Original article

Vegetative growth of citrus nursery trees related to the container volume

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Abstract — **Introduction**. The determination of an adequate container volume that combines rational use of substrate with maximization of vegetative growth is very important to optimize citrus nursery tree production. This experiment aims to evaluate the influence of container volumes on vegetative growth of citrus nursery trees. **Materials and Methods**. Pera sweet orange nursery trees [*Citrus sinensis* (L.) Osbeck] budded on Rangpur lime (*Citrus limonia* Osbeck) were produced in six container volumes [(3.0, 3.8, 4.5, 4.6, 5.0 and 5.8) L], with the respective container dimensions of [(20 × 32, 20 × 35, 22 × 32, 22.5 × 35, 25 × 32 and 25 × 35) cm]. Another 5.0-L container studied had the dimensions of 20 cm x 40 cm. Commercial substrate was composed of *Pinus* bark and a controlled-release fertilizer was used. Parameter evaluation started after moving the rootstocks from seedling trays, 3.5 months after sowing, to plastic containers and continued until nursery trees reached one year old. The studied parameters were shoot height, diameter and leaf area of rootstocks and nursery trees, bud take percentage and scion and root dry matter of nursery trees. **Results and discussion**. The development of Rangpur lime plants was not affected by any treatment until budding. The largest container volumes induced faster and more vigorous vegetative development of Pera sweet orange nursery trees budded on Rangpur lime. A 5.0-L container volume could be indicated as a technical and economical option for the production of containerized citrus nursery trees.

Brazil / *Citrus sinensis* / *Citrus limonia* / plant propagation / plant nurseries / container planting / growth / measurement

Croissance végétative des arbres en pépinière d'agrumes en rapport avec le volume du container.

Résumé — **Introduction**. La détermination d'un volume de container adéquat qui combine une utilisation rationnelle du substrat et une croissance végétative optimale est très importante pour optimiser la production d'arbres en pépinière d'agrumes. Cette expérimentation a visé à évaluer l'influence des volumes de containers sur la croissance végétative d'agrumes en pépinière. **Matériel et méthodes**. Des orangers de la variété Pera [*Citrus sinensis* (L.) Osbeck] greffés sur limettier Rangpur (*Citrus limonia* Osbeck) ont été plantés dans des containers de six volumes différents [(3,0 ; 3,8 ; 4,5 ; 4 ;6 ; 5,0 et 5,8) L], correspondant à des dimensions respectives de (20 × 32, 20 × 35, 22 × 32, 22.5 × 35, 25 × 32 et 25 × 35) cm. Un autre container de 5,0 L et 20 cm × 40 cm a été testé. Le substrat commercial était constitué d'écorce de pin et un engrais à libération contrôlée a été utilisé. Les mesures ont commencé après transfert, 3,5 mois après le semis, des porte-greffes issus de plantules en planches dans des containers de plastique et elles ont été poursuivies jusqu'à ce que les arbres de pépinière aient atteint l'âge d'un an. Les paramètres étudiés ont été la hauteur de tige, le diamètre et la surface des feuilles des porte-greffes et des arbres de pépinière, le pourcentage de reprise et de la matière sèche du scion et des racines des arbres de pépinière. **Résultats et discussion**. Quel que soit le traitement, le développement du porte-greffe Rangpur a été le même jusqu'au greffage. Les plus grands volumes de container ont induit un développement végétatif plus rapide et plus vigoureux des orangers Pera greffés sur limettiers Rangpur. Finalement, des containers de 5,0 L seraient techniquement et économiquement conseillés pour la production des arbres conteneurisés de pépinière d'agrumes.

Brésil / *Citrus sinensis* / *Citrus limonia* / multiplication des plantes / pépinière / plantation en container / croissance / mesure

1. Introduction

The Certified Citrus Nursery Tree Program of the State of São Paulo, Brazil, was established in order to improve the quality of citrus nursery trees commercialized in the State. This system includes the use of screened or closed environments, where the nursery trees must be grown in containers with no soil-derived substrate, water free of pathogens, and indexed budwood for viruses and Citrus Variegated Chlorosis (CVC) [1, 2]. Consequently, the production of certified citrus nursery trees becomes technically and economically viable when the nursery trees are managed in containers properly developed to be used with specific substrates.

