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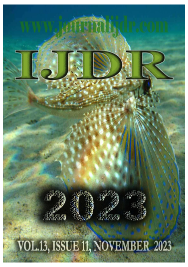

RESEARCH ARTICLE

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SWEET ORANGE CLONES SUITABLE FOR THE CLIMATIC CONDITIONS OF THE STATE OF ACRE, BRAZIL

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ABSTRACT

Considering that the genetic improvement of orange trees usingdifferent scion-rootstock combinations requires extensive research, we aimed to evaluate the agronomic performance and fruit quality of32 native clones of sweet orange grafted onto 'Cravo'lime and grown on for eight years. The cultivar 'Aquiri' orange was employed as control since it is currently recommended by Embrapa for cultivation in Acre. Grafted treeswere evaluated with respect toproductivity and number of fruits per plant, while fruit quality was assessed in terms of mass, dimensions, juice content, total soluble solids (TSS) and titratable total acidity (TTA). Of the 32 clones investigated, eight exhibited very high productivities and two were considered elite clones since they exhibited productivity values (49.29 and 59.91 t ha^{-1}) and numbers of fruits per plant (2048 and 1970.67) that exceeded those of the control 'Aquiri'(37.78 t ha^{-1} and 1263 fruits per plant). Mass, dimensions and juice content of the fruits were similar for all of the clones and the control, but nine clones showed superior values for TSS and TTA. Our findings warrant further research on combinations of these clones with alternative rootstocks to establish the most productive pairs that generate the highest quality fruits.

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INTRODUCTION

Citriculture is the principal activity in the fruit tree sector in Brazil, with 250 million trees distributed over an area of more than 800000haand yielding20 million tons of fruit per year. However, citrus fruit production in the State of Acre is extremely limited, occupying an area of only 600 ha and yielding approximately 5000 tons of fruit per year (0.025% of national production),an amount that is insufficient to meet localdemand thereby necessitating significant importation from other States(IBGE, 2010).The main reason for the inadequacy of citrus fruit production in Acre is the underperformance of orchardsarising from the lack of well-adaptedcultivars, the high incidence of diseases, the unevenness of plantations and the low numbers of fruits produced per plant (BRUCKNER, 2002). The improvement of citrus cultureat the regional level entails bothidentification/selection oforange varieties that generate good quality fruits and diversification of rootstocks. Unfortunately, thecultivarsthat are currently available to farmers are poorly adapted to the climaticconditions prevailing inthe different regions of Brazil. For example,the life time of orchards located in the State of São Paulo (southeastern Brazil), where 75% of national citrus production is concentrated, is approximately 15 to 18 years while in the northern and northeastern regions of the country the life time is12 to 15 years. In other citrus-producing countries, such asJapan and the United States of America, citrus orchards continue to produce for more than 60 years (FUNDECITRUS, 2004). 'Pera' sweet orange [*Citrus sinensis* (L.) Osbeck] is the variety most commonlyplanted in the country as a whole, althoughthecultivar 'Aquiri' is attaining prominencein Acre. 'Pera' and 'Aquiri'present similar characteristics in terms of productivity and fruit quality. However, in order to improve citrusorchards, it would be interesting to select indigenous orange varietiesthat have superior traits in comparison with the recommended cultivars (LARANJEIRA *et al*., 2002; MÜLLER *et al*., 2002; ICET, 2004; FUNDECITRUS, 2004).The existence oforange tree plantationsoriginatingfrom seedsopens the possibility of discovering such local varieties through cloning (LEDO *et al*., 1996; CAVALCANTE *et al*., 1999; ICET, 2004). Currently, orange growers in Acre employ 'Cravo" lime (*Citrus limonia*Osb.) almost exclusively as rootstock, and this is a matter of some concern because of its susceptibility to various fungal diseases, including gummosis and citrus dieback, as well to infections caused by exocortis and xyloporosisviroids. Despite these constraints, 'Cravo' lime remains the recommended rootstock because it induces higher fruit yields and canopy vigor, along with greater resistance to drought and citrus tristeza virusin comparison with other rootstocks such as 'Carrizo' citrange, 'Sunki' and 'Cleopatra' tangerines. An alternative rootstock could be *Poncirustrifoliata* (L.) Raf., which is not only resistant to gummosis and citrus decay but also induces desirable agronomic characteristics in the grafted trees such as premature development, high productivity and good fruit quality. Thegeneralpredominance of the 'Pera' orangeand 'Cravo' limescion-rootstock combination in Brazilian orchards contributes to the overall vulnerability ofthe citriculture sector.Thus, evaluation and selectionof resistant rootstocksand productive oranges genotypes that generate good quality fruits are fundamental for improving citrus culturenot only in Acre but in other regions of Brazil as well.However, as is the case forother tropical and perennial fruit trees, there has been insufficient researcheffort to improve citrus crops, probably because of the many difficulties involved with this type of culturesuch asthe protracted period required for trees to produce fruit, the large areas already under cultivation and the lack of financial resources. Considering that genetic improvement of orange trees using different scion-rootstock combinations requires extensive research, we aimed to evaluate the agronomic performance and fruit quality of32native clonesof sweet orange grafted onto 'Cravo'lime. Our study will contribute to the discovery of citrus combinations that are more adapted to the climatic conditions of northern Brazil.

