# FRUIT QUALITY OF 'TAHITI' LIME (*Citrus latifolia* Tanaka) GRAFTED ON TWELVE DIFFERENT ROOTSTOCKS[1]

EDUARDO SANCHES STUCHI[2], ANTONIO BALDO GERALDO MARTINS[3], RODRIGO RODAS LEMO[3], TATIANA CANTUARIAS-AVILÉS[4]

**ABSTRACT -** In the present work, the effect of twelve rootstocks on fruit quality of the nucellar clone IAC-5 of 'Tahiti' lime, (*Citrus latifolia* Tanaka) and the influence of fruit position on tree in fruit quality was evaluated in the Citrus Experimental Station of Bebedouro (EECB), located in the Bebedouro county, state of São Paulo, Brazil. A 8.0 x 5.0m planting frame was utilized. The evaluated rootstocks were: 'Carrizo' citrange (*C. sinensis* (L.) Osbeck x *Poncirus trifoliata* (L.) Raf.); the hybrids 'Rangpur' lime x 'Swingle' citrumello (*C. limonia* Osbeck x *P. trifoliata* Raf) and 'Changsha' x 'English Small' (*C. sunki* Hort. ex Tan. x *P. trifoliata* Raf.); the mandarins 'Sun Chu Sha Kat' (*C. reticulata* Blanco) and 'Sunki' (*C. sunki* Hort. ex Tanaka); the 'Rangpur' limes 'Cravo Limeira' and ' Cravo FCAV' (*C. limonia* Osbeck); the 'Swingle' citrumello (*P. trifoliata* Raf. x *C. paradisi* Macf.); the 'Orlando' tangelo (*C. reticulata* Blanco x *C. paradisi* Macf.) and the trifoliates cvs. 'Rubidoux', 'FCAV' and 'Flying Dragon' (*P. trifoliata* Raf.). The experiment was arranged in a randomized block design, with twelve treatments, six replicates and one plant per plot. The rootstocks induced differences in fruit quality; however, all the evaluated quality characteristics were within the values considered as normal and acceptable for the variety, constituting good alternative rootstocks for the 'Rangpur' lime. Additionally, the fruit position in the plant (northeastern or southwestern) had a significant influence on the external fruit color regardless of the rootstock.
**Index terms:** fruit position, fruit color, fruit dimension and mass.

## QUALIDADE DE FRUTOS DE LIMEIRA-ÁCIDA 'TAHITI' (*Citrus latifolia* Tanaka) ENXERTADA EM DOZE PORTA-ENXERTOS

**RESUMO -** No presente trabalho, avaliou-se a influência de doze porta-enxertos sobre a qualidade dos frutos da lima-ácida 'Tahiti' (*Citrus latifolia* Tanaka), clone 'IAC-5', amostrados em duas posições nas plantas, em experimento conduzido na Estação de Citricultura de Bebedouro, em um pomar de três anos. O espaçamento utilizado foi de 8.0 x 5.0m. Os porta-enxertos utilizados foram: citrangeiro 'Carrizo' (*C. sinensis* (L.) Osbeck x *Poncirus trifoliata* (L.) Raf.); os híbridos 'Cravo' x 'Swingle' (*C. limonia* Osbeck x *P. trifoliata* (L.) Raf. x *C. paradisi* Macf.) e 'Changsha' x 'English Small' (*C. sunki* Hort. ex Tan. x *P. trifoliata* Raf.); as tangerineiras 'Sun Chu Sha Kat' (*C. reticulata* Blanco) e 'Sunki' (*C. sunki* Hort. ex Tanaka); os limoeiros 'Cravo Limeira' e 'Cravo FCAV' (*C. limonia* Osbeck); o citrumeleiro 'Swingle' (*P. trifoliata* Raf. x *C. paradisi* Macf.), o tangeleiro 'Orlando' (*C. reticulata* Blanco x *C. paradisi* Macf.) e os trifoliateiros 'Rubidoux', 'FCAV' e 'Flying Dragon' (*Poncirus trifoliata* Raf.). Foi utilizado um delineamento em blocos casualizados, com doze tratamentos e seis repetições. Os distintos porta-enxertos induziram diferenças na qualidade dos frutos, entretanto todas as características de qualidade foram consideradas aceitáveis para a variedade, sendo bons substitutos para o limão 'Cravo'.
**Termos para indexação**: posição do fruto, coloração do fruto, dimensões e massa dos frutos.

