cd	107.40 a	496 d	13.08 cd	1.29 ab
VC (%)	18.83	12.20	18.14	18.85	25.30

Means followed by the same letter in the column for each year do not differ by the Tukey test at 5% probability level.

TABLE 3 - Mean values of longitudinal diameter (DL, mm) and equatorial diameter (DE, mm) of fruits, juice yield (RS,% juice), total soluble solids (SST, ° Brix), titratable acidity (AT, % citric acid) and vitamin C content (TVC, in mg.100 ml^{-1} of juice) in 2011, 2012 and 2013 of 'Tahiti' acid lime grafted on 12 rootstocks. Jaíba, Minas Gerais.

Rootstock	DL	DE	RS	SS	AT	TVC
			2011			
'Rangpur' lime	59.28 a	55.13 a	55.65 a	8.75 d	6.93 a	30.22 ab
'Troyer' citrange	58.17 a	54.67 a	54.85 a	9.38 bc	7.14 a	29.56 bc
'Carrizo' citrange	57.12 a	54.78 a	53.67 a	9.98 a	7.33 a	32.67 a
1707 Hybrid	58.11 a	54.10 a	54.40 a	9.21 c	6.99 a	31.87 ab
1710 citrandarin	59.02 a	56.18 a	54.17 a	9.43 bc	6.93 a	30.40 bc
1697 citrandarin	57.99 a	55.54 a	54.69 a	9.53 b	6.96 a	27.56 c
1708 citradia	58.13 a	54.03 a	53.36 a	9.63 ab	7.21 a	28.45 bc
'Swingle' citrumelo	59.12 a	55.92 a	54.27 a	9.76 ab	6.83 a	29.32 bc
'Cleópatra' mandarin	57.71 a	54.29 a	51.69 a	9.22 c	7.20 a	28.56 bc
'Sunki' mandarin	57.12 a	55.16 a	53.35 a	9.51 b	7.52 a	32.20 a
'Volkameriano' lemon	58.98 a	55.13 a	53.83 a	8.75 d	7.24 a	32.89 a
'Limeira' trifoliate	56.17 a	54.23 a	53.17 a	9.97 a	7.02 a	33.45 a
VC (%)	10.32	8.82	12.78	6.21	4.84	11.39
			2012			
'Rangpur' lime	58.12 a	54.38 a	60.64 a	8.33 b	6.49 a	31.22 bc
'Troyer' citrange	57.43 a	54.17 a	58.27 a	8.71 ab	6.41 a	30.45 c
'Carrizo' citrange	56.26 a	54.07 a	58.57 a	8.89 a	8.89 a	32.00 b
1707 Hybrid	57.71 a	54.38 a	60.75 a	8.72 ab	6.26 a	32.37 b
1710 citrandarin	59.02 a	56.18 a	58.09 a	8.68 ab	6.00 a	29.40 c
1697 citrandarin	58.09 a	55.14 a	58.87 a	9.04 a	6.38 a	28.60 c
1708 citradia	57.21 a	54.18 a	59.23 a	9.03 a	6.14 a	29.35 c
'Swingle' citrumelo	59.31 a	55.22 a	59.18 a	9.15 a	6.61 a	30.72 b
'Cleópatra' mandarin	56.38 a	54.02 a	55.63 a	8.74 ab	6.63 a	29.66 c
'Sunki' mandarin	56.22 a	53.97 a	58.33 a	9.03 a	6.95 a	33.10 ab
'Volkameriano' lemon	59.03 a	55.33 a	57.28 a	8.27 b	6.63 a	34.89 a
'Limeira' trifoliate	55.16 a	53.08 a	57.46 a	8.87 a	6.38 a	31.54 bc
VC (%)	10.56	7.97	10.61	2.68	4.69	11.55
			2013			
'Rangpur' lime	60.27 a	55.42 a	46.12 a	8.27 b	7.01 a	30.77 a
'Troyer' citrange	58.18 a	54.17 a	47.31 a	8.18 b	6.49 a	28.04 a
'Carrizo' citrange	58.23 a	54.07 a	47.74 a	8.83 a	6.93 a	29.91 a
1707 Hybrid	57.93 a	54.38 a	46.22 a	8.48 ab	7.13 a	29.31 a
1710 citrandarin	58.86 a	56.18 a	46.89 a	8.30 b	6.21 a	28.84 a
1697 citrandarin	57.77 a	55.14 a	47.30 a	8.43 ab	6.55 a	29.05 a
1708 citradia	58.32 a	54.18 a	47.42 a	8.51 ab	6.71 a	28.47 a
'Swingle' citrumelo	59.76 a	55.22 a	48.03 a	8.80 a	7.15 a	29.23 a
'Cleópatra' mandarin	57.89 a	54.08 a	46.29 a	8.33 b	6.07 a	29.36 a
'Sunki' mandarin	58.47 a	55.19 a	46.87 a	8.92 a	6.22 a	30.88 a
'Volkameriano' lemon	59.60 a	55.25 a	47.78 a	8.27 b	6.96 a	30.84 a
'Limeira' trifoliate	56.75 a	54.12 a	47.13 a	8.71 a	6.29 a	30.78 a
VC (%)	9.13	11.18	8.29	11.27	12.28	9.79

Means followed by the same letter in the column for each year do not differ by the Tukey test at 5% probability level.

CONCLUSIONS

'Rangpur' lime, 'Volkameriano' lemon and 'Carrizo' citrange were the rootstocks that induced greater vegetative vigor and productivity to 'Tahiti' acid lime. On the other hand, 'Limeira' trifoliate and '1708' citradia induced lower vigor and higher production efficiency, and could be used as alternative rootstocks to 'Rangpur' lime, provided that adjustments are made in planting spacings in order to increase productivity.

In general, fruits presented physical and chemical characteristics within commercial standards.

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