Table 1. Origin of sweet orange clones derived from plants collected in different locations in the State of Acre, Brazil (data from Gondim et al., 2001)

Clone no.	Location of mother plant	Age of mother plant (years)	Fruit producing season
1	Plácido de Castro	18	May – July
3	Plácido de Castro	17	May –June
4	Plácido de Castro	20	May – July
5	Plácido de Castro	18	April–June
6	Plácido de Castro	12	May –June
8	Plácido de Castro	18	March - June
9	Senador Guiomard	22	Continuous
11	Senador Guiomard	27	May
13	Senador Guiomard	18	June
14	Senador Guiomard	17	June - July
15	Senador Guiomard	29	May
16	Senador Guiomard	21	June - July
18	Capixaba	12	May - June
19	Capixaba	12	May - June
22	Capixaba	25	June - July
24	Xapuri	20	May - June
28	Xapuri	28	June - August
29	Xapuri	18	June - July
31	Xapuri	20	June
36	Sena Madureira	15	February - March
37	Sena Madureira	15	March - April
39	Brasiléia	12	April - July
40	Brasiléia	12	April - June
43	Epitaciolândia	23	April - June
46	Epitaciolândia	22	May - June
47	Epitaciolândia	22	May - June
48	Porto Acre	100	May - June
49	Porto Acre	100	April - May
50	Porto Acre	18	June - August
51	Porto Acre	25	June - July
52	Porto Acre	18	Continuous
53	Rio Branco	18	September - October
'Aquiri'cultivar control	Rio Branco	10	April - June

MATERIALS AND METHODS

The experiment was carried out at Embrapa Acre, Rio Branco, Acre, Brazil (10º1'S 67º42'W; altitude 160 m) during 2012. According to the Köppen classification, the climate of the area is of type AWI (hot and humid) with maximum and minimum temperatures of 30.92 and 20.84ºC, respectively, mean annual precipitation of 1648.94 mm and relative humidity of 83% (AGRITEMPO, 2008). The dystrophic red-yellow argisol in the experimental area was well drained and of medium texture, and presented the following physicochemical attributes in the 0 to 20 cm layer: pH 5.6, 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, sum of bases 6.8 $cmol_c dm^{-3}$, cation exchange capacity 10.19 $cmol_c dm^{-3}$, 0.92 dag kg^{-1}organic C and 66.73% base saturation. Clones derived from 32of the 54 superior sweet orange treesthat had been collected from nine different locations in Acre and characterized in 1999 by Gondim *et al*. (2001), were installed in the experimental field of Embrapa Acre in February 2004 (Table 1). These clones, each identified by the original plant number (GONDIM *et al*., 2001), together with the Embrapa-recommended cultivar 'Aquiri' as control, were grafted onto'Cravo'lime rootstocks. The experimental design consisted of randomized blocks involving 33treatments with three repetitions each and one plant per plot. The grafted plants were cultivated in an orchard with a layout comprising 8.0 x 8.0 m spacing between trees, and 'Pera'orange/'Cravo' lime plants weregrownalong the borders of the orchard. The production of orange fruit was evaluated when the grafted trees were eight years old by assessing variables relating to agronomical characteristics, i.e.productivity (t ha^{-1}), mean number of fruitsper plantand mean mass of fruits (g), together withthe physicochemical characteristics of the fruit, namely dimensions (length/diameterratio), juice content (%),total soluble solids (TSS; °Brix) and titratable total acidity (TTA; g L^{-1}).Evaluations of all variables, with the exception of productivity and mean number of fruits per plant, were performed in the Laboratory of Food Technology at Embrapa Acre with 10 fruits collected randomly from each plant.

