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Nota/Note

Biometric evaluation of orange cultivars using different rootstocks in the semiarid region of Ceará, Brazil

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SUMMARY

Cultivation of citrus fruits is important for the development of the Northeast region of Brazil due to some competitive advantages such as land availability, adequate ecological conditions, and geographic localization in relation to internal and external markets. However, these crops present a great vulnerability resulting from low diversification of scion and rootstock cultivars. The objective of this work was to verify the initial development of three orange cultivars in different rootstocks in the semiarid region of the State of Ceará. A completely randomized design was used, with three cultivars (Pera D-6, Valencia Tuxpan and Rubi) and three rootstocks (Santa Cruz Rangpur lime, Citrandarin Indio and Citrandarin Riverside), thus totaling nine treatments with four repetitions per treatment. The soil of the area is Typical Hydromorphic Orthic Vertisol (SiBCS), and the spacing used was 5.0 m x 2.0 m. The parameters evaluated were height (H), diameter between trees (Dl) and between rows (Dr), canopy volume (V^3) and stem diameter 5cm above and below the grafting line. Biometric measurements were performed 18, 24 and 30 months after transplantation. The treatments, T1S1-Pera D-6 x Santa Cruz Rangpur lime and T2S2-Valencia Tuxpan x Citrandarin Indio, had significantly different height (H) and canopy volume (V^3) at the 18th and 30th month, respectively: Height: T1S1 = 1.20 m and 1.75 m, T2S2 = 1.29 m and 1.84 m; canopy volume: T1S1 = 0.90 m^3 and 2.56 m^3, T2S2 = 0.87 m^3 and 2.77 m^3. The combinations Pera D-6 x Santa Cruz Rangpur lime and Valencia Tuxpan x Citrandarin Indio presented better adaptation and vegetative development in the semiarid conditions studied, allowing their indication for use in this region.

Index terms: biometrics, citrus, diversification, vegetative development.

Avaliação biométrica de cultivares de laranjeira sob diferentes porta-enxertos no semiárido do Ceará, Brasil

RESUMO

A citricultura é importante no desenvolvimento da região Nordeste, apresentando como vulnerabilidade a baixa diversificação de cultivares porta-enxertos. O objetivo do trabalho foi verificar o desenvolvimento inicial de três cultivares de laranjeira em diferentes porta-enxertos no

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semiárido cearense. Utilizou-se delineamento inteiramente casualizado (DIC), com três cultivares copa (Pera D-6, Valência Tuxpan e Rubi) e três porta-enxertos (Limão Cravo Santa Cruz, Citrandarin Índio e Citrandarin Riverside), totalizando nove tratamentos. Usou-se quatro repetições por tratamento em Vertissolo Hidromórfico Órtico Típico (SiBCS), sob o espaçamento de 5,00 m x 2,00 m. Avaliou-se altura (H), diâmetro entre plantas e entre linhas (Dl e Dr), volume de copa (V^3) e diâmetro do caule 5 cm acima e abaixo da enxertia, realizando biometria aos 18, 24 e 30 meses após o transplantio. Os tratamentos, T1S1-Pera D-6 x limão Cravo Santa Cruz e T2S2-Valência Tuxpan x citrandarin Índio, diferiram significativamente quanto à altura (H) e volume de copa (V^3) aos 18 e 30 meses, citando-se respectivamente: altura: T1S1=1,20 m e 1,75 m, T2S2=1,29m e 1,84m; volume de copa: T1S1=0,90 m^3 e 2,56 m^3, T2S2=0,87 m^3 e 2,77 m^3. As combinações Pera D-6 x limão Cravo Santa Cruz e Valência Tuxpan x citrandarin Índio apresentaram melhor adaptação e desenvolvimento vegetativo nas condições de semiárido, recomendando-se adoção nessas condições.

Termos de indexação: biometria, citros, diversificação, desenvolvimento vegetativo.

