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VEGETATIVE GROWTH AND FRUIT PRODUCTION POTENTIAL OF 'PEAR' AND 'AQUIRI' ORANGE GRAFTED ONTO DIFFERENT CITRUS ROOTSTOCKS GROWN

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ABSTRACT

The rootstock for grafting sweet orange is 'Cravo" lime acid, a variety that is susceptibility to various fungal diseases. In order to improve citrus orchardsit is essential to employ rootstocks with more advantageous traits. The aim of this study was to evaluate the vegetative and reproductive characteristics in young plants of 'Pear' or 'Aquiri' sweet orange grafted onto different rootstocks. The field experiment followed a randomized block design with a simple 2 x 8 factorial scheme comprising 16 combinations of eight rootstocks and two scions, with four repetitions of two plants per plot. The rootstocks employed were 'Cravo Santa Cruz' lime, 'Sunki TSK×CTTR-002' tangerine, 'Sunki Tropical' tangerine, 'Volkamer' lemon, 'Sunki TSK×CTTR-017' tangerine, 'Cleopatra' tangerine, 'Carrizo' citrange and 'Cravo' lime. In 2-year-old plants, 'Cravo Santa Cruz'lime, 'Volkamer' lemon and 'Cravo' lime induced the best vegetative growth (plant height, crown projection area and graft compatibility index) and the best reproductive performance (number of fruits per plant), whereas Sunki TSK×CTTR-002 tangerine induced the poorest growth and the lowestfruit productivity. Considering that vigor and early fruiting are associated with improved production, 'Cravo Santa Cruz' lime and 'Volkamer' lemon represent possible alternatives to 'Cravo' lime for use in orange orchards in Acre.

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INTRODUCTION

Oranges represent the main citrus fruit crop in Brazil with production in excess of 16.2 million tons in 2021 (IBGE, 2021a). However, only 6,545 tons of oranges were harvested in the state of Acre in 2021, representing around 0.04% of national production and rendering the state one of the lowest producers of oranges in the country (IBGE, 2021b). Since this quantity of fruit is insufficient to supply local demand, Acre needs to import citrus fruits from other Brazilian states. One of the fundamental factors in the development of citriculture in Acreis the establishment of orchards formed with well-adapted, vigorous, healthy and productive varieties. This goal can only be achieved through the diversification of suitable rootstocks for grafting orange scionsconsidering that, at the present time, grafts employ exclusively 'Cravo'(or 'Rangpur') lime (*Citrus* × *limonia* Osbeck). This citrus varietyis susceptible to various diseases including gummosis caused by the species of the fungus Phytophthora, citrus decline (dieback) disease, exocortis, xyloporosis, leprosis and citrus sudden death (BRUCNER, 2002; FUNDECITRUS, 2004; ICT, 2007). Nonetheless, 'Cravo' lime is recommended as a rootstock because it not only induces higher fruit yields and vegetative vigor but also imparts resistance to drought and citrus tristeza virus (CTV) unlike other rootstocks such as 'Sunki' and 'Cleopatra' tangerine and 'Carrizo' citrange, among others. Alternative rootstocks would be trifoliate orange [*Poncirus trifoliata* (L.) Raf.] and its various hybrids, which show resistance to gummosis and offer desirable traits such as early fruit production, high productivity and top-quality fruits (LEDO *et al*., 1996; CAVALCANTE *et al*., 1999; LARANJEIRA *et al*., 2002; MULLER *et al*., 2002).

Embrapa Acre has selected a number of citrus scions and rootstocks as superior citrus genotypes based on their advantageous traits, including resistance to CTV and gummosis and tolerance to drought, whichcould be employed to improve citrus production and reduce the significant losses in yield experienced in Acre. Considering that vigor and early fruiting are associated with improved production in mature plants, the aim of the present study was to evaluate the vegetative and reproductive characteristics of young plants of 'Pear' or 'Aquiri' sweet orange grafted onto eight selected citrus rootstocks (lime, lemon, tangerine and citrange).