Regarding the production of containerized citrus nursery trees, several advantages can be pointed out, such as greater control over pathogens, less time to produce nursery trees, higher root volume, higher seedling survival after transplanting, higher nutritional control and higher production of nursery trees per unit of area [3]. The disadvantages are production of smaller nursery trees, that need more care during the first year after planting, higher initial costs due to control of environmental conditions in the nursery and the risk of having to transplant nursery trees to larger containers in the case of commercialization delay [4, 5].

Plant density is very important for the production of nursery trees in greenhouses or even in field nurseries [6]. Aeration, light and heat distribution will certainly affect the development of plants, since there is no competition for water or nutrients. The container volume is directly related to the density of the nursery trees in the greenhouse. Cleopatra mandarin (*Citrus reshni* Hort. ex Tanaka) seedlings showed a better performance cultivated at 0.4 m × 0.6 m, while seedlings of sour orange (*Citrus aurantium* L.) and Swingle citrumelo [*Poncirus trifoliata* (L.) Raf. × *Citrus paradisi* Macfad.] rootstocks reached optimum growth in the field with 0.3-m spacing between double lines [7]. It was also observed that spacing did not significantly alter macronutrient leaf concentrations, but the opposite occurred with micronutrient leaf concentrations.

The volume of the substrate also seems to influence the final development of containerized citrus nursery trees, hence the necessity to test different volumes of commercial containers [8]. Therefore, it is necessary to establish research that determines if differences in development among nursery trees produced in different volume containers are exclusively attributed to physical space limitation and nutrient availability, or if the differences are mainly associated with competition for light and temperature effects. The current work attempted to evaluate the influence of different volumes of substrate and container dimensions on the development of containerized citrus nursery trees.

2. Materials and methods

The experiment was carried out in a commercial greenhouse that produces certified citrus nursery trees in Conchal, São Paulo State, Brazil. The geographical location is 22° 38" South latitude, 47° 35" West longitude, 590 m above sea level. The climate is Cwa, i.e., humid tropical with a dry winter and rainy summer [9], with an average daily temperature of 21.1 °C, annual rainfall of 1300 mm, relative humidity of 75% and average monthly solar radiation of 201.5 h.

The trial was developed from August to May, during the summer season. Pera sweet orange [*Citrus sinensis* (L.) Osbeck] was chosen as the scion variety to be studied in this experiment. Rangpur lime (*Citrus limonia* Osbeck) was chosen as rootstock, because it is the predominant variety in São Paulo citrus groves. Evaluation started 3.5 months after sowing, when rootstocks were transferred from seedling trays to plastic containers, and ended 8.5 months later with the commercialization of the nursery trees. The following container volumes were evaluated: (3.0, 3.8, 4.5, 4.6, 5.0 and 5.8) L, with the dimensions (width × height) of (20 × 32, 20 × 35, 22 × 32, 22.5 × 35, 25 × 32 and 25 × 35) cm. Another 5.0-L container studied had the dimensions of 20 cm × 40 cm.

A commercial *Pinus* bark was used as substrate (Rendmax^{TM} Citrus). The controlled-release fertilizer (Osmocote^{TM}) used was 22–04–08 + micronutrients given in the following amounts: 22% N, 4% P, 8% K, 1% Mg, 3% S, 0.02% B, 0.05% Cu, 1% Fe, 0.1% Mn, 0.001% Mo and 0.05% Zn. For each cubic meter of substrate, 2.8 kg·m^{-3} of fertilizer was applied. Irrigation varied from (80 to 120) mL·day^{-1} for each plant, using a drip irrigation system and according to environmental conditions and substrate water saturation.