Values of TSS weredeterminedusing a manual refractometer and corrected according to room temperature. Data were submitted to analysis of variance (ANOVA) and mean values compared using the Scott Knott test at 5% probability. In order to achieve homoscedasticity for ANOVA, productivity data were transformed according to the expression $(x + 1)^{0.5}$ while thenumbers of fruits per plantwere submitted to log x transformation.

RESULTS AND DISCUSSION

Orange clones 5, 14, 15, 19, 31, 39, 47 and 50 were the most productive with yieldsthat were significantly higher than those of the

Table 2. Agronomic and physicochemical characteristics of sweet orange clones derivedfrom plants collected in different locations in the State of Acre, Brazil

Clone no.	Agronomic characteristics			Physicochemical characteristics				
	Productivity (t ha^{-1})	Fruit mass (g)	No. fruits $plant^{-1}$	Length/diameter ratio	Juice content (%)	TSS (°Brix)	TTA (g L^{-1})	TSS/TTA ratio
1	34.36b	213.0	1034.00c	0.93	42	7.67b	0.55d	14.34
3	31.94b	196.0	1048.67c	1.03	46	8.00b	0.63d	12.62
4	35.75b	187.0	1225.33c	0.95	45	9.00a	0.65d	13.79
5	49.29a	154.0	2048.00a	0.95	47	7.76b	0.67d	11.55
6	38.18b	217.0	1133.00c	0.97	42	7.93b	0.60d	13.34
8	42.10b	200.0	1349.67c	0.97	45	8.70b	065d	13.37
9	38.05b	204.0	1182.00c	0.97	48	8.17b	0.76c	10.92
11	36.58b	200.0	1181.67c	0.93	47	9.13a	0.78c	12.01
13	36.57b	193.0	1225.00c	0.95	51	7.47b	0.65d	10.10
14	59.91a	196.0	1970.67a	0.99	48	8.30b	0.65d	12.76
15	45.06a	219.0	1320.00c	1.01	37	7.33b	0.72c	10.41
16	40.97b	209.0	1269.00c	1.00	43	8.00b	0.61d	12.99
18	33.97b	199.0	1078.67c	0.95	45	7.83b	0.74c	10.63
19	46.21a	199.0	1487.00b	0.97	47	7.67b	0.72c	11.09
22	30.23b	208.0	941.67c	0.97	50	8.17b	1.06a	7.72
24	36.88b	182.0	1318.67c	0.98	47	8.25a	0.76c	10.97
28	29.44b	210.0	899.67c	0.96	49	8.33a	0.80c	10.55
29	34.37b	197.0	1108.67c	0.99	43	7.47b	0.60d	12.58
31	45.45a	191.0	1522.00b	0.89	47	8.63a	0.73c	12.08
36	28.69b	154.0	1176.67c	1.16	48	7.93b	0.63d	12.6
37	40.64b	164.0	1582.67b	0.95	47	8.33a	0.69c	12.12
39	51.62a	215.0	1531.33b	0.93	47	8.67a	0.77c	11.55
40	41.27b	189.0	1402.33c	0.99	38	7.50b	0.59d	12.64
43	39.53b	178.0	1420.67c	0.94	47	7.67b	0.60d	12.99
46	37.61b	189.0	1274.67c	0.96	48	7.90b	0.73c	11.21
47	47.36a	180.0	1682.33b	0.97	47	8.17b	0.68d	12.22
48	36.66b	191.0	1243.33c	1.00	47	8.17b	0.67d	12.11
49	37.49b	192.0	1253.33c	0.99	50	8.00b	0.69c	11.59
50	45.78a	188.0	1553.67b	0.94	49	8.67a	0.69c	12.6
51	34.78b	203.0	1114.00c	0.95	49	8.67a	0.65c	13.33
52	40.14b	192.0	1349.33c	0.98	45	8.17b	0.72c	11.37
53	32.34b	189.0	1123.00c	0.97	48	8.46a	0.69c	12.22
'Aquiri' cultivar control	37.78b	191.0	1263.00c	0.93	50	8.5a	0.78c	10.97
Mean	39.30	193.0	1312.53	0.96	46	8.19	0.70	12.14
Coefficient of variation (%)	30.88	11.67	30.68	6.81	13.29	7.17	11.54	14.64

