

Performance of 'Oneco' mandarin on six rootstocks in South Brazil

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Abstract – The objective of this work was to assess the effect of six rootstocks on yield, fruit quality, and growth of 'Oneco' mandarin during the first seven harvesting seasons, in Butiá, Rio Grande do Sul State, Brazil. The rootstocks evaluated were: 'Swingle' citrumelo (*Citrus paradisi* × *Poncirus trifoliata*), 'Caipira' orange (*C. sinensis*), 'Troyer' citrange (*C. sinensis* × *P. trifoliata*), 'Rangpur' lime (*C. limonia*), 'Volkamer' lemon (*C. volkameriana*), and 'Flying Dragon' trifoliata orange (*P. trifoliata* var. *monstrosa*). Plants budded onto 'Flying Dragon' had the lowest vegetative development, which indicates the dwarfing characteristics of this rootstock, and had the highest mean production efficiency, despite low yield. Plants grafted on 'Volkamer' lemon and 'Rangpur' lime had the highest alternate bearing. Under the experimental conditions evaluated, the most adequate rootstocks for mandarin 'Oneco' are 'Swingle' citrumelo and 'Troyer' citrange, regarding fruit yield and quality.

Index terms: *Citrus reticulata*, alternate bearing, fruit quality, yield.

Comportamento da tangerineira 'Oneco' sobre seis porta-enxertos no Sul do Brasil

Resumo – O objetivo deste trabalho foi avaliar o efeito de seis porta-enxertos sobre a produção, a qualidade dos frutos e o crescimento da tangerineira 'Oneco', durante as sete primeiras safras, em Butiá, Rio Grande do Sul. Os porta-enxertos avaliados foram: citrumeleiro 'Swingle' (*Citrus paradisi* × *Poncirus trifoliata*), laranja 'Caipira' (*C. sinensis*), citrangeiro 'Troyer' (*C. sinensis* × *P. trifoliata*), limoeiro 'Cravo' (*C. limonia*), limoeiro 'Volkameriano' (*C. volkameriana*) e trifoliata 'Flying Dragon' (*P. trifoliata* var. *monstrosa*). As plantas enxertadas sobre 'Flying Dragon' apresentaram menor desenvolvimento vegetativo, o que indica as características nanizantes deste porta-enxerto, e obtiveram a maior eficiência produtiva média, apesar da baixa produção. As plantas enxertadas sobre os limoeiros 'Volkameriano' e 'Cravo' apresentaram as maiores alternâncias de produção. Nas condições experimentais avaliadas, os melhores porta-enxertos para a tangerineira 'Oneco' são o citrumeleiro 'Swingle' e o citrangeiro 'Troyer', no que se refere à produção e à qualidade dos frutos.

Termos para indexação: *Citrus reticulata*, alternância de produção, qualidade de fruto, produtividade.

Introduction

'Oneco' mandarin (*Citrus reticulata* Blanco) is a selection of 'Ponkan' mandarin, which occupies 58% of the mandarin-producing area in Brazil (Amaro & Caser, 2003). In general, 'Oneco' is very similar to 'Ponkan', which has a columnar tree canopy, with high yields, and a tendency to alternate bearing (Stenzel et al., 2003).

'Oneco' was identified as a potential alternative cultivar to 'Ponkan', due to its high productivity and longer harvesting period evidenced by a higher capacity

of fruit storage (Sartori et al., 1998). Furthermore, 'Ponkan' has a very concentrated harvesting period that contributes to the rise of seasonal prices (Amaro & Caser, 2003). However, there is a lack of information on the effects of different rootstocks on 'Oneco' mandarin fruit quality, tree development and productivity.

Rootstocks affect canopy growth and development, production, and fruit quality in citrus, as well as tolerance to various stresses (Castle, 1987). 'Rangpur' lime (*Citrus limonia* Osbeck) is the main rootstock in Brazil, and is used in 80% of Brazilian citrus orchards because of its drought tolerance (Pompeu Júnior, 2005).

However, in Rio Grande do Sul state, *Poncirus trifoliata* (L.) Raf is the most common rootstock, due to its greater cold-hardiness; and at least 90% of the citrus trees in the state are budded onto this rootstock (Schäfer et al., 2001a).