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[2]Embrapa Mandioca e Fruticultura Tropical, Estação Experimental de Citricultura de Bebedouro, Rodovia Brigadeiro Faria Lima, km 384, Caixa Postal 74, 14700-971, Bebedouro, SP, Brasil stuchi@estacaoexperimental.com.br
[3]Departamento de Produção Vegetal, Via de Acesso Prof. Paulo Donato Castelane km 5, 14884-900, Jaboticabal, SP, Brasil baldo@fcav.unesp; rrlemo@yahoo.com.br
[4]Departamento de Produção Vegetal, ESALQ/USP-SP, Av. Pádua Dias 11, Caixa Postal 9, 13418-900, Piracicaba, SP, Brasil tatiana.cantuarias@gmail.com

## INTRODUCTION

Citriculture had established itself in the Brazilian scenery as one of the most important agricultural activities. Nowadays Brazil is the world's largest orange producer, and the state of São Paulo is responsible for 85% of the country's citric fruit production, mainly destined to the industry of concentrated orange juice (MATTOS et al., 2005). With the 'Tahiti' lime it is not different, and the state of São Paulo dominates the internal market, with about 70% of the whole country production. In this context, the cultivation of 'Tahiti' lime has been calling the growers' attention, because of its high profitability and expansion possibility, as the application of new techniques allows a secondary crop in the out season, when fruit prices become more attractive.

Iriarte-Martel et al. (1999) referred to the 'Tahiti' lime as one of the more suitable Brazilian citric fruits for export, with the possibility of supplying the lack of Spanish lemons in the European market during 3 to 4 months, satisfying the demands of the domestic and foreign markets (BOTEON, 1999).

The rootstock may influence several aspects of citrus growth and development, including yield, fruit quality, and tolerance to stress caused by biotic and abiotic factors. The rootstocks effects on fruit quality were reviewed by Stuchi et al (1996). In general, it was referred that water and nutrients uptake capacities play a major role on the influence of the rootstocks in fruit quality.

The green color of the peel is extremely desirable for fresh fruit commercialization, while a full or partial yellowish coloration reduces fruit acceptance by the consuming market. In the field the fruits are picked green, after reaching full development and they are marketed while the peel color still remains green (JOMORI et al., 2003). Therefore, it is fundamental to determine the rootstock's influence over this characteristic.

As for citrus in general, the principal rootstock used for the cultivation of the 'Tahiti' lime in Brazil is the 'Rangpur' lime, which is very resistant to drought and tolerant to the citrus tristeza virus, but it is susceptible to the citrus blight and to root rot caused by *Phytophthora citrophthora* and *Phytophthora parasitica* (COELHO, 1993).

Considering those factors, an experiment was installed in the Citrus Experimental Station of Bebedouro (EECB) with the aim of studying new alternative rootstocks, which shall confer a similar or better fruit quality to the 'Tahiti' lime, as compared to that induced by the 'Rangpur' lime and other traditional rootstocks.

