Performance of Tahiti lime on *Poncirus trifoliata* var. *monstrosa* Flying Dragon in four densities

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Abstract — Introduction. Tahiti lime trees grafted on Rangpur lime grown in São Paulo State, Brazil, in sub-tropical climatic conditions, have a high level of vigor, poor tolerance to *Phytophthora* spp. and low productivity. Using *Poncirus trifoliata* var. *monstrosa* Flying Dragon rootstock which allows one to obtain dwarfed trees and high yields could solve this problem. **Materials and methods**. In an experiment set up in November 1994 in Brazil, the tree size, fruit production and quality of Tahiti lime grafted on trifoliate orange Flying Dragon were evaluated at four planting spaces: 4 m × 1 m (2 500 trees·ha^{-1}); 4 m × 1.5 m (1 666 trees·ha^{-1}); 4 m × 2 m (1 250 trees·ha^{-1}) and 4 m × 2.5 m (1 000 trees·ha^{-1}), in a randomized block design, with four trees per plot. The cultural practices did not include supplementary irrigation. **Results**. Trees planted in the 4 m × 1 m planting space had greater canopy diameters (2.75 m) than trees planted with the other planting spaces. Whatever the densities considered, tree height did not differ. Average fruit yield (1998 to 2000) was the greatest on the 4 m × 1 m planting space with 21.6 t·ha^{-1}, significantly differing from the 4 m × 2.5 m planting space with 13.1 t·ha^{-1}. Fruit quality was affected by the plant planting space, but all the production was commercially acceptable. **Discussion**. The use of a high density planting of Tahiti lime grafted on *P. trifoliata* var. Flying Dragon would be of commercial interest, due to greater yields than trees in traditional cropping systems.

Brazil / *Citrus latifolia* / rootstocks / dwarfs / density / yields

Performance de la lime Tahiti greffée sur *Poncirus trifoliata* var. *monstrosa* Flying Dragon en fonction de quatre densités.

Résumé — Introduction. Dans l'état de São Paulo, Brésil, conditions climatiques subtropicales, les limettiers Tahiti greffés sur limettier Rangpur ont une vigueur élevée, une faible tolérance aux espèces de *Phytophthora* et une faible productivité. L'utilisation du porte-greffe *Poncirus trifoliata* var. *monstrosa* Flying Dragon qui permet d'obtenir des arbres nains et des hauts rendements pourrait résoudre ce problème. **Matériel et méthodes**. Une expérimentation installée en novembre 1994 au Brésil a permis d'évaluer le développement des arbres, leur production en fruits et la qualité des limes Tahiti produites par des arbres greffés sur *P. trifoliata* var. Flying Dragon. Quatre distances de plantation ont été testées : 4 m × 1 m (2 500 arbres·ha^{-1}); 4 m × 1.5 m (1 666 arbres·ha^{-1}); 4 m × 2 m (1 250 arbres·ha^{-1}) et 4 m × 2.5 m (1 000 arbres·ha^{-1}), dans un dispositif en blocs randomisés, avec quatre arbres par parcelle élémentaire. Les blocs n'ont pas reçu d'irrigation complémentaire. **Résultats**. Les arbres plantés à la distance de 4 m × 1 m ont eu une frondaison de plus grand diamètre (2,75 m) que des arbres plantés aux autres densités. Quelles que soient les densités considérées, la hauteur des arbres n'a pas été différente. Le meilleur rendement moyen en fruits (21.6 t·ha^{-1}), de 1998 à 2000, a été obtenu avec les arbres plantés à la distance de 4 m × 1 m, ce qui diffère de manière significative des rendements (13.1 t·ha^{-1}) observés avec les arbres plantés à 4 m × 2,5 m. La qualité du fruit a été affectée par la densité de plantation, mais toute la production a été commercialisable. **Discussion**. L'utilisation d'une plantation à haute densité de limettiers Tahiti greffés sur *P. trifoliata* var. Flying Dragon serait commercialement intéressante du fait de meilleurs rendements alors obtenus par rapport aux arbres des vergers conduits selon les systèmes traditionnels au Brésil.

Brésil / *Citrus latifolia* / porte greffe / nain / densité / rendement

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Resumen Español, *p. 17*

1. Introduction

In the state of São Paulo (Brazil), production of acid limes reached (28.26 and 31.82) million 25 kg-boxes in the 1996/1997 and 1997/1998 seasons, respectively. The value of this production was estimated at about (63 and 40) million $US, respectively. This corresponds to 1.17% and 0.67% of the total agricultural activity value for this state, thus surpassing other crops like peanuts, watermelon, grape, rice, cassava root, tomato for processing and wheat.

The state of São Paulo is the great Brazilian producer of Tahiti lime. It produces about 73% of the total lime crop [1]. The Tahiti industry is characterized by small rural family properties, with a great amount of labor, notably for weed control and harvesting. Scion is based on just two selections, the IAC-5 or Peruano, and the Quebra-Galho varieties. Trees are grafted mostly on Rangpur lime (*Citrus limonia* Osbeck) due to its traditional use and lack of more studies on alternative rootstocks [2]. These scion/rootstock combinations have a short commercial life, because of a poor tolerance to *Phytophtora* spp., present in many groves, and contaminations with severe strains of tristeza, and with exocortis in the case of the Quebra-Galho selection [3]. The big size of the trees is another problem [4], along with the yield concentration in the first six months of the year. *Poncirus trifoliata* var. *monstrosa* Flying Dragon is considered to be a dwarfing rootstock with a similar horticultural performance to *P. trifoliata* for *Phytophthora* spp. tolerance [5], even with great sensibility to drought stress. The use of irrigation would allow the induction of a larger flowering in the months of April through June. Thus, it could allow the harvesting of a part of the crop during the low offer seasons with high prices (September to November).

The objectives of this work were to evaluate the plant yield, vegetative growth and fruit quality of Tahiti (*Citrus latifolia* Tan.) lime cv. Peruano, grafted on the dwarfing rootstock *Poncirus trifoliata* var. *monstrosa* Flying Dragon, in four high-density plantings.

2. Materials and methods

The experiment started in November 1994, in the Estação Experimental de Citricultura de Bebedouro (EECB), Bebedouro county, state of São Paulo, Brazil. The soil was classified as Haplustox (38% clay). The climate is Cwa, according to Koeppen classification.

The scion/rootstock combination was Tahiti acid lime cv. Peruano grafted on *Poncirus trifoliata* var. *monstrosa* Flying Dragon. Trees were planted at four densities: 2 500 trees·ha^{-1} with a (4.0 × 1.0) m planting space; 1 666 trees·ha^{-1} with a (4.0 × 1.5) m planting space; 1 250 trees·ha^{-1} with a (4.0 × 2.0) m planting space; and 1 000 trees·ha^{-1} with a (4.0 × 2.5) m planting space. The experimental design was randomized blocks, with four treatments and five replications, with four trees per plot.

The cultural practices did not include supplementary irrigation. Fertilizers were applied every year according to the *Citrus Fertilizer and Limestone Recommendations* for the state of São Paulo [6]. The tree size was evaluated in May 2000; fruit production (t·ha^{-1}) was assessed from 1998 to 2000. Fruit quality was evaluated in 1999, from the characteristics: total soluble solids, acidity, and the fruit weight, height and diameter. The methods used for total soluble solids and acidity evaluations were described by Kimball [7].

The results were submitted to variance analysis and the means compared with the Tukey test at the significance level of 5%.

3. Results

The average maximum height of 2,24 m was obtained in the plots with the strongest densities (4.0 × 1.0 m planting space, 2 500 trees·ha^{-1}). Nevertheless, this height was not significantly different from that of about 2.00 m measured for the trees of the three other densities (*table I*). Significant differences occurred between scion diameter values as the trees of the strongest

densities presented the widest average diameter (2.75 m) while the other treatments ranged from (2.42 to 2.52) m.

From 1998 through 2000, plant yields were always the highest in the 4.0 × 1.0 m planting space (2 500 trees·ha^{-1}) and the lowest in the lowest density. Thus, there were significant differences between the treatment with 2 500 trees·ha^{-1} that presented the largest average productivity (21.6 t·ha^{-1}) and the treatment with 1 000 trees·ha^{-1} (13.1 t·ha^{-1}). The two other densities were intermediate between these two extremes (*table II*).

Whatever the treatment considered, no significant differences occurred for fruit total soluble solids, weight and height. Fruit acidity was greater in the treatment with 1 666 trees·ha^{-1}, which differed significantly from the others. The largest fruit medium diameter was observed in the treatment with 1 000 trees·ha^{-1}, which significantly differed from the plots with 1 666 trees·ha^{-1} (*table III*).

Table I.
Tree height and canopy diameter (m) of 66-month-old Tahiti lime grafted on *Poncirus trifoliata* var. Flying Dragon at four different planting densities, Bebedouro, Brazil, 2000.

Density (trees·ha^{-1})	Planting space (m)	Tree height (m)	Canopy diameter (m)
2 500	4.0 × 1.0	2.24 a	2.75 a
1 666	4.0 × 1.5	2.03 a	2.48 b
1 250	4.0 × 2.0	2.05 a	2.52 b
1 000	4.0 × 2.5	2.00 a	2.42 b
Coefficient of variation (%)		6.4	10.94

a, b: means followed by the same lower case in the column do not differ by the Tukey test (5%).

Table II.
Fruit yield (t·ha^{-1}) in the period from 1998 to 2000 and means of the period of Tahiti lime grafted on P*oncirus trifoliata* var. Flying Dragon in four different planting densities, Bebedouro, Brazil, 1998–2000.

Density (trees·ha^{-1})	Planting space (m)	1998	1999	2000	Mean
2 500	4.0 × 1.0	10.95	34.69	19.05	21.6 a
1 666	4.0 × 1.5	10.71	28.09	17.50	18.8 ab
1 250	4.0 × 2.0	7.27	24.98	12.96	15.1 ab
1 000	4.0 × 2.5	4.70	22.27	12.32	13.1 b
Annual mean	–	8.41	27.51	15.46	–
Coefficient of variation (%)		–	–	–	37.97

a, b: means followed by the same lower case in the column do not differ by the Tukey test (5%).

4. Discussion

The fruit weight values obtained in our experiment were higher than the average value reported for Tahiti by Figueiredo [8] only in the treatment with the (4.0 × 2.5) m planting space. Other densities showed close values to those referred to by that author (70 g) and lower ones than those reported by Iriarte-Martel *et al.* [9]. For all treatments, the fruit diameter was within the range indicated by Donadio *et al.* [10], (4.7 to 6.3) cm, and the fruit height hovered close to the inferior limit of the range indicated by Donadio *et al.* [10], (5.5 to 7.0) cm.

In Brazil, citrus trees are considered to be producing when they are more than 5 years old. In our results, the average tree height in the whole experiment, 66 months after the planting, did not exceed 2.24 m, and the general height average did not exceed 2.08 m, characterizing these trees as dwarfed ones, according to Bitters *et al.* [11]. Thus, these measurements confirm the Flying Dragon dwarfing character, commented on by Roose [5].

Figueiredo *et al.* [2] reported an average fruit yield of the first three harvest years (4th to the 6th year after planting) of Tahiti on 11 rootstocks, planted in a density of 208 trees·ha^{-1}, in Brazil. In this research, the greatest productivity was induced by Orlando tangelo (9.88 t·ha^{-1}), Morton citrange (9.82 t·ha^{-1}), Rangpur lime (7.6 t·ha^{-1}), *Poncirus trifoliata* (7.36 t·ha^{-1}), Volkamer

Table III.
Fruit quality (total soluble solids, acidity, weight, diameter and height) of Tahiti lime grafted on *Poncirus trifoliata* var. Flying Dragon in four different planting densities, Bebedouro, Brazil, 1999.

Density (trees·ha^{-1})	Planting space (m)	Fruit				
		TSS (°Brix)	Acidity (%)	Weight (g)	Diameter (cm)	Height (cm)
2 500	4.0 × 1.0	6.9 a[1]	5.7 b	70.7 a	4.8 ab	5.4 a
1 666	4.0 × 1.5	6.9 a	6.4 a	70.0 a	4.75 b	5.5 a
1 250	4.0 × 2.0	7.1 a	5.9 b	71.3 a	4.83 ab	5.5 a
1 000	4.0 × 2.5	7.0 a	6.0 b	80.0 a	5.0 a	5.8 a
Coefficient of variation (%)		2.53	1.95	6.01	1.49	2.86

a, b: means followed by the same lower case in the column do not differ by the Tukey test (5%).

lemon (6.92 t·ha^{-1}) and Swingle citrumelo (6.07 t·ha^{-1}) rootstocks. Comparing the results of Figueiredo *et al.* [2] with those obtained in our experiment [(13.1 to 21.6) t·ha^{-1}], there is an evident advantage in yield for the high density plantings, on a per area basis, for the initial period of the grove, a fact also related by Mademba-Sy *et al.* [12]. Mademba-Sy *et al.* [12] also showed that, in spite of the higher costs of planting, the profitability was superior in high-density orchards of Tahiti grafted on Flying Dragon when compared with groves with conventional planting space on *Citrus volkameriana* in tropical conditions, with supplementary irrigation.

Despite greater average productivity, for the conditions of the present experiment, the higher installation cost should be taken into consideration, mainly due to the higher number of nursery trees, and irrigation installation needs. The economic evaluation of this study is being accomplished for the initial phase of the grove. The horticultural evaluations will be accomplished until the tenth year after planting.

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Desempeño de la lima Tahití injertada en *Poncirus trifoliata* var. *monstrosa* Flying Dragon en función de cuatro densidades.

Resumen — Introducción. En el estado de São Paulo (Brasil), en condiciones climáticas subtropicales, los limeros Tahití injertados en limeros Rangpur tienen un vigor alto, baja tolerancia a las especies de *Phytophthora* y una baja productividad. La utilización del patrón *Poncirus trifoliata* var. *monstrosa* Flying Dragon, que permite obtener árboles enanos y altos rendimientos, podría solucionar este problema. **Material y métodos**. Un experimento establecido en noviembre de 1994 en Brasil permitió evaluar el desarrollo de los árboles, su producción de frutos y la calidad de las limas Tahití injertadas en *P. trifoliata* var. Flying Dragon. Se experimentaron cuatro distancias de plantación: 4 m × 1 m (2 500 árboles·ha^{-1}); 4 m × 1.5 m (1 666 árboles·ha^{-1}); 4 m × 2 m (1 250 árboles·ha^{-1}) y 4 m × 2.5 m (1 000 árboles·ha^{-1}), en un diseño de bloques aleatorios con cuatro árboles por parcela elemental. Los bloques no recibieron riego complementario. **Resultados**. Los árboles plantados a la distancia de 4 m × 1 m lograron unas copas de mayor diámetro (2,75 m) que los árboles plantados con las otras densidades. Sean cuales fueren las densidades consideradas, la altura de los árboles no fue diferente. El mejor rendimiento promedio en frutos (21.6 t·ha^{-1}), de 1998 a 2000, se obtuvo con los árboles plantados a la distancia de 4 m × 1 m, lo que contrasta de manera significativa con los rendimientos (13.1 t·ha^{-1}) observados en los árboles plantados a 4 m × 2,5 m. La calidad de la fruta se vio afectada por la densidad de plantación, pero toda la producción fue comercializable. **Discusión**. La utilización de una plantación de alta densidad de limeros Tahití injertados en *P. trifoliata* var. Flying Dragón sería comercialmente interesante debido a que se obtendrían mejores rendimientos que los que se consiguen con los árboles de huertos manejados con los sistemas tradicionales de Brasil.

Brasil / *Citrus latifolia* / portainjertos / enano / densidad / rendimiento / portainjertos / enano / densidad / rendimiento