Within a column, mean values followed by dissimilar lowercase letters are significantly different according to the Scott Knott test at 5% probabili

other clones (Table 2). The highest productivity was observed forclone 14 (59.91 t ha^{-1}), the recorded value of which was1.6-fold greater than that of the 'Aquiri' cultivar control. Clones 5 and 14 also produced the highest numberof fruits per plant(approximately 2000)and could, therefore, be consideredto form an elite group.The productivities of these clones were higher than that reported by TeófiloSobrinho (1991) for the scion/rootstock combination 'Caipira' orange and 'Cravo' lime,but lower than those described previously for 'Pera' orange and 'Cravo' lime combinations (DONADIO *et al*., 1992; ROBERTO *et al*., 1999; SCHAFER *et al*., 2006; DAVOGLIO JUNIOR *et al*., 2006; TAZIMA *et al*., 2008). Although most of the evaluated clones presented lower numbers of fruits per plant than the elite clones 5 and 14, many produced numbers that were similar to, or even higher than, that of the 'Aquiri' cultivar control. However, it is important to emphasize that full production and stability of yieldcommences onlyafter trees have attained seven years of age (TEÓFILO SOBRINHO, 1991).Moreover, the production ofa citrus crop can oscillate, either increasing or decreasing, depending on various factors. In this context, Souto *et al*. (2001) described the pronounced alterations in production by a single orange genotype. Possible explanations for thisbehavior are the cyclic nature of the culture (STENZEL *et al*., 1999 and 2005) andthe manifestation of environmental stresses such as drought and other abiotic pressure that can affect flowering, number of fruits and productivity (RAMALHO *et al*., 2004). The number of fruits is of particular agronomic importance considering thesubstantial demand from the local consumer market for good quality fresh fruit. In the present study, however, all of the clones were similar regarding fruit mass and presented values that did not differ from that of the 'Aquiri' cultivar control or fromthose reported previously for sweat orange varieties (BLUMER *et al*., 2003; BOLOGNA and VITTI, 2006;LEDO *et al*., 1999 and 2008). This finding confirms the views of Guardiola (2000) and Duenhas *et al*. (2002) thatcitrus productivity is influenced by, anddirectly associated with, the number of fruits per plantrather than fruit mass. In addition, all clones evaluated herein were similar with respect to fruit quality as determined by length/diameter ratio, juice content and TSS/TTA ratio. However, the highest TSS values were found in clones 4, 11, 24, 28, 31, 37, 39, 50, 51, 53, and were equivalent to that of the 'Aquiri' cultivar control. A number of researchers have stated that citrus productivity is somewhat dependent on the rootstock employed.For example,Auler *et al*. (2008) reported that 'Valencia' orange in combination with rootstock 'Sunki' mandarin [*Citrus sunki* (Hayata) Yu.Tanaka]exhibited higher productivity in comparison with combinations involving other rootstocks.Moreover, 'Pera' orangegrafted onto rootstocks 'Cleopatra' tangerine (*Citrus reshni*hort ex Tanaka) or 'Volkamer' lemon (*Citrus volkameriana* Pasq) presented higher productivities than other rootstock combinations (TEÓFILO SOBRINHO, 1991; CARVALHO *et al*., 1991; STUCHI *et al*., 2000 and 2004). Variations in plant vigor and, consequently, productivity can also be influenced by the edaphoclimatic and cultural conditions of the grafts (NEL; BENNIE, 1983).

CONCLUSIONS

Of the 32orange clones investigated, eight (i.e. 5, 14, 15, 19, 31, 39, 47 and 50) presented the highest levels of productivity. Among these top clones, 5 and 14 were considered elite since they exhibited values for productivity (49.29 and 59.91 t ha^{-1}, respectively) and number of fruits (2048 and 1970.67 $plant^{-1}$, respectively) that exceeded those ofthe cultivar 'Aquiri'(37.78 t ha^{-1} and 1263 $plant^{-1}$) that is currently recommended by Embrapa for cultivation in Acre. Fruit mass, dimensions and juice content of the fruits were similar for all of the clones and the control, but nine clones (i.e. 4, 11, 24, 28, 31, 37, 39, 50 and 51) showed superior values for TSS and TTA.Our findings warrant further research on combinations of these clones with alternative rootstocks to find the most productive pairs that generate the highest quality fruits.

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