INTRODUCTION

“Citros” are part of a large group of trees of the genus *Citrus* and other related genera (*Fortunella* and *Poncirus*) from the family Rutaceae mostly represented by oranges [*Citrus sinensis* (L.) Osbeck], mandarins [*Citrus reticulata* Blanco, *Citrus deliciosa* (Ten.) and *Citrus clementina* hort. ex (Tanaka)], lemons [*Citrus limon* (L.) Burm and *Citrus aurantifolia* (Christm.)], acid limes such as Tahiti [*Citrus latifolia* (Tanaka)], and sweet limes such as Palestian [*Citrus limettioides* (Tanaka)], citron [*Citrus medica* (L.)], sour orange [*Citrus aurantium* (L.)] and grapefruit [*Citrus grandis* (L.) Osbeck and *Citrus paradisi* (Macfad)] (Cunha Sobrinho et al., 2013). The Brazilian citriculture presents expressive figures that reflect its great economic and social importance, with almost 1 million hectares of cultivated area, and a fruit production that surpasses 19 million tons, making Brazil the world’s largest producer of sweet orange (*Citrus sinensis*) since the 1980s, a ranking recently overtaken by China, besides the title of the largest exporter of frozen concentrated orange juice, which along with other derivatives have generated a profit of approximately 1.5 billion dollars per year (Almeida & Passos, 2011; Cunha Sobrinho et al., 2013; IBGE, 2015).

Sweet orange is the most cultivated and consumed *Citrus* species in the world. It is originally from Southeast Asia, between China and India, and has spread throughout the globe with the advent of the great navigations in Portugal during the 15th century (Barbieri & Stumpf, 2008). Orange trees are classified into four groups according to their characteristics: common orange (Pera, Valencia and Rubi), navel orange (Bahia, Baianinha and Cara Cara), blood oranges such as Mooro and low acidity oranges (Lima, Piralima and Serra D’agua). Orange fruits can be used both for unprocessed consumption and industry. The national citriculture has directed its production for the market of frozen concentrated juice, the principal commodity in the agribusiness sector of citrus cultivation worldwide. However, the Northeast of Brazil, the second largest citrus producer in the country, allocates citrus production to the market of fresh fruits for unprocessed consumption and the processing industry in general (Almeida & Passos, 2011; Cunha Sobrinho et al., 2013; Bastos et al., 2015).

Sweet oranges predominate in the Brazilian citrus industry, and among this group, Pera orange is the almost exclusive variety used in industry and for domestic and foreign fresh fruit markets (Donadio, 1999; Bastos et al., 2015). Pera orange is a medium size tree, producing more or less upright branches, acuminate leaves, medium size and uniformly yellow and fleshy fruits with slightly rough skin, weighting around 200g with 50% of juice content and without seeds (0 to 6), with midseason to late season harvesting and average productivity (around 30 tons/ha), (Passos et al., 2009; Cunha Sobrinho et al., 2013)., Valencia Tuxpan orange is a late variety, high size tree, producing uniformly yellow fleshy fruits with slightly rough skin, weighting around 230g with average juice content and 6 seeds per fruit (Passos & Soares Filho, 2004). Rubi orange is a midseason variety, high size tree, medium size and spherical fruit with one or two seeds per fruit, slightly warty skin and intense reddish pulp, colorful juice, with soluble solids content of 9.9 °Brix. Rubi orange can be used as an alternative to diversify the sweet orange varieties for both the internal fresh fruit market and the juice processing industry (Cunha Sobrinho et al., 2013; Bastos et al., 2015).

Due to the need for a diversification programe of the national citriculture, the present work aiming to evaluate the vegetative development of orange trees on different rootstocks tolerant or resistant to major biotic or abiotic stresses, through biometrics in semiarid conditions.

MATERIAL AND METHODS

The research was conducted between 2013 and 2016 in the Citrus Experimental Area – Sítio Pau Branco, located in the rural area of Russas, Ceará, Brazil, located in the geographic coordinates 4°53'0.10" S, 37°55'1.20" W, with an altitude of approximately 19m. Russas is a city of Ceará located in the mesoregion of the Jaguaribe Valley, area circumscribed in the geographic coordinates 4°56'24"S, 37°58'33"W, with an average altitude of 20.51 m. The climate of the region is BSw 'h' (Köppen) classified as dry and very hot. The average annual temperature is 28.5°C, with a minimum of 22°C and a maximum of 35°C, and the average annual rainfall is 772 mm. The plants used in the experiment were provided by Embrapa Semiárido, in the form of changes in school, through the Active Citrus Germplasm Bank from Embrapa Mandioca e Fruticultura, in Cruz das Almas, Bahia, Brazil.

A completely randomized design in a 3 x 3 scheme was used, with combinations of three sweet orange cultivars on three rootstocks, totaling nine treatments with four replications. The treatments were: T1S1 - Pera D-6 x Santa Cruz Rangpur lime; T2S1 - Valencia Tuxpan x Santa Cruz Rangpur lime; T3S1 - Rubi x Santa Cruz Rangpur lime; T1S2 - Pera D-6 x Citrandarin Indio; T2S2 - Valencia Tuxpan x Citrandarin Indio; T3S2 - Rubi x Citrandarin Indio; T1S3 - Pera D-6 x Citrandarin Riverside; T2S3 - Valencia Tuxpan x Citrandarin Riverside and T3S3 - Rubi x Citrandarin Riverside. The useful plants were transplanted into pits previously dug (40 x 40 x 40cm) and distributed at a dense spacing of 5 x 2m in Typical Hydromorphic Orthic Vertisol (SiBCS), which was previously mechanized and corrected, using physical and chemical analyses of the soil as reference (Ribeiro et al., 1999). Fertilization with organic carnauba straw- [*Copernicia prunifera* (Miller) H.E. Moore] and manure-based compost was carried out at planting, in a proportion of 20 liters per hole. An irrigation system was placed so as to supply the demand of the crop, in addition to the completion of sampling for plant management.

Biometry was performed 18, 24 and 30 months after transplantation, and included measures of height up to the tree apex (H), canopy diameter between plants and between rows (Dl and Dr) measured with a tape graded in millimeters, and average volume of the canopy (V^3) through the equation: $V = (\pi/6) \times H \times Dl \times Dr$, as described by Fallahi & Rodney (1991). We also measured the stem diameter 10 cm below and above the grafting line of useful plants as indicator of the scion-rootstock compatibility ratio (CR), considering values equivalent to 1 as full compatibility (Simonetti, 2015; Rodrigues et al., 2016)

All variables were subjected to analysis of variance (ANOVA) and in cases of significant difference, pair-wise comparisons of means were made through the Scott-Knott test at 5% probability ($p \leq 0.05$), using the statistical software ASSISTAT® for the analyses (Silva, 2014).

RESULTS AND DISCUSSION

We found a significant difference in compatibility ratios (CR) between rootstocks and scions, where the combinations between the three scions and the Santa Cruz Rangpur lime rootstock (T1S1, T2S1 and T3S1), as well as the combination between the Pera D-6 scion and the Citrandarin Indio rootstock (T1S2), presented CR above 0.84, statistically different from the other treatments. The lowest CR values were obtained in combinations with the Citrandarin Riverside rootstock, with CR values of 0.79, 0.78 and 0.75 with the Pera D-6 (T1S3), Valencia Tuxpan (T2S3) and Rubi (T3S3) scions, respectively, for a maximum of 1 (Table 1). Rodrigues et al. (2016) evaluated an array of combinations between four citrus scions and 14 different rootstocks and obtained mean CR values of 0.68 in the combinations with the Pera orange trees, and values between 0.67 and 0.88 in combinations with Westin and tangerine-tangor Piemonte orange trees, within only 90 days after the transplantation. These values are lower than those obtained in the present study, where the longest period of assessment and the semiarid conditions may have influenced the result, and also indicate a high affinity between the canopies and the Santa Cruz Rangpur lime rootstock, as well as between the Pera D-6 cultivar and The Citrandarim Indio rootstock. The affinity in these cases corresponds to full compatibility indicated by a ratio equal to 1. In turn, the affinity between the other combinations, although satisfactory, was statistically different, what we can attribute to the different requirements of canopies and rootstocks (Lima, 2013).

The analysis of the vegetative development of combinations (treatments) was split into three main variables: initially, the height (m), then the canopy diameter (m) and finally the average volume of canopy (m^3). As for height, despite the lower performance of the combination

T1S2 - Pera D-6 x Citrandarin Indio, at 18 months after planting, with a value of 0.84 m, a significant difference was found only from the 24 month onwards, when the combinations between the Pera D-6 scion and Santa Cruz Rangpur lime rootstock (T1S1), as well as the three combinations that used Valencia Tuxpan as canopy (T2S1, T2S2 and T2S3), differed statistically from the others, especially in this evaluation period, reflecting the final evaluation at the 30th month after planting, when the combinations presented the following heights: T1S2: 1.75m; T2S1: 1.74m; T2S2: 1.84m and T2S3: 1.73m (Table 2). The combinations between Valencia Tuxpan and the three rootstocks evaluated had higher vertical growth, differing from the other combinations with respect to time, producing a vigorous canopy regardless of the rootstock and corroborating the literature that reports its potential on different rootstocks (Simonetti, 2015; Rodrigues et al., 2016). As for average canopy diameter, despite the fact that no significant differences were found between the combinations until the 18th month, the treatments that used Santa Cruz Rangpur lime as rootstock (T1S1, T2S1 and T3S1), and the combination of the Valencia Tuxpan with Citrandarin Indio (T2S2) initially presented consistent numbers: T1S1: 1.17m; T2S1: 1.01m; T3S1: 1.05m and T2S2: 1.11m. However, early in the development in relation to other treatments, found no significant difference at 24 and 30 months after planting (Table 3).