High disease incidence, to which rootstock resistance is crucial, has prompted the need to investigate rootstock assortment. Diseases, such as citrus tristeza virus, gummosis (*Phytophthora* sp.), and citrus sudden death, reinforce the call for research on diverse citrus species and hybrids as potential rootstock material.

The objective of this work was to assess the effect of six rootstocks on yield, fruit quality, and growth of 'Oneco' mandarin during the first seven harvesting seasons, in Butiá, Rio Grande do Sul state, Brazil.

Materials and Methods

'Oneco' mandarin was budded onto six rootstocks: 'Swingle' citrumelo [*Citrus paradisi* Macfad × *P. trifoliata*], 'Caipira' orange (*C. sinensis* Osbeck), 'Troyer' citrange (*C. sinensis* × *P. trifoliata*), 'Rangpur' lime (*C. limonia* Osb.), 'Volkamer' lemon (*C. volkameriana* Ten. & Pasq.), and trifoliata 'Flying Dragon' orange [*P. trifoliata* var. *monstrosa* (T. Ito Swing.)].

The experiment was carried out in a private grove (30°07'5"S, 51°51'22"W) close to the city of Butiá, about 70 km west of Porto Alegre, Rio Grande do Sul State, Brazil. The soil is classified as Paleudult (United States Department of Agriculture, 1999), and the climate as Cfa, according to Köppen. The average annual temperature is 19.2°C, and the average temperatures of the coldest (June) and warmest (January) months are 13.5 and 24.6°C, respectively. Annual rainfall is approximately 1.440 mm (Bergamaschi et al., 2003).

Trees were planted in August 1997, in a 6.0x2.5 m spacing, with 667 trees per hectare. The experiment was managed according to the usual cultural practices (Koller, 2009), with plants being hand-thinned every year between February and March, and pruned in the winter of 2004 to eliminate dead wood and crooked branches.

Individual measurements of tree height (H), perpendicular (D_p) and parallel (D_l) canopy diameters, and trunk circumference at 5 cm above the bud union were taken from 2003 to 2007, after the summer growth flush. Canopy volume (V) was calculated using the formula:

$$V = (\pi/6) \times H \times D_l \times D_p \text{ (Zekri, 2000).}$$

Production efficiency (kg m⁻³) was determined by the ratio of total fruit mass to canopy volume. The canopy projection area (CPA) was calculated using the formula $CPA = \pi[(D_l + D_p)/4]^2$ (Schäfer et al., 2001b). An alternate bearing index (ABI) was calculated as described by Stenzel et al. (2003):

$$ABI = [(1/(n - 1)) \times \{ [(a_2 - a_1)/(a_2 + a_1)] + [(a_3 - a_2)/(a_3 + a_2)] + \dots + [(a_n - a_{n-1})/(a_n + a_{n-1})] \}],$$

in which n is the number of years, and $a_1, a_2, \dots, a_{n-1}, a_n$ is the yield per tree in the corresponding year. The ABI ranges from 0 to 1, and the closest it is to 0, the less variation there is in yield between years. This trait was evaluated for the following periods: 2001/2003, 2002/2004, 2003/2005, 2004/2006, 2005/2007, 2001/2004, 2004/2007, and 2001/2007.

Fruit harvest occurred from 2001 to 2007. Total annual yield per tree and accumulated yield were calculated for this period. Starting in 2002, 20 fruits harvested from each replicate of each treatment were randomly selected to determine fruit quality. The measurements taken were: juice content (JC, %), calculated by the difference of mass between juice and fruits; total soluble solids (TSS), with a table refractometer; and titratable acidity (TA, % of citric acid), determined by titration of 10 mL juice diluted in 90 mL of distilled water up to pH 8.1. Mass (M), length (L), and diameter (D) of individual fruits were also determined, in which L and D were used to estimate fruit shape through the ratio L:D.

The experiment was set up in a completely randomized block design with four replicates and four trees as an experimental unit, for each rootstock. Data for total yield, vegetative growth, and fruit quality were analyzed using analysis of variance, and means were compared with Duncan's multiple range test, at 5% probability.