## MATERIAL AND METHODS

The experiment was carried out at the Bebedouro Citrus Experimental Station (EECB), located in the Bebedouro County, São Paulo State, Brazil (latitude 20º53'16" S, longitude 48º28'11" W and 601 m above sea level.) The soil is classified as a dark-red Oxysol (Haplustox), epieutrophic, endoallic, acid soil, with medium texture and 38% clay content. The experimental area had a light slope. The climate corresponds to Cwa according to Köeppen's classification (subtropical with moderate and dry winter, hot and rainy summer), with annual average temperature of 23.5ºC and an average annual precipitation of about 1.500 mm. The following treatments (rootstocks) were evaluated: 'Carrizo' citrange (*C. sinensis* (L.) Osbeck x *Poncirus trifoliata* (L.) Raf.); the hybrids 'Rangpur' lime x 'Swingle' citrumello (*C. limonia* Osbeck x *P. trifoliata* Raf.) and 'Changsha' x 'English Small' (*C. sunki* Hort. ex Tan. x *P. trifoliata* Raf.); the mandarins 'Sun Chu Sha Kat' (*C. reticulata* Blanco) and 'Sunki' (*C. sunki* Hort. ex Tanaka); 'Rangpur' lime (*C. limonia* Osbeck) cvs. 'Cravo Limeira' and 'Cravo FCAV'; 'Swingle' citrumelo (*P. trifoliata* Raf. x *C. paradisi* Macf.); 'Orlando' tangelo (*C. reticulata* Blanco x *C. paradisi* Macf.) and the trifoliates (*P. trifoliata* Raf.) cvs. 'FCAV', 'Flying Dragon' and 'Rubidoux'. All the rootstocks are tolerant to the citrus tristeza virus and they were budded with the IAC 5-1 nucellar clone of 'Tahiti' lime (*C. latifolia* Tanaka). Trees were planted on February 28, 2001, in a spacing of 8.0 x 5.0 m, without irrigation. Cultural practices were common for all the treatments. The experimental design was in randomized blocks, with twelve treatments disposed in six replicates, and one tree per plot. The treatments corresponded to the previously described rootstocks, with 72 plants under measurement and 8 plants as external borders. Physical and chemical fruit analyses were performed at the Laboratory of Fruit Technological Analyses of the Bebedouro Citrus Experimental Station, on April 15, 2005, with the objective of evaluating fruit quality of the main crop. Peel thickness and fruit color were measured on June 29, 2005 at the Laboratory of the Horticulture Department of the Faculty of Agricultural and Veterinarian Sciences of the São Paulo State University (UNESP – Jaboticabal). Samples of 10 fruits were picked from each plant for external color determination. Fruits were separately picked from the southwestern and northeastern side of the tree row to evaluate the

influence of fruit orientation, together with the influence of the different rootstocks, over fruit color. For fruit quality analyses and peel thickness determination, samples of 5 fruits were homogenously collected from the four quadrants of each plant. Fruit length and diameter were determined using a graduated ruler and the fruits were then weighed on a plate scale. External coloration of fruits picked from the southwestern and northeastern row side was determined by visual comparison with a color table for export fruit classification that defines five external color levels (level 1 - deep green; level 5 – light green to yellowish) (CEAGESP, 2000). Peel thickness was measured after cutting each fruit into two halves, with the aid of a caliper. Fruit juice was extracted with an automatic squeezer and it was then weighed to determine fruit juice percentage (JP). Soluble solids (SS) were measured as Brix degrees by using a digital refractometer, according to the methodology described by Redd et al. (1986). Titrable acidity (TA) was determined by titration with 0.1 N NaOH and the results were expressed in grams of citric acid per 100 ml of juice. The maturation index, corresponding to the SS/TA ratio, was then calculated. Finally, the technological index (TI) was calculated from the expression: TI= (SS x JP x 40.8) / 10000, which expresses the SS content obtained from the juice extracted from one fruit box of 40.8 kg weight. The data were submitted to variance analysis and the treatment means were compared by the Tukey test at 5% probability level.

## RESULTS AND DISCUSSION

**Soluble solids (SS)**

Fruits picked from the 'Flying Dragon' rootstock had the largest SS content, followed by the fruits picked from 'Carrizo' citrange, the 'Sun Chu Sha Kat' mandarin, the hybrid 'Rangpur' lime x 'Swingle' citrumello and the 'Rubidoux' trifoliate (Table 1).

The 'Rangpur' lime cv. 'Cravo Limeira' and the 'Orlando' tangelo induced the lowest SS contents, which did not significantly differ from those conferred by the rootstocks 'Changsha' x 'English Small', 'Rangpur' lime cv. 'Cravo FCAV', 'Swingle' citrumello and 'Sunki' mandarin. This fact may be caused by the higher fruit juice dilution, typical of Rangpur lime rootstock (CASTLE, 1995). The other rootstocks, including the 'Sunki' mandarin and the 'Swingle' citrumello, induced intermediate SS values. In general, the observed SS values were higher than those found by Stenzel & Neves (2004), but they were close to the mean SS values described by Donadio et al. (1995), of about 9° Brix.