Rootstock biometric data collected before budding (3 months after sowing) consisted of the following parameters: shoot height, stem diameter measured 12 cm above substrate, leaf area and bud take percentage. Final shoot height, stem diameter, leaf area and scion and root dry matter were evaluated 5 months after budding. Scion and root dry matter were obtained after 72 h at 64 °C. Leaf area was measured with an electronic planimeter (Li-Cor 3100). The experiment was conducted in randomized blocks with seven treatments in three blocks. The plot was made up of twelve containers with one plant each, in a total of 252 plants. Data collected was compared by regression analysis.

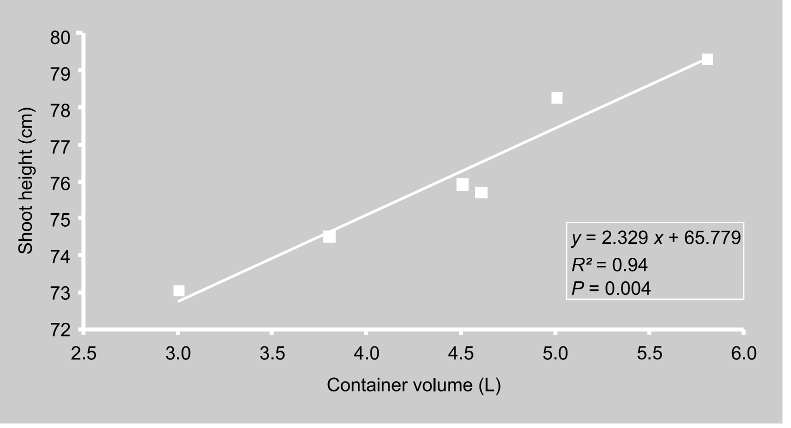

Figure 1.
Shoot height of 1-year-old Pera sweet orange nursery trees budded on Rangpur lime due to container volume, 5 months after budding (n = 36, Conchal-SP, Brazil, 2000).

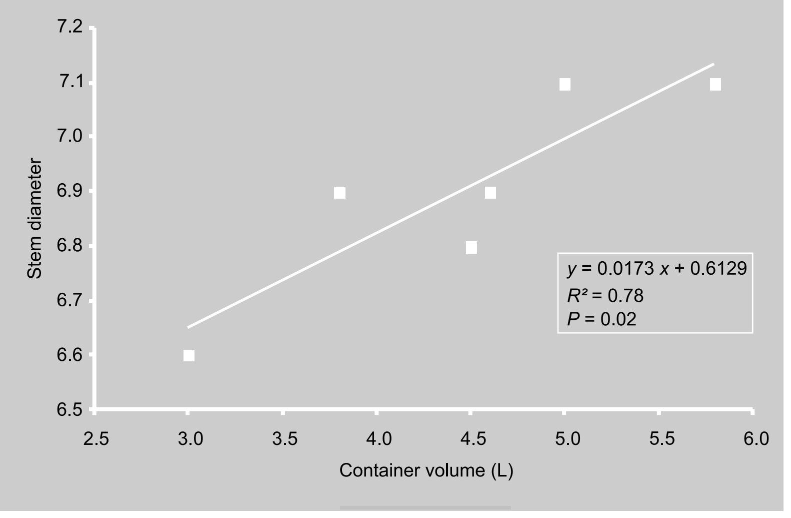

Figure 2.
Stem diameter of 1-year-old Pera sweet orange nursery trees budded on Rangpur lime due to container volume, 5 months after budding (n = 36, Conchal-SP, Brazil, 2000).

3. Results and discussion

The vegetative growth of Rangpur lime rootstock was not affected by substrate volume from transplant until budding (data not shown). This probably occurred because, during rootstock production, there were no physical or nutritional limitations in any of the container volumes. This behavior changed after budding, affecting mainly shoot growth during the last 4 months. This response might be a consequence of higher controlled-release fertilizer availability due to higher container volume [10].

The highest vegetative development of nursery trees after budding was directly proportional to the container volume, for all the parameters analyzed (*figures 1–4*). Other authors working with different substrate volumes, similar to the ones used in this experiment, also observed similar behavior in citrus nursery trees [8]. A higher volume container indicates a higher volume of substrate with more physical space, nutrient and water availability for the plants. This leads to greater vegetative development and dry matter accumulation after longer periods of time. However, there were no differences regarding leaf mineral composition of the scion [8], which was satisfactory according to the reference values proposed for this cultivar [11].