MATERIALS AND METHODS

The study was performed in the experimental nursery of Embrapa Acre (9º58'30"S, 67º48'36"W; altitude 153 m) located in the state capital Rio Branco. The climate in the region is tropical hot and humid (type Aw according to the Köppen classification)with a mean annual temperature of 25°C (minimum 20.84°C; maximum 30.92°C),a mean relative humidity of 85% and an annual rainfall of 1,800 mm (AGRITEMPO, 2008). The soil in the experimental area is classified as medium texture dystrophic red-yellow latosol and is well drained. The main physicochemical characteristics of the soil in the 0 to 20 cm layer were determined to be: pH5.6, 6 mg dm^{-3}P, 0.3 $cmol_c$ dm^{-3}K, 5.8 $cmol_c$ dm^{-3} Ca, 0,7 $cmol_c$ dm^{-3} Mg, 0.7 $cmol_c$ dm^{-3} Al^{+3}, 3.39 $cmol_c$ dm^{-3} H + Al, 6.8 $cmol_c$ dm^{-3}sum-of-bases,10.19 $cmol_c$ dm^{-3} cation exchange capacity,0.92 dag kg^{-1} organic matter and 66.73%base saturation. The field experiment was implemented on 23 March 2010 and followed a randomized block design with a simple 2 x 8 factorial scheme comprising 16 combinations of eight rootstocks and two scions, with four repetitions and two plants per plot. The rootstocks employed, namely 'Cravo Santa Cruz' lime, 'Sunki TSK×CTTR-002' tangerine, 'Sunki Tropical' tangerine, 'Volkamer' lemon, 'Sunki TSK×CTTR-017' tangerine, 'Cleopatra' tangerine, 'Carrizo' citrange and 'Cravo' lime, were supplied by Embrapa Mandioca e Fruticultura, (Cruz das Almas, BA, Brazil). The scions 'Pear' and 'Aquiri' orange were provided by Embrapa Acre (Rio Branco, Acre, Brazil).Grafted plants were grown with a spacing of 7.0 m between plants and 7.0m between rows. Plants of 'Aquiri' orange grafted onto 'Cravo lime' were used at the border of the plots. Evaluations of the vegetative and reproductive attributes of grafted oranges were carried out with 1-year-old (April 2011), 1.5-year-old(October 2011) and 2-year-old (April 2012) plants. The variables assessed were plant height (PH; m), trunk diameter 10 cm below the grafting line (TD1; mm) and 10 cm above the grafting line (TD2; mm), crown projection area (CPA; m^2, as defined by crown diametersmeasured in the line of the row and at 90º to therow), graft compatibility index (GCI; defined as TD2/TD1) and number of fruits per plant (subjected to log x transformation). Data were submitted to analysis of variance (ANOVA) and the mean values were compared using the Scott-Knott test at 5% probability.

RESULTS AND DISCUSSION

There were significant differences regarding the vegetative attributes of orange plants with different scion-rootstock combination sat all ages tested (Tables 1 - 3), indicating that the variety of rootstock influenced the agronomic characteristics of the scions. In 2-year-old plants, the rootstocks 'Cravo Santa Cruz' lime, 'Volkamer lemon' and 'Cravo' lime induced superior PH and CPA values in both grafted 'Pear' and 'Aquiri' orange (Table 3). In particular, 'Aquiri' orange grafted onto 'Volkamer' lemon produced the highest values of PH (2.65 m) and CPA (3.07 m^2), and this rootstockdisplayed good compatibility with a mean GCI of 0.86 for the two scions tested. Moreover, 'Volkamer' lemon also conferred excellent reproductive ability to 2-year-old grafted oranges as demonstrated by the number of fruits per plant (mean of 34.5 with the two scions), which was higher than that obtained with the other rootstocks. In contrast, the trifoliate hybrid Sunki TSK×CTTR-002 tangerine induced the poorest PH and CPA values in both grafted 'Pear' and 'Aquiri' orange plants at 2 years of age, while the lowest values of PH (1.23 m), CPA (0.17 m^2) and GCI (0.80) we rerecorded with 'Aquiri' orange grafted onto the trifoliate hybrid rootstock. It is possible that the cut surfaces of the scion and rootstock in this combination were in contact but not anatomically joined so that the xylem fibers failed to interlock. Alternatively, there may bea low affinity between the scion and the hybrid rootstock**.** In addition, Sunki TSK×CTTR-002 tangerine also conferred poor reproductive ability to 2-year-old grafted oranges as demonstrated by the extremely low number (0.25) of fruits per plant. 'Pear' and 'Aquiri' orange with rootstocks 'Cravo' lime, "Cleopatra' or 'Sunki Tropical' tangerines showed the highest compatibilities, whereas the least compatible combinations were those involving 'Carrizo' citrange, 'Sunki Tropical' tangerine and 'Sunki' TSK×CTTR-002 tangerine.