The growth and the vigor of the combinations T1S1, T2S1 and T2S2 in height and canopy diameter translated into canopy volume (V^3), resulting in a significant difference between the treatments in all biometric assessments conducted. The analysis of the average canopy volume (V^3) showed a predominance of the combinations between Pera D-6 and Valencia Tuxpan scions and Santa Cruz Rangpur lime rootstock(T1S1 and T2S1), in addition to the combination T2S2 - Valencia Tuxpan x Citrandarin Indio, and T3S3 - Rubi x Citrandarin Riverside, which presented an accelerated growth between the 24th and 30th month (Table 4 and Figure 1), obtaining the final values: T1S1: 2.56m^3; T2S1: 2.57m^3; T2S2: 2.76m^3 and T3S3: 2.31m^3, respectively. This indicates a rapid adaptation to the edaphoclimatic conditions of the semiarid, which is associated

Table 1. Compatibility ratios (CR) of the combinations at the 30th month after planting, Russas, Ceará, Brazil. 2016

Treatment	IC
T1S1 - Pera D-6 x Santa Cruz Rangpur lime	0.85 a
T2S1 - Valencia Tuxpan x Santa Cruz Rangpur lime	0.89 a
T3S1 - Rubi x Santa Cruz Rangpur lime	0.87 a
T1S2 - Pera D-6 x Citrandarin Indio	0.84 a
T2S2 - Valencia Tuxpan x Citrandarin Indio	0.76 b
T3S2 - Rubi x Citrandarin Indio	0.79 b
T1S3 - Pera D-6 x Citrandarin Riverside	0.78 b
T2S3 - Valencia Tuxpan x Citrandarin Riverside	0.75 b
T3S3 - Rubi x Citrandarin Riverside	0.77 b
C. V. (%)	8.22
F value	2.39*

Means followed by the same letter did not differ statistically from each other. *Significant at 5% level of probability ($p < 0.05$).

Table 2. Average height (m) of the combinations at 18, 24 and 30 months after planting, Russas, Ceará, Brazil. 2016

Treatment	18 months	24 months	30 months
T1S1-Pera D-6 x Santa Cruz Rangpur lime	1.19 a	1.63 a	1.75 a
T2S1-Valencia Tuxpan x Santa Cruz Rangpur lime	1.09 a	1.59 a	1.74 a
T3S1 - Rubi x Santa Cruz Rangpur lime	1.12 a	1.40 b	1.51 b
T1S2 - Pera D-6 x Citrandarin Indio	0.84 a	1.44 b	1.65 a
T2S2-Valencia Tuxpan x Citrandarin Indio	1.29 a	1.56 a	1.84 a
T3S2 - Rubi x Citrandarin Indio	1.09 a	1.34 b	1.49 b
T1S3 - Pera D-6 x Citrandarin Riverside	1.04 a	1.43 b	1.56 b
T2S3-Valencia Tuxpan x Citrandarin Riverside	1.08 a	1.54 a	1.73 a
T3S3 - Rubi x Citrandarin Riverside	1.02 a	1.25 b	1.46 b
C. V. (%)	13.56	10.33	10.23
F value	2.85*	2.82*	2.70*

Means followed by the same letter did not differ statistically from each other. *Significant at 5% level of probability ($p < 0.05$).

Table 3. Average canopy diameter (d^2/m) of the combinations at 18, 24 and 30 months after planting, Russas, Ceará, Brazil. 2016

Treatment	18 months	24 months	30 months
T1S1 - Pera D-6 x Santa Cruz Rangpur lime	1.17 a	1.52 a	1.63 a
T2S1- Valencia Tuxpan x Santa Cruz Rangpur lime	1.01 a	1.52 a	1.65 a
T3S1 - Rubi x Santa Cruz Rangpur lime	1.05 a	1.36 a	1.51 a
T1S2 - Pera D-6 x Citrandarin Indio	0.77 b	1.24 a	1.46 a
T2S2 - Valencia Tuxpan x Citrandarin Indio	1.11 a	1.40 a	1.66 a
T3S2 - Rubi x Citrandarin Indio	0.83 b	1.25 a	1.57 a
T1S3 - Pera D-6 x Citrandarin Riverside	0.84 b	1.36 a	1.41 a
T2S3-Valencia Tuxpan x Citrandarin Riverside	0.92 b	1.32 a	1.62 a
T3S3 - Rubi x Citrandarin Riverside	0.78 b	1.32 a	1.59 a
C. V. (%)	20.09	14.51	15.59
F value	2.39*	1.03 ns	0.52 ns

Means followed by the same letter did not differ statistically from each other. *Significant at 5% level of probability ($p < 0.05$). [NS]Non significant.

Table 4. Canopy volume (m^3) of the combinations at 18, 24 and 30 months after planting, Russas, Ceará, Brazil. 2016

Treatment	18 months	24 months	30 months
T1S1 - Pera D-6 x Santa Cruz Rangpur lime	0.90 a	1.99 a	2.56 a
T2S1 - Valencia Tuxpan x Santa Cruz Rangpur lime	0.57 b	1.99 a	2.57 a
T3S1 - Rubi x Santa Cruz Rangpur lime	0.67 a	1.40 b	1.90 b
T1S2 - Pera D-6 x Citrandarin Indio	0.28 b	1.18 b	1.86 b
T2S2 - Valencia Tuxpan x Citrandarin Indio	0.85 a	1.63 a	2.76 a
T3S2 - Rubi x Citrandarin Indio	0.56 b	1.15 b	2.06 b
T1S3 - Pera D-6 x Citrandarin Riverside	0.38 b	1.39 b	1.67 b
T2S3 - Valencia Tuxpan x Citrandarin Riverside	0.49 b	1.40 b	2.37 a
T3S3 - Rubi x Citrandarin Riverside	0.35 b	1.13 b	2.31 a
C. V. (%)	41.47	29.31	32.21
F value	3.36*	2.34*	2.48*

Means followed by the same letter did not differ statistically from each other. *Significant at 5% level of probability ($p < 0.05$).

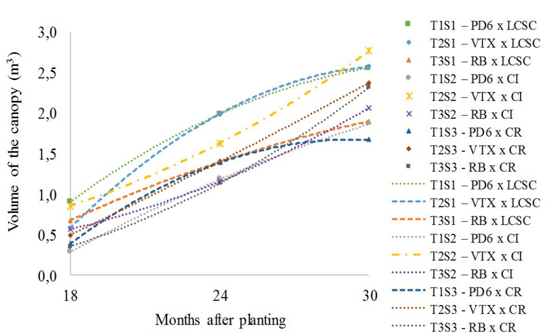

Figure 1. Development curves of the average canopy volume (m^3) of the combinations at 18, 24 and 30 months after planting, Russas, Ceará, Brazil. 2016.

to the compatibility values, and demonstrates the influence exerted by rootstocks on the vigor and development of the canopy (Bastos et al., 2015; Carvalho et al., 2016; Rodrigues et al., 2016).

When considering the whole evaluation period, the combinations between the Valencia Tuxpan orange and Santa Cruz Rangpur lime (T2S1) and the Citrandarin Indio (T2S2), as well as between Pera D-6 orange and Santa Cruz Rangpur lime (T1S1), showed vegetative a higher and more uniform development, and high compatibility ratios (CR), what probably reflected on the average height, average canopy diameter and average canopy volume, demonstrating their potential use as alternatives to diversify scion/rootstock varieties, with emphasis to rootstocks that are resistant or tolerant to major biotic or abiotic stresses, as show the studies of Rodrigues et al. (2016) and Carvalho et al. (2016).

CONCLUSION

The combinations Pera D-6 x Santa Cruz Rangpur lime and Valencia Tuxpan x Citrandarin Indio showed a higher and more uniform vegetative development throughout the evaluated period, demonstrating the rapid adaptation and high vigor of the combinations before the typical semiarid climatic conditions. Thus, we recommend their use in climate and soil conditions similar to those studied here. The lower vegetative growth was seen in the combination of the Pera D-6 orange tree and Citrandarin Riverside rootstock, possibly due to different requirements of canopy and rootstock. Further studies are necessary to verify the effects of the respective combinations on the productivity and quality of fruits.

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