Results and Discussion

Annual yield (Table 1) was affected by rootstocks, except in 2002 and 2006, when production was low and variable due to alternate bearing. In general, trees on 'Swingle' consistently had greater yields than those on the other rootstocks. Trees budded onto 'Rangpur' and 'Swingle' were the most precocious, having the highest yields in 2001. The highest cumulative yields

were found for trees grafted on 'Swingle', whereas no significance was found for yields of trees on 'Caipira', 'Troyer', or 'Rangpur'. The lowest cumulative yields were obtained for plants budded onto 'Flying Dragon', while plants on 'Volkamer' had intermediate yields. Stenzel et al. (2003), who compared seven rootstocks for 'Ponkan' mandarin grown in Paraná state, Brazil, also found equivalent yields for plants grafted on 'Rangpur' lime and 'Volkamer' lemon, while plants on *P. trifoliata* had the lowest yields. Mourão Filho et al. (2007) observed that cumulative yield for plants budded on 'Rangpur' lime was higher than for plants on 'Swingle'. Georgiou (2000), while evaluating 'Nova' mandarin, reported that plants grafted on 'Volkamer' lemon were superior to those on 'Swingle' and 'Troyer'.

The highest ABI was found for trees budded on 'Volkamer' lemon and 'Rangpur' lime (Table 2), which

indicates that these rootstocks have the least constant production. These results are contrary to those obtained by other authors (Georgiou, 2000; Smith et al., 2004; Espinoza-Núñez et al., 2007; Mourão Filho et al., 2007). Stenzel et al. (2003) found low ABIs for 'Ponkan' grafted onto citrange C-13 and *P. trifoliata*. Espinoza-Núñez et al. (2008), who evaluated 'Fairchild' mandarin, also obtained highest ABI for plants budded on 'Rangpur' lime, as in the present work. However, Stuchi et al. (2008) and Cantuarias-Avilés et al. (2010) found the lowest ABI, respectively, for 'Swatow' mandarin and 'Okitsu' satsuma grafted on 'Rangpur' lime.

The ABIs were affected by rootstocks especially during the first years of the orchard's production. No effect from the rootstocks was observed in 2004/2007, which indicates that this effect can be associated with initial plant yield instability (Smith et al., 2004).

Table 1. Annual and cumulative yields, and production efficiency of 'Oneco' mandarin grafted onto six different rootstocks grown in Butiá, Rio Grande do Sul state, Brazil⁽¹⁾.

Rootstock	2001	2002	2003	2004	2005	2006	2007	Cumulative
	Yield (kg per tree)							
'Swingle' citrumelo	22.1ab	5.5	50.1a	20.8ab	21.5a	7.8	52.4a	180.1a
'Caipira' orange	19.3b	6.0	50.5a	17.2b	20.5a	9.8	41.1ab	164.4a
'Troyer' citrange	10.3cd	10.0	29.5b	24.4a	15.6a	17.4	49.4a	156.7a
'Rangpur' lime	29.1a	4.9	54.4a	8.3c	18.3a	2.3	33.5b	150.8a
'Volkamer' lemon	16.3bc	1.5	33.9b	6.5c	13.7ab	12.0	32.4b	116.4b
'Flying Dragon' trifoliolate orange	4.7d	2.4	13.3c	6.9c	6.1b	22.1	16.3c	71.8c
P	<0.0001	0.11	<0.0001	<0.0001	0.0097	0.45	0.0002	<0.0001
	Production efficiency (kg m ⁻³)							
'Swingle' citrumelo	-	-	11.0ab	5.4ab	4.8abc	1.3	4.9	27.5b
'Caipira' orange	-	-	10.6ab	5.2ab	2.7c	2.3	3.5	24.0b
'Troyer' citrange	-	-	7.2b	6.6a	3.9bc	2.8	5.1	25.5b
'Rangpur' lime	-	-	15.5a	2.6b	5.6ab	0.9	4.5	29.0b
'Volkamer' lemon	-	-	12.6a	2.4b	6.7a	2.7	3.7	27.5b
'Flying Dragon' trifoliolate orange	-	-	10.6ab	6.2a	5.1ab	11.4	6.1	40.0a
P	-	-	0.0356	0.0248	0.0275	0.22	0.11	0.0274

⁽¹⁾Means followed by equal letters, in the columns, do not differ significantly by Duncan's multiple range test, at 5% probability.

Table 2. Alternate bearing index of 'Oneco' mandarin grafted onto six different rootstocks grown in Butiá, Rio Grande do Sul state, Brazil⁽¹⁾.

Rootstock	2001/2003	2002/2004	2003/2005	2004/2006	2005/2007	2001/2004	2004/2007	2001/2007
'Swingle' citrumelo	0.66ab	0.62ab	0.29b	0.30	0.59	0.59abc	0.43	0.53b
'Caipira' orange	0.62ab	0.58ab	0.28ab	0.29	0.51	0.54bcd	0.40	0.51b
'Troyer' citrange	0.44b	0.35c	0.17b	0.30	0.51	0.34d	0.40	0.38b
'Rangpur' lime	0.78a	0.71a	0.44a	0.44	0.63	0.72ab	0.52	0.71a
'Volkamer' lemon	0.76a	0.73a	0.47a	0.55	0.76	0.69a	0.64	0.73a
'Flying Dragon' trifoliolate orange	0.44b	0.35bc	0.17b	0.30	0.51	0.34cd	0.40	0.37b
P	0.0202	0.0014	0.0054	0.1403	0.1521	0.0013	0.1399	0.0011

⁽¹⁾Means followed by equal letters, in the columns, do not differ significantly by Duncan's multiple range test, at 5% probability.

Production efficiency was influenced by rootstocks, except for the last two years of evaluation. Highest cumulative production efficiency was observed, from 2003 to 2007, for trees grafted onto 'Flying Dragon', despite low yields. Therefore, this rootstock has potential for high-density plantings of citrus cultivars with characteristics similar to 'Oneco', in spite of previous reports with disappointing results regarding this rootstock (Wheaton et al., 1991). Cantuarias-Avilés et al. (2010) also found high production efficiency when working with the cultivar Okitsu satsuma.

Vegetative growth, which was measured in January 2008, was influenced by rootstocks (Table 3). Trunk perimeter and canopy height were highest in trees budded onto 'Caipira' orange, while canopy volume and CPA were highest on 'Caipira' orange and 'Swingle' citrumelo trees. 'Flying Dragon' trifoliolate trees had the lowest vegetative growth, with a 37% decrease in tree height, a 75% decrease in canopy volume, a 62% decrease in the projected canopy area, and a 59% decrease in trunk perimeter in comparison to the most

vigorous rootstocks. Similar vegetative responses of trees grafted on 'Rangpur' lime and 'Volkamer' lemon were found in previous studies (Parente et al., 1993; Georgiou, 2000; Stenzel et al., 2003). However, Parente et al. (1993) did not find differences in tree height or trunk circumferences for 'Ponkan' mandarin trees budded onto 'Caipira' orange, 'Rangpur' lime, 'Volkamer' lemon, 'Swingle' citrumelo or 'Troyer' citrange.

Plants grafted on 'Swingle' had greater vegetative growth than those on 'Rangpur' lime, probably due to the edaphoclimatic conditions in which the present study took place, with colder winters, since 'Rangpur' lime is sensitive to cold and 'Swingle' citrumelo shows some cold resistance (Castle, 1987). Parente et al. (1993), Georgiou (2000), Espinoza-Núñez et al. (2007), and Mourão Filho et al. (2007) did not find any differences among these rootstocks.

'Oneco' trees budded onto citrange 'Troyer' had a lower CPA than trees on 'Swingle'. Schäfer et al. (2001b), working with eight-year-old 'Montenegrina' trees, under the same environmental conditions, did not find differences in CPA between these rootstocks.

The reduction in vegetative growth observed in trees grafted on 'Flying Dragon' indicates the dwarfing characteristics of this rootstock, which is reported to maintain plant height under 2.5 m (Cheng & Roose, 1995). These plants showed similar vegetative characteristics to eight-year-old 'Monte Parnaso' orange (Reis et al., 2008) and ten-year-old 'Michal' mandarin (Brugnara et al., 2009) trees in the same orchard. Canopy height and volume reduction of plants budded onto 'Flying Dragon', in comparison to 'Troyer', are similar to the reduction observed by Roose (1986) for 'Valencia' orange.

Fruit quality was significantly influenced by rootstock, except for JC (Table 4). Fruit picked from

Table 3. Tree height, volume, canopy projection area (CPA) and trunk perimeter of 'Oneco' mandarin grafted onto six different rootstocks grown in Butiá, Rio Grande do Sul state, Brazil⁽¹⁾.

Rootstocks	Tree height (m)	Canopy volume (m ³)	CPA (m ²)	Trunk perimeter (cm)
'Swingle' citrumelo	3.62b	11.61a	4.78a	34.5b
'Caipira' orange	3.81a	11.70a	4.62ab	41.5a
'Troyer' citrange	3.59b	9.68ab	3.97bc	34.8b
'Rangpur' lime	3.28c	8.12bc	3.58cd	33.4bc
'Volkamer' lemon	3.29c	6.88c	3.05d	31.4c
'Flying Dragon' trifoliolate orange	2.39d	2.88d	1.81e	17.1d
P	<0.0001	<0.0001	<0.0001	<0.0001

⁽¹⁾Means followed by equal letters, in the columns, do not differ significantly by Duncan's multiple range test, at 5% probability.

Table 4. Total soluble solids (TSS), titratable acidity (TA), TSS:TA ratio, juice content (JC), diameter (D), length (L), L:D ratio, and average fruit mass (M) of 'Oneco' mandarin grafted onto six different rootstocks grown in Butiá, Rio Grande do Sul State, Brazil (averages from 2002/2007)⁽¹⁾.

Rootstock	TSS (%)	TA (%)	TSS:TA	JC (%)	D (mm)	L (mm)	L:D	M (g)
'Swingle' citrumelo	8.8a	0.64b	15.1cd	41.2	75.0c	57.7c	0.771b	164.9c
'Caipira' orange	8.5b	0.55cd	17.0ab	40.6	76.6bc	58.8bc	0.769b	173.0bc
'Troyer' citrange	8.9a	0.56c	17.1ab	41.3	75.3c	58.0c	0.771b	167.5c
'Rangpur' lime	7.7c	0.53cd	15.5bc	41.2	77.3ab	60.0ab	0.777b	181.9ab
'Volkamer' lemon	7.9c	0.49d	17.4a	39.5	78.5a	61.1a	0.779b	187.1a
'Flying Dragon' trifoliolate orange	8.8a	0.72a	13.8d	41.5	70.6d	55.9d	0.794a	145.4d
P	<0.0001	<0.0001	0.0009	0.22	<0.0001	0.0002	0.0099	<0.0001

⁽¹⁾Means followed by equal letters, in the columns, do not differ significantly by Duncan's multiple range test, at 5% probability.

'Flying Dragon', 'Swingle', and 'Troyer' rootstocks had the highest TSS contents. 'Flying Dragon' also had the highest TA content, whereas fruit from 'Volkamer' lemon had the lowest, which resulted in the highest and lowest TSS:TA ratios, respectively. Georgiou (2000), Espinoza-Núñez et al. (2007), Mourão Filho et al. (2007), and Brugnara et al. (2009) also found lower content of soluble solids in citrus grafted on 'Rangpur' lime in comparison to citrus budded onto 'Swingle', as well as higher TSS contents in 'Ponkan' grafted on *P. trifoliata* in comparison to trees on 'Rangpur' lime and 'Volkamer' lemon (Stenzel et al., 2003). However, Yonemoto et al. (2004) observed that 'Shirakawa' satsuma grafted on 'Flying Dragon' had higher soluble solids in comparison to those on *P. trifoliata*, independently of the fruit load on trees. Rootstocks had no effect on JC, as reported by other authors (Koller et al., 2000; Pérez-Zamora et al., 2002; Castle et al., 2007; Espinoza-Núñez et al., 2007; Mourão Filho et al., 2007; Brugnara et al., 2009).

Mandarins harvested from plants on 'Flying Dragon' had the smallest fruit among the tested rootstocks, while 'Volkamer' lemon produced the largest and heaviest ones (Table 4). Fruits from trees grown on 'Flying Dragon' were more spherical than those on the other tested rootstocks, which were more oblong.

The highest average fruit weight for plants budded on 'Volkamer' lemon is similar to that found for 'Nova' tangerine (Georgiou, 2000), although, in the present work, there were no differences in fruit diameter for 'Rangpur', 'Troyer', 'Swingle', and 'Volkamer' rootstocks. The effect of rootstocks on the L:D ratio was also observed by Koller et al. (2000) for 'Hamlin' orange, under the same climatic conditions.

Conclusions

1. The most adequate rootstocks for mandarin 'Oneco' in the tested region are 'Swingle' citrumelo and 'Troyer' citrange, regarding fruit yield and quality.

2. Plants grafted onto 'Flying Dragon' rootstock have higher production efficiency, in spite of lower canopy volume.

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