According to Ledo *et al*. (2008) 'Cravo" lime and 'Caipira' orange are suitable rootstocks for the commercial orange varieties used as scions in the present study, while other authors (DONADIO *et al*., 1992; ROBERTO *et al*., 1999; DAVOGLIO JUNIOR *et al*., 2006; SCHAFER *et al*., 2006; TAZIMA et. al., 2008) have confirmed that 'Cravo' lime induced advantageous qualities in 'Pear' orange. In the present study, 'Cravo' lime induced superior vegetative growth in both 'Pear' and 'Aquiri' orange, while the number of fruits produced per plant after 2 years of growth was acceptable and directly related to fruit productivity, as noted by Guardiola (2000). In contrast to our findings, Auler *et al*. (2008) reported that 'Sunki' and 'Cleopatra' tangerine, as well as 'Troyer' citrange, offered a number of specific advantages when employed as alternative rootstocks to 'Cravo' limefor 'Valencia' orange grafts cultivated in the northwest of Paraná state. Moreover, other studies (CARVALHO*et al*., 1991; STUCHI *et al*., 2000; GONDIM *et al*, 2001, STUCHI *et al*., 2004; BOLOGNA and VITTI, 2006) have shown that'Cleopatra' tangerine and 'Volkamer' lemon rootstocks exert positive effects on the productivity of commercial orange varieties. The reduced growth and vigor of oranges grafted onto 'Cleopatra' tangerine recorded herein was probably caused by the edaphoclimatic and cultural conditions of Acre. Some scion-rootstock combinations do not consolidate over the years, thereby impairing the development and productivity of grafted plants from the early to mature stages. The attributes of grafted citrus plantsmust be consistent during repeated studies (NEL & BENNIE, 1983). The superior performance of 'Volkamer' lemon in comparison with other rootstock varieties and hybrids has been described previously and such supremacy could be observed at a very early stage when the rootstock seedlings were produced (DECARLOS NETO *et al*., 2002). While these researchers reported that oranges grafted onto 'Volkamer' lemon presented enhanced vegetative growth (PH and TD) along with other positive reproductive characteristics, our results showed that the rootstock induced the greatest level of precocious fruit production in 2-year-old grafted oranges, as demonstrated by the highest number of fruits per plant (Table 3).

Table 1. Mean values[1] and coefficients of variation (CV) of plant height (PH) and graft compatibility index (GCI)for 1-year-old 'Pear' and 'Aquiri' orange plantson different rootstocks cultivated in Rio Branco, AC, Brazil, April 2011

Rootstock	PH (m)			GCI	
	'Pear'	'Aquiri'	Mean	'Pear'	'Aquiri'
'Cravo Santa Cruz' lime	1.51	1.48	1.50 a	0.81 a	0.86 a
'Sunki TSK×CTTR-002' tangerine	1.22	1.32	1.26 b	0.72 b	0.82 a
'Sunki Tropical' tangerine	0.94	1.34	1.14 b	0.79 b	0.87 a
'Volkamer' lemon	1.42	1.67	1.55 a	0.81 a	0.81 a
'Sunki TSK×CTTR-017' tangerine	1.03	1.23	1.13 b	0.88 a	0.81 a
'Cleopatra' tangerine	1.02	1.32	1.17 b	0.89 a	0.84 a
'Carrizo' citrange	1.11	1.35	1.22 b	0.71 b	0.68 b
'Cravo' lime	1.44	1.60	1.52 a	0.88 a	0.87 a
Overall mean	1.21 B	1.42 A			
CV (%)	8.50			7.89	

[1] For each variable, mean values in the column (row) followed by dissimilar lowercase (uppercase) letters are significantly different at 5% probability (Scott-Knott test).

Table 2. Mean values[1], coefficients of variation (CV) and minimum significant differences (MSD) of plant height (PH), crown projection area (CPA) and graft compatibility index (GCI) of 1.5-year-old 'Pear' and 'Aquiri' orange plants on different rootstocks cultivated in Rio Branco, AC, Brazil, October 2012

Rootstock	PH[2] (m)	CPA[2] (m^2)	GCI[2]
'Cravo Santa Cruz' lime	2.12 a	1.86 a	0.77 a
'Sunki TSK×CTTR-002' tangerine	1.07 c	0.31 c	0.65 b
'Sunki Tropical' tangerine	1.94 b	1.22 b	0.87 a
'Volkamer' lemon	2.33 a	2.16 a	0.81 a
'Sunki TSK×CTTR-017' tangerine	1.71 b	1.10 b	0.85 a
'Cleopatra' tangerine	1.75 b	1.01 b	0.87 a
'Carrizo' citrange	2.14 a	0.82 b	0.80 a
'Cravo' lime	2.16 a	2.02 a	0.88 a
Overall mean	1.92	1.31	0.81
CV (%)	12.77	27.42	15.79
MSD	0.12	0.18	0.06

[1] For each variable, mean values in the column followed by dissimilar lowercase letters are significantly different at 5% probability (Scott-Knott test). [2] Datarelating to "Pear" and 'Aquiri' orange(scions) were combined.