Irrigation was another factor to be considered. Independently of container volume, the same amount of water was applied in all treatments every time plants required irrigation. Irrigation volume varied according

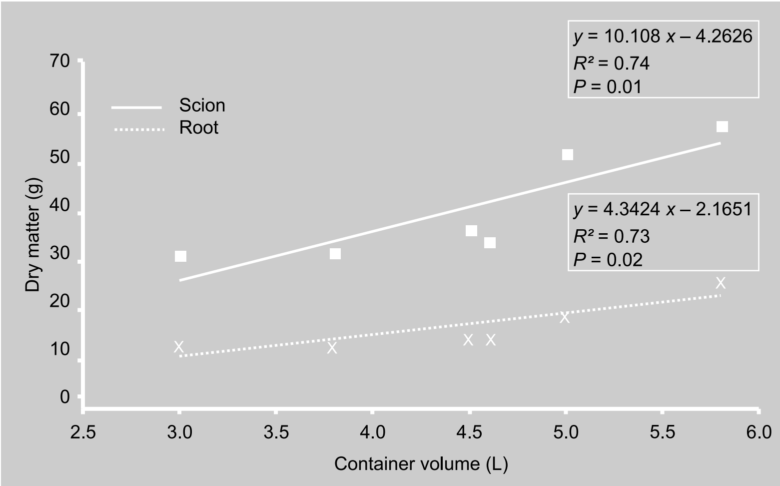

Figure 3.
Scion and root dry matter of 1-year-old Pera sweet orange nursery trees budded on Rangpur lime due to container volume, 5 months after budding (n = 36, Conchal-SP, Brazil, 2000).

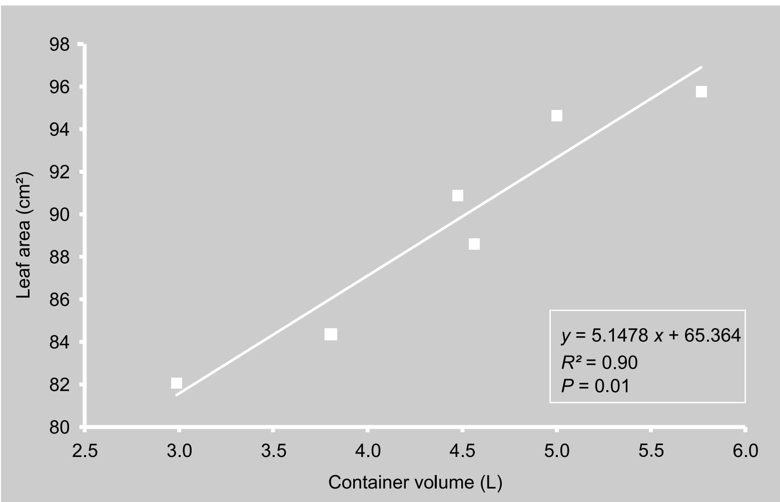

Figure 4.
Leaf area of 1-year-old Pera sweet orange nursery trees budded on Rangpur lime due to container volume, 5 months after budding (n = 36, Conchal-SP, Brazil, 2000).

to daily temperature. On sunny days, a volume of 120 mL was applied for each plant, while on cloudy days this volume was reduced to 80 mL. Therefore, smaller containers obtained a higher grade of substrate saturation, leading to physical disorders such as lower substrate aeration, which could damage the root system. This could explain the lower development of nursery trees grown in these containers. Moreover, these conditions may promote the appearance of diseases such as foot rot *Phytophthora* spp. [1].

In this experiment, plant density due to container arrangement was not directly evaluated. Lower container volume allows a higher plant density in the greenhouse. There is the possibility of producing a larger number of nursery trees by using lower volumes of substrates. This would reduce substrate purchase costs and increase profits. On the other hand, smaller containers would lead to longