Growth and yield of the Murcott tangor in different rootstocks along the first six years in the orchard

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Abstract - The 'Murcott' tangor is among the most important cultivars to produce fruits classified as tangerines in Brazil. Information about its interaction with some rootstocks is insufficient and sometimes conflicting, especially concerning budding incompatibilities with *Poncirus trifoliata* and its hybrids. In this context, this study was conducted to evaluate 'Murcott' agronomic performance when grafted on different rootstocks under the edaphoclimatic conditions of western Santa Catarina state. A total of 13 rootstocks were evaluated for effects on growth, yield, and average fruit mass over six years. The rootstocks were divided into four groups with similar tree heights. Among the moderately tall trees, 'Sunki' x 'Benecke'; 'Rangpur' x 'Sunki'; 'Sunki' x 'Rangpur'; 'Fepagro C 13'; 'Swingle'; and 'Fepagro C37 Dornelles' yielded more fruit per tree, whereas 'Carrizo' and 'Rangpur' x 'Sunki' stood out for their higher production per m³ of canopy. The hybrid 'HFD11 EEI' had a semi-dwarfing and 'Flying Dragon' a dwarfing effect, and the later had a lower average fruit mass.

Index terms: *Citrus sinensis* x *Citrus reticulata;* Tangerine; Compatibility; *Poncirus trifoliata*; Hybrid.

Crescimento e produção do tangoreiro Murcott em diferentes porta-enxertos nos seis anos iniciais do pomar

Resumo - O tangoreiro 'Murcott' está entre os mais importantes cultivares destinados à produção de frutos classificados como tangerinas no Brasil. As informações sobre sua interação com alguns porta-enxertos são insuficientes e as vezes conflitantes, especialmente quanto à compatibilidade de enxertia com *Poncirus trifoliata* e seus híbridos. Então, este trabalho foi desenvolvido no intuito de avaliar o desempenho agronômico do tangoreiro 'Murcott' quando enxertado em diferentes porta-enxertos nas condições edafoclimáticas do oeste do estado de Santa Catarina. Dezesseis porta-enxertos foram testados quanto aos efeitos no crescimento, produção e massa média dos frutos durante seis anos. Os porta-enxertos formaram quatro grupos com alturas de planta semelhantes. Dentre os porta-enxertos que formam plantas moderadamente altas, 'Sunki' x 'Benecke,' 'Cravo' x 'Sunki,' 'Sunki' x 'Rangpur,' 'Fepagro C 13,' 'Swingle' e 'Fepagro C37 Dornelles' proporcionam maior produção de frutos por planta, enquanto 'Carrizo' e 'Cravo' x 'Sunki' se destacam pela maior produção por m³ de copa. Já o híbrido 'HFD11 EEI' teve efeito semi-nanicante e o 'Flying Dragon' nanicante, e este último com massa média de frutos menor.

Termos para indexação: *Citrus sinensis* x *Citrus reticulata;* Tangerina; Compatibilidade; *Poncirus trifoliata*; Híbrido.

Introduction

The 'Murcott' tangor tree is a hybrid plant obtained by crossing a mandarin tree with a sweet orange tree [*Citrus reticulata* Blanco x *Citrus sinensis* (L.) Osb.] (KOLLER & SOPRANO, 2013). 'Murcott' fruit is marketed as a tangerine due to its flavor, flattened shape, and moderate adherence of the albedo to the endocarp, making peeling easier than an orange. This fruit is very appreciated and known by the consumers of fresh tangerines. Due to its on-tree storage until October or November, depending on the region, it is the latest harvest among the widely grown tangerines. The 'Murcott' trees have medium vigor, high productivity, and alternate bearing (PIO et al., 2005).

In citrus plants propagated by grafting, the rootstock affects, among other characteristics, the nutrient content of the leaves, the production and

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development of the canopy, the size of the fruits, the water supply, and the flow of sap, nutrients, and growth regulators for the canopy (VITTI et al., 2003; YONEMOTO et al., 2004; GONZATTO et al., 2011; VELLAME et al., 2012; TOPLU et al., 2012; BRUGNARA & SABIÃO, 2021), leading orchards of the same canopy cultivar to different performances.

The longevity of 'Murcott' cultivation in soils with a high clay or moisture content depends on the use of rootstocks tolerant to gummosis, a necrotic disease of the roots and trunk caused by *Phytophtora* spp. This requirement limits the use of 'Rangpur' lime (*Citrus limonia* Osb.), which is the main rootstock in Brazil, especially in the Southeast region. On the other hand, the trifoliate orange [*Poncirus trifoliata* (L.) Raf.] and some hybrids of it, such as the citrumelo 'Swingle' [*Citrus paradisi* Macf. x *Poncirus trifoliata* (L.) Raf.], common in south Brazil, despite resisting gummosis, are known to be incompatible with 'Murcott,' leading the trees to decline and die (POMPEU JÚNIOR, 1991; GARNSEY et al., 2001). Souza et al. (1992) evaluated rootstocks for 'Murcott' for 12 years in sandy soil in Rio Grande do Sul state. They observed the death of trees on C 14 citrange (sweet orange x trifoliate orange crossing). In contrast, in four other citranges, the production did not differ from 'Cleopatra', 'Cravo Taquari', and other *Citrus* spp. However, the experimental means ranged from 15 to 57kg tree^{-1}. In Rio Grande do Sul, some of the 'Murcott' combinations considered incompatible are used without records of incompatibility symptoms (GONZATTO et al., 2018).

Considering the importance of the 'Murcott' cultivar, the insufficiency and conflicting information about its interaction with some rootstocks, this study aimed to evaluate its agronomic performance when grafted on different rootstocks under the edaphoclimatic conditions of western Santa Catarina state.

Material and methods

The field experiment was established in Coronel Freitas, SC (570m altitude). The local soil is Haplic Cambisol previously cultivated with corn (*Zea mays* L.) and ryegrass (*Lollium multiflorum* L.) pasture. In the first 20cm of the profile, main chemical levels were 28.5% of clay, pH 5.9, CEC of 11.1$cmol_c$ dm^{-3}, 264mg dm^{-3} of potassium, 53.3mg dm^{-3} of available phosphorus, and no exchangeable aluminum. No tillage was performed due to the satisfactory chemical and physical condition. Seedlings were produced in a certified commercial nursery in polyethylene bags containing organic substrate. The propagation material was obtained at Epagri, Itajaí Experimental Station, in Itajaí, SC. They were planted in September 2016, in 25cm in diameter and 30cm deep pits, enough to accommodate the root system, and spaced 7 x 3m (476 trees per hectare).

A completely randomized unbalanced design (depending on the number of trees available) was used, with three plants per plot. The treatments were the 'Murcott' tangor budded on 13 rootstock varieties, whose nomenclature and number of repetitions (n) used were:

- 'Cleópatra' mandarin (*Citrus sunki* Hort. ex Tan), n=5;
- 'Rangpur' x 'Cleópatra' hybrid (*Citrus limonia* Osb. x *Citrus reshni* Hort.), n=4;
- 'Sunki' x 'Rangpur' hybrid (*Citrus limonia* Osb. x *Citrus sunki* Hort. ex Tan), n=4;
- 'Rangpur' x 'Sunki' EEI hybrid (*Citrus limonia* Osb. x *Citrus sunki* Hort. ex Tan), n=4;
- 'Changsha' x 'English Large Trifoliate' citrandarin [*Citrus reticulata* Blanco x *Poncirus trifoliata* (L.) Raf.], n=3;
- 'Sunki' x 'Benecke' citrandarin [*Citrus sunki* Hort. ex Tan. x *Poncirus trifoliata* (L.) Raf.]; n=4;
- 'Carrizo' citrange [*Poncirus trifoliata* (L.) Raf. x *Citrus sinensis* (L.) Osb.], n=4;
- 'Fepagro C 13' citrange [*Citrus sinensis* (L.) Osb. x *Poncirus trifoliata* (L.) Raf.],n=4;
- 'Fepagro C37 Dornelles' citrange [*Citrus sinensis* (L.) Osb. x *Poncirus trifoliata* (L.) Raf.], n=5;
- 'SCS453 Nasato' trifoliate orange [*Poncirus trifoliata* (L.) Raf.], n=4;
- 'Flying Dragon' trifoliate orange [*Poncirus trifoliata* var. *monstrosa* (T. Ito) Swing.], n=4;
- 'HFD11 EEI', F1 tree obtained by open pollination of 'Flying Dragon', n=4;
- 'Swingle' citrumelo [*Citrus paradisi* Macf. x *Poncirus trifoliata* (L.) Raf.], n=4.

Fertilization was based on Brunetto et al. (2016), considering yield expectations of 17t ha^{-1} in the fifth year and 30t ha^{-1} in the sixth year. Spraying of insecticides/miticides was conducted according to the occurrence of pests (*Phyllocoptruta oleivora, Anastrepha fraterculus, Toxoptera citricida, Phyllocnistis citrella*, and *Alleurocanthus woglumi*). Fungicides were used since the 5th year, in spring, with an average periodicity of 20 days, according to the occurrence of rains, for suppression of *Alternaria alternata*.

Weeds were managed with mowing between rows, manual or chemical weeding in the crowns or strips during spring and summer, and coverage with *L. multiflorum* in winter.

The trees annually received training and pruning until the third year. Afterwards, annual pruning at the end of winter removed vertical branches from the center of the canopy, up to approximately 20% of its volume, following Koller et al. (2013). With the beginning of bearing, hand thinning was performed on fruitlets in December, keeping one fruitlet on terminal branches shorter than 10cm and two on the others.

The evaluations were conducted from the beginning of fruit production (second year) until six years (fifth harvest). The fruits were harvested along July and August, and were counted and weighed to compose the variables number (nº tree^{-1}) and mass (kg tree^{-1}) of fruits produced per tree. After harvesting, canopies were measured for height (m), transversal, and longitudinal (to the row) diameters (m). With the measured values, other variables were calculated: the average fruit mass (g fruit^{-1}), the canopy projection area (CPA) (m^2), the canopy volume (m^3), the yield efficiency (kg m^{-3}) (accumulated fruit mass up to the sixth year divided by the canopy volume in the sixth year), and shape index (CPA divided by height).

Data were checked for normality and variance of homogeneity and then submitted to analysis of variance (ANOVA). In cases of significant rootstock effect, Scott-Knott tests were performed. The relationships among the response variables were analyzed using a Principal Component Analysis and biplot charts. Statistical analyses were performed in R 4.1.0 software amended with the *ScottKnott* package (JELIHOVSCHI et al., 2014; R CORE TEAM, 2021).

Results and discussion

The ANOVA showed significant differences between rootstocks in all dependent variables. The Scott-Knott test grouped the rootstocks into four groups with differences in tree height (Figure 1). ‘Cleopatra’ and the ‘Rangpur’ x ‘Cleopatra’ hybrid formed a group of taller trees (tall group), whose averages (3.1 and 3.04m) were more than double that of ‘Flying Dragon’ (1.42m) (dwarfing group). The ‘HFD11 EEI’ hybrid constituted the moderately dwarfing group, with a height of 2.07m, higher than ‘Flying Dragon’, but lower than the

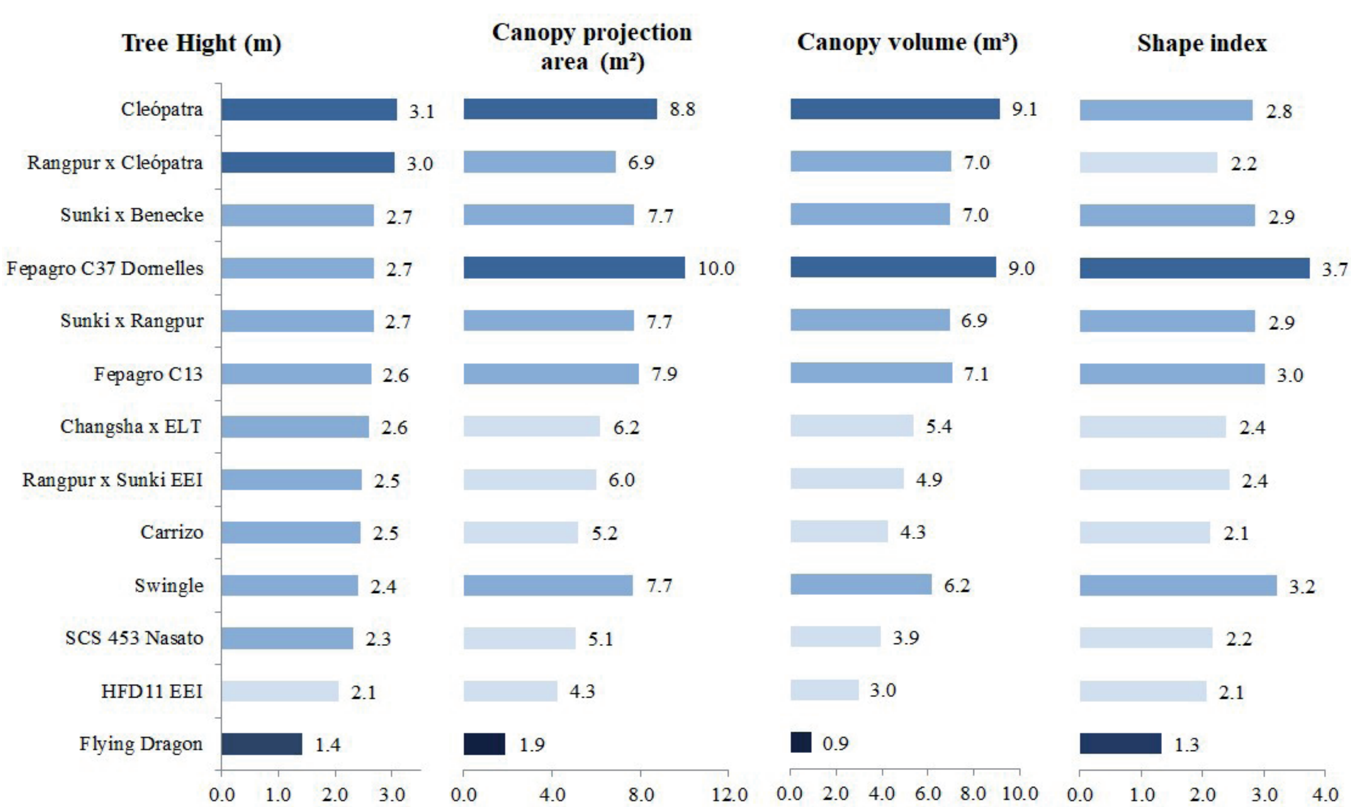

Figure 1. Canopy height, projection area, volume, and shape index of ‘Murcott’ tangor trees on different rootstocks. Same color bars represent means with no significant difference according to the Scott-Knott test (α=0.05).
Figura 1. Altura, área de projeção, volume e índice de conformação da copa de tangoreiros ‘Murcott’ sobre diferentes porta-enxertos. Barras com cores iguais representam médias sem diferença pelo Teste de Scott-Knott (α=0,05).

moderately tall group. The smaller trees of ‘Murcott’ tangor grafted on ‘Flying Dragon’ corroborates observations in Florida, USA, in which seven-year-old trees had a smaller canopy volume than those grafted on ‘Swingle’, ‘Cleopatra’ and ‘Carrizo’ (WHEATON et al., 1991).

Although pruning reduced tree height by removing central and vertical branches, taller trees tended to have more significant CPA and canopy volume, as revealed by PC1 and PC2 components of the principal component analysis (Figure 2). However, significant differences happened in projection area and canopy volume inside the moderately tall group. ‘Fepagro C37 Dornelles’ stood out by its bigger averages. Its significantly higher shape index (3.74) confirms this characteristic. As a rootstock for ‘Valencia’ orange tree in Rio Grande do Sul, it produced trees with similar height to others such as ‘Cleopatra’ and trifoliate orange (PORTO & SOUZA, 1984), which may be due to insufficient experimental precision. Within the tall group, a significant difference was also found in shape index, which was higher in ‘Rangpur’ x ‘Cleopatra’ (2.25) than ‘Cleopatra’ (2.82).

Trees in all treatments yielded fruit in the second year (2017/18 season), and fluctuated from then on, alternating rising fruit loads (4th and 6th year) and minor ones (3rd and 5th years) (Table 1), which characterizes the alternate bearing, intrinsic to tangerine trees in general and to ‘Murcott’ (KOLLER & SOPRANO, 2013). An offseason harvest occurred after the 5th year regular one, probably due to the small production in that season (MARINHO & SOUZA, 1997). The accumulated fruit production per tree had a positive relationship with CPA and with canopy volume in a smaller grade (Figure 2). The highest productions occurred in the tall group and in the moderately tall group (42 to 77kg). However, some rootstocks like ‘Fepagro C37 Dornelles’ formed high-yielding trees (77kg) despite the moderate height of 2.68m, favored by its higher CPA.

In a study conducted in Itirapina, São Paulo state, the ‘Cleópatra’ mandarin root promoted higher annual average fruit production to ‘Murcott’ in comparison to several other tangerine rootstocks, the ‘Rangpur’ lime, and the trifoliate orange (FIGUEIREDO et al., 2006), corroborating our results (Table 1). Moreover, Souza et al. (1992) observed the excellent performance of ‘Cleopatra’ in Rio Grande do Sul. In fact, ‘Cleopatra’ has been indicated

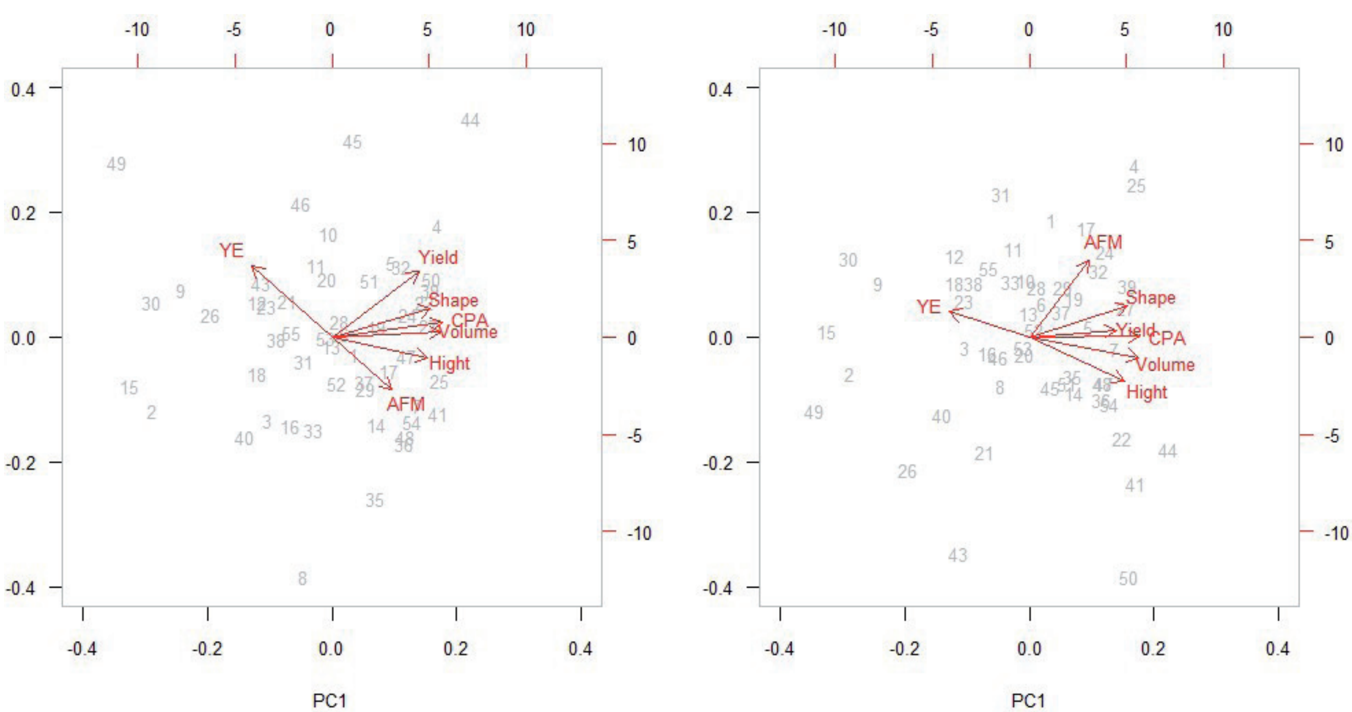

Figure 2. Biplot charts representing the main three Principal Components PC1, PC2, and PC3, explaining 68, 15, and 11% of the variation in the experimental data, respectively. YE = yield efficiency; CPA = canopy projection area; AFM = average fruit mass.
Figura 2. Gráficos biplot representando os três principais componentes PC1, PC2 e PC3 que explicam 68, 15 e 11% da variação nos dados do experimento, respectivamente. YE = eficiência produtiva; CPA = área de projeção da copa; AFM = massa média de frutos.

Table 1. Tree yield and yield efficiency (YE) of 'Murcott' tangor trees budded on different rootstocks

Tabela 1. Produção de frutos e eficiência produtiva (YE) de tangoreiros 'Murcott' enxertados em diferentes porta-enxertos

Rootstock	Yield by season						Total yield(3)	YE(3)
	2	3	4	5a(1)	5b(2)	6		
	- - - - - - - - - - - - - kg tree^{-1} - - - - - - - - - - - - -							kg m^{-3}
'Fepagro C37 Dornelles'	3.44	2.52	22.51	4.26	2.34	42.38	77.45a	9.34b
'Fepagro C 13'	1.56	1.21	15.40	2.11	1.51	42.04	63.82a	10.10b
'Swingle'	2.83	2.86	15.94	2.29	2.48	34.52	60.93a	10.66b
'Sunki' X 'Rangpur'	3.45	1.85	18.35	1.48	2.38	33.00	60.51a	9.31b
'Cleópatra'	2.67	1.81	14.90	2.69	1.87	36.32	60.26a	7.38b
'Rangpur' x 'Sunki'	4.02	2.40	16.01	0.39	2.97	30.96	56.74a	12.53a
'Sunki' x 'Benecke'	2.32	1.54	11.75	2.36	1.64	36.78	56.39a	8.92b
'Changsha' x 'English L.T.'	2.26	2.23	11.98	1.12	0.77	31.48	49.83b	10.87b
'SCS 453 Nasato'	1.99	1.12	10.44	3.02	2.34	26.42	45.33b	13.87a
'Carrizo'	1.47	2.57	8.33	1.63	3.68	27.20	44.88b	12.01a
'Rangpur' x 'Cleópatra'	2.23	1.18	11.63	1.07	0.41	25.91	42.43b	6.08b
'HFD 11 EEI'	1.34	3.08	7.30	1.56	1.07	16.66	31.01b	13.38a
'Flying Dragon'	1.30	0.98	2.93	0.39	1.68	5.87	13.15c	16.24a
Mean	**2.43**	**1.96**	**13.18**	**1.91**	**1.91**	**30.27**	**50.98**	**10.66**

[1] Main harvest; [2] Offseason harvest; [3] Same letters represent means with no significant difference according to the Scott-Knott test (α =0.05).
[1] Safra da época normal; [2] safra da época temporã; [3] Médias seguidas pela mesma letra nãodiferem estatisticamente pelo teste de Scott-Knott (α=0.05).

as a rootstock for 'Murcott' in Santa Catarina due to the insecurity in indicating rootstocks of the species *P. trifoliata* and its hybrids (BRUGNARA et al., 2021). However, its adaptation to clayey soils is limited by sensitivity to gummosis (MEDINA FILHO et al., 2003), which can be overcome by selecting new rootstocks.

The yield efficiency presented a strong inverse relationship with tree height. In total, three rootstocks from the moderately tall group ('Rangpur' x 'Sunki' EEI, 'Carrizo', and 'SCS 453 Nasato'), the dwarfing group, and the moderately dwarfing group outperformed the other rootstocks in terms of yield efficiency (Table 1). Smaller trees can produce more fruit per cubic meter of the canopy, allowing greater planting densities, facilitating the inspection of pests and diseases, reducing costs, and improving safety in the harvest (POMPEU JUNIOR, 2005). However, 'Murcott' can suffer collapse due to high productivity, characterized by wilting, defoliation, and death following an excessive fruit load that depletes root carbohydrates (SMITH, 1976), which suggests more caution with these rootstocks.

'Flying Dragon' (129.4g) and 'SCS 453 Nasato' (139.2g) had lower average fruit mass than the other treatments, which did not differ from each other and presented an average of 168.9g (data not shown). Figure 2 expressed a negative correlation between average fruit mass and yield efficiency, which means that trees yielding greater fruit masses per m³ of the canopy tended to yield smaller fruits. The effect has been demonstrated by experiments with fruit thinning, in which reducing the number of fruits increases their average mass due to less competition for assimilates; however, this process reduces the mass of fruit produced (SAMRA & SHALAN, 2014).

The data in this article could be analyzed in the light of a possible occurrence of incompatibility between scion and rootstock that, in theory, would be expressed later. Once this is overcome, the results point out promising rootstocks, such as 'Fepagro C37 Dornelles', which presented canopy volume, yield, yield efficiency, and average fruit mass similar to 'Cleopatra', but with a lower tree height, which eases orchard management. Regarding the rootstock of 'Valencia' orange tree up to the sixth year of the orchard in the west of Santa Catarina, it presented trees of moderate height and high yield efficiency by canopy volume (BRUGNARA & SABIÃO, 2021), agreeing with the performance observed with 'Murcott'. The rootstocks 'Flying Dragon', 'HFD11 EEI', 'SCS 453 Nasato', 'Carrizo', and 'Rangpur' x 'Sunki' EEI showed different degrees of tree size reduction and, despite the lower yields per tree, showed potential for use in high density orchards because they have greater yield efficiency. They have already been evaluated in the western region of Santa Catarina as 'Valencia' rootstocks (BRUGNARA & SABIÃO, 2021), showing some degree of tree size reduction, but only 'Flying Dragon' and 'Rangpur' x 'Sunki' EEI showed high yield efficiency. It should be noted that the average fruit mass obtained with 'Flying Dragon' and its offspring 'HFD11 EEI' may limit their use. As the average fruit mass was negatively correlated with the yield efficiency, it is possible that these rootstocks demand greater fruit thinning to balance the leaf area with the fruit load.

Conclusions

- The growth, fruit production, and average mass of the 'Murcott' tangor tree cultivated up to the sixth year under the edaphoclimatic conditions of western Santa Catarina are influenced by the rootstock.
- Among the rootstocks that induce greater tree height, 'Cleopatra' mandarin stands out for its higher fruit production per tree, with good fruit mass.
- Among the rootstocks that form moderately tall trees, 'Sunki' x 'Benecke', 'Rangpur' x 'Sunki' EEI, 'Sunki' x 'Rangpur', 'Fepagro C 13', 'Swingle' and 'Fepagro C37 Dornelles' yield greater mass of fruit per tree, whereas 'Carrizo', 'SCS 453 Nasato' and 'Rangpur' x 'Sunki' EEI stand out for their higher production per m³ of canopy; but the fruits have a lower average mass under 'SCS 453 Nasato'.
- 'HFD11 EEI' has a semi-dwarfing effect and 'Flying Dragon' has a dwarfing effect, both inducing a high production per m³ of canopy to 'Murcott', but the second induces a lower average fruit mass.

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