Table 3. Mean values[1], coefficients of variation (CV) and minimum significant differences (MSD) of plant height (PH), crown projection area (CPA), graft compatibility index (GCI) and number of fruits per plant for 2-year-old 'Pear' and 'Aquiri' orange plants on different rootstocks cultivated in Rio Branco, AC, Brazil, April 2012

Rootstock	PH (m)		CPA (m^2)		GCI[2]	Fruits per plant[2]
	'Pear'	'Aquiri'	'Pear'	'Aquiri'		
'Cravo Santa Cruz' lime	2.42 a	2.49 a	2.19 a	2.54 b	0.87 b	21.00 b
'Sunki TSK×CTTR-002' tangerine	1.53 c	1.23 c	0.53 d	0.17 d	0.80 b	0.25 c
'Sunki Tropical' tangerine	1.93 b	2.30 a	1.02 b	1.94 b	0.91 a	6.63 c
'Volkamer' lemon	2.24 a	2.65 a	2.02 a	3.07 a	0.86 b	34.5 a
'Sunki TSK×CTTR-017' tangerine	1.81 b	1.97 b	1.22 b	1.12 c	0.86 b	1.75 c
'Cleopatra' tangerine	1.74 c	2.13 b	0.93 b	1.35 c	0.92 b	3.75 c
'Carrizo' citrange	2.03 b	2.39 a	0.92 b	1.04 b	0.81 b	5.38 c
'Cravo' lime	2.33 a	2.55 a	2.27 a	2.28 b	0.93 a	19.13 b
Overall mean	**2.00 B**	**2.22 A**	**1.39 B**	**1.69 A**	**0.87**	**11.55**
CV (%)	**8.18**		**29.47**		**8.52**	**65.59**
MSD	**0.09**		**0.23**		**0.04**	**4.91**

[1] For each variable, mean values in the column (row) followed by dissimilar lowercase (uppercase) letters are significantly different at 5% probability (Scott-Knott test). [2] Data relating to "Pear" and 'Aquiri' orange (scions) were combined.

It is important to note that citrus plants attain full and stable production at around7 years of age (TEÓFILO SOBRINHO, 1991) and that the yield of citrus fruit occurs in a pattern of alternating increases and decreases. Souto *et al*. (2001) monitored the performance of 16 clones of sweet orange grafted onto 'Cravo' lime rootstock and cultivated in the north of Minas Gerais, and observed pronounced alternations in the yields of fruit over the period 1994 to 1998.The possible explanations for this behavior are the cyclical character of the culture (STENZEL *et al*., 2005) as well as abiotic stresses or environmental factors such as drought and unfavorable weather conditions, which affect flowering, productivity and the number of fruits (RAMALHO *et al*., 2004). According to previous research by Ledo *et al*. (1999) and Blumer *et al*. (2003), plant vigor and early fruiting are associated with improved production in mature plants. Thus, despite the young age of the plants in the present study, the results obtained relating to vegetative growth (PH, TD, CPA), graft compatibility (GCI) and citrus productivity (fruits per plant) made it possible to predict grafting combinations exhibiting better production potential. However, whilst citrus productivity is influenced by the number of fruit per plant (DUENHAS *et al*., 2002), visible characteristics involve both the number and quality of fruit, and these attributes are particularly important in the acceptance of citrus plants by producers bearing in mind consumer demand for high-quality product.

CONCLUSION

The rootstocks 'Cravo Santa Cruz'lime, 'Volkamer' lemon and 'Cravo' lime conferred superior vegetative growth and the best reproductive performance in2-year-old grafts with scions 'Pear' or 'Aquiri' orange, whereas Sunki TSK×CTTR-002tangerine induced the poorest growth and the lowest number of fruits per plant.

Considering that vigor and early fruiting are associated with improved production in mature plants, 'Cravo Santa Cruz' lime and 'Volkamer' lemon represent possible alternative rootstocks for use in orange orchards in Acre.

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