The 'Flying Dragon' trifoliate outstands due to its higher content of soluble solids, representing a good alternative rootstock for 'Tahiti' lime cultivation, with good behavior under high density planting (STUCHI et al., 2003; STUCHI & SILVA, 2005).

**Titrable Acidity (TA)**

The evaluated rootstocks did not promote significant differences in juice acidity of 'Tahiti' lime fruits, possibly due to the large variability observed among the rootstocks (Table 1). Total tritable acidity levels were higher than those obtained by Stenzel & Neves (2004), who reported values of 5.0 to 5.8%, while in the present work the total tritable acidity varied between 6.5 and 6.8%. These acidity levels were within the range described by Gayet (1995), of 6 to 8%.

**Maturation index (SS/TA ratio)**

There were significant differences in the maturation index between the rootstocks (Table 1). The 'Flying Dragon' trifoliate induced the largest mean maturation index (1.37), and it was statistically similar on its effect to the 'Carrizo' citrange, the trifoliates 'FCAV' and 'Rubidoux', the hybrid 'Rangpur' lime x 'Swingle' and the 'Sun Chu Sha Kat' mandarin. The other rootstocks presented intermediate values of maturation index, except for the 'Orlando' tangelo, which achieved lower values than the trifoliates 'FCAV' and 'Rubidoux', the hybrid 'Rangpur' lime x 'Swingle' and the 'Carrizo' citrange.

The obtained maturation index values were higher than those reported by Iriarte- Martel (1993), of 0.95 to 1.08, but they were closer to the mean maturation index of 1.5, described by Figueiredo (1991) for 'Tahiti' lime on different rootstocks.

**Fruit height, diameter and peel thickness**

Consistently with the results reported by Stuchi et al. (2002), no significant differences in fruit height and diameter were found among the treatments (Table 2). Mean peel thickness was largest in the fruits picked from the hybrid 'Rangpur' lime x 'Swingle', as compared to 'Swingle' citrumello, 'Flying Dragon' trifoliate and 'Rangpur' lime cv. 'Cravo FCAV'. The other rootstocks conferred intermediate values. All the evaluated rootstocks induced thinner fruit peel thickness than that reported by Iriarte-Martel (1993), who found values of 2.60 to 3.00 mm for 'Tahiti' lime fruits produced on eleven different rootstocks. In both experiments, the 'Swingle' citrumelo consistently

induced thinner peel thickness.

**Fresh fruit mass**

The 'Changsha' x 'English Small' hybrid induced the largest fresh fruit mass, differing from 'Orlando' tangelo and 'Flying Dragon' trifoliate, which produced the light weight ones. The other rootstocks produced intermediate fruit mass values (Table 3).

The measured fresh fruit mass values were close to those reported by Stuchi et al. (2002), who obtained mean values of 91 g/fruit, while in the present work, the observed fruit mass values varied between 81 and 96 g/fruit. Stenzel & Neves (2004) found larger fresh fruit mass, varying between 96.5 to 113.5 g/fruit.

**Juice percentage (JP)**

The 'Flying Dragon' trifoliate conferred the highest fruit juice content, differing from the 'Carrizo' citrange, which produced the lowest values among the evaluated rootstocks (Table 3). Our results do not agree with Stenzel & Neves (2004) who reported that juice yield was the highest for 'Rangpur' lime differing from trifoliate orange. However, it should be noted that all the rootstocks induced juice contents above 42%, which according to Gayet et al. (1995) is the minimum juice content required for fruits destined to exportation. The obtained results of juice content are very close to those found by Iriarte-Martel (1993) and by Stenzel & Neves (2004), who reported values between 40.8% to 46.7% and between 36.7 to 47.3% for 'Tahiti' lime, respectively.

**Technological index (TI)**

The 'Flying Dragon' trifoliate induced the largest technological index, with 1.77 kg of soluble solids for a 40.8 kg fruit box of 'Tahiti' lime (Table 3), which significantly differed from the other rootstocks, except for the 'Rangpur' lime x 'Swingle' hybrid, the 'Sun Chu Sha Kat' mandarin and the 'Rubidoux' trifoliate. The 'Orlando' tangelo induced the smallest technological index, while the remaining rootstocks showed intermediate values.

**Fruit external coloration**

In relation to mean fruit coloration, there were no significant differences between the treatments, confirming that the studied rootstocks do not affect this attribute (Table 4). Nevertheless, when analyzing the mean coloration of the fruits collected separately from the southwestern and northeastern side of the tree row, we noticed that the fruits picked from the southwestern direction had a more yellowish coloration, while those picked from the northeastern direction were greener, thus confirming the influence of fruit position on its external coloration (Table 5), regardless of the rootstock.

The deep, well-drained and adequately prepared soil in this research may have contributed to the fact that all the analyzed quality characteristics were within the range of values considered as normal and acceptable for the 'Tahiti' lime. The less known rootstocks as 'Cravo' x 'Swingle', Changsha' x 'English Small', 'Sun Chu Sha Kat' showed to be adequate for Tahiti lime scion in terms of induction of fruit quality as expected for 'Swingle' citrumelo, 'Orlando' tangelo, and for the trifoliates.

**TABLE 1 -** Soluble solids (SS, °Brix), Total Tritable Acidity (TA, %) and ratio (SS/TA) of 'Tahiti' lime on twelve rootstocks. Bebedouro, Brazil, 2005.

| Rootstock | SS (°Brix) | TA (%) | ratio (SS/TA) |
|---|---|---|---|
| 'Carrizo' citrange | 8.78 ab | 6.80 a | 1.30 ab |
| 'Rangpur' lime x 'Swingle' | 8.55 abc | 6.73 a | 1.27 ab |
| 'Sun Chu Sha Kat' mandarin | 8.62 abc | 6.83 a | 1.26 abc |
| 'Rubidoux' trifoliate | 8.53 abc | 6.70 a | 1.28 ab |
| 'Changsha' x 'English Small' | 7.97 de | 6.71 a | 1.19 bc |
| 'Rangpur' lime cv. ' Cravo Limeira' | 7.70 e | 6.55 a | 1.18 bc |
| 'Swingle' citrumello | 8.12 cde | 6.69 a | 1.22 bc |
| 'Orlando' tangelo | 7.83 e | 6.86 a | 1.14 c |
| 'FCAV' trifoliate | 8.38 bcd | 6.51 a | 1.29 ab |
| 'Flying Dragon' trifoliate | 8.97 a | 6.55 a | 1.37 a |
| 'Sunki' mandarin | 8.18 cde | 6.66 a | 1.23 bc |
| 'Rangpur' lime cv. ' Cravo FCAV' | 8.02 de | 6.62 a | 1.21 bc |
| DMS | 0.5152 | 0.4365 | 0.1238 |
| CV (%) | 3.15 | 3.31 | 5.05 |

Means followed by the same lower case letter within each column do not differ by the Tukey test (5%).

**TABLE 2 -** Height and diameter (April 2005) and peel thickness (June 2005) for 'Tahiti' lime on twelve rootstocks. Bebedouro, Brazil, 2005.

| Rootstock | Height (cm) | Diameter (cm) | Peel thickness (mm) |
|---|---|---|---|
| 'Carrizo' citrange | 5.45 a | 5.08 a | 2.88 ab |
| 'Rangpur' lime x 'Swingle' | 5.57 a | 5.23 a | 3.05 a |
| 'Sun Chu Sha Kat' mandarin | 5.65 a | 5.20 a | 2.80 ab |
| 'Rubidoux' trifoliate | 5.60 a | 5.17 a | 3.02 ab |
| 'Changsha' x 'English Small' | 5.78 a | 5.12 a | 2.70 ab |
| 'Rangpur' lime cv. ' Cravo Limeira' | 5.62 a | 5.37 a | 2.98 ab |
| 'Swingle' citrumello | 5.57 a | 5.22 a | 2.62 b |
| 'Orlando' tangelo | 5.48 a | 5.12 a | 2.80 ab |
| 'FCAV' trifoliate | 5.63 a | 5.22 a | 2.68 ab |
| 'Flying Dragon' trifoliate | 5.43 a | 5.15 a | 2.62 b |
| 'Sunki' mandarin | 5.62 a | 5.28 a | 2.65 ab |
| 'Rangpur' lime cv. 'Cravo FCAV' | 5.77 a | 5.33 a | 2.62 b |
| DMS | 0.4180 | 0.3053 | 0.4299 |
| CV (%) | 3.79 | 2.99 | 7.83 |

Means followed by the same lower case letter within each column do not differ by the Tukey test (5%).

**TABLE 3 -** Juice percentage (JP), technological index (TI) and fresh mass of 'Tahiti' lime fruits on twelve rootstocks. Bebedouro, Brazil, 2005.

| Rootstock | JP (%) | TI (kg SS/fruit box) | Fresh fruit mass (g) |
|---|---|---|---|
| 'Carrizo' citrange | 43.41 b | 1.55 bc | 84.17 ab |
| 'Rangpur' lime x 'Swingle' | 46.99 ab | 1.64 ab | 88.83 ab |
| 'Sun Chu Sha Kat' mandarin | 45.92 ab | 1.62 ab | 87.63 ab |
| 'Rubidoux' trifoliate | 46.46 ab | 1.62 ab | 85.73 ab |
| 'Changsha' x 'English Small' | 47.56 ab | 1.54 bc | 96.72 a |
| 'Rangpur' lime cv. ' Cravo Limeira' | 46.84 ab | 1.47 bc | 93.67 ab |
| 'Swingle' citrumello | 46.46 ab | 1.54 bc | 88.20 ab |
| 'Orlando' tangelo | 43.88 ab | 1.40 c | 81.37 b |
| 'FCAV' trifoliate | 46.17 ab | 1.58 bc | 87.50 ab |
| 'Flying Dragon' trifoliate | 48.46 a | 1.77 a | 82.73 b |
| 'Sunki' mandarin | 47.02 ab | 1.57 bc | 89.10 ab |
| 'Rangpur' lime cv. ' Cravo FCAV' | 46.75 ab | 1.53 bc | 93.47 ab |
| DMS | 4.7945 | 0.1860 | 13.2675 |
| CV (%) | 5.25 | 6.02 | 7.62 |

Means followed by the same lower case letter within each column do not differ by the Tukey test (5%).

**TABLE 4 -** Fruit coloration 'Tahiti' lime grafted on twelve rootstocks. Bebedouro, Brazil, 2005.

| Rootstocks | External fruit color |
|---|---|
| 'Carrizo' citrange | 3.39 a |
| 'Rangpur' lime x 'Swingle' | 3.00 a |
| 'Sun Chu Sha Kat' mandarin | 3.17 a |
| 'Rubidoux' trifoliate | 2.95 a |
| 'Changsha' x 'English Small' | 2.86 a |
| 'Rangpur' lime cv. 'Cravo Limeira' | 2.93 a |
| 'Swingle' citrumello | 3.05 a |
| 'Orlando' tangelo | 3.38 a |
| 'FCAV' trifoliate | 3.45 a |
| 'Flying Dragon' trifoliate | 3.35 a |
| 'Sunki' mandarin | 3.01 a |
| 'Rangpur' lime cv. 'Cravo FCAV' | 3.12 a |
| DMS | 0.6532 |
| CV (%) | 14.94 |

Means followed by the same lower case letter within each column do not differ by the Tukey test (5%).

**TABLE 5 -** Fruit coloration of 'Tahiti' lime grafted on twelve rootstocks and picked from different positions at the plant. Bebedouro, Brazil, 2005.

| Fruit position | Color |
|---|---|
| Southwestern side of tree row | 3.34 a |
| Northeastern side of tree row | 2.93 b |
| DMS | 0.0967 |
| CV (%) | 9.14 |

Means followed by the same lower case letter within each column do not differ by the Tukey test (5%).

## CONCLUSION

The evaluated rootstocks induced differences in fruit quality; however, all the analyzed quality characteristics were within the range of values considered as normal and acceptable for the 'Tahiti' lime, hence all of them have potential as alternatives to Rangpur lime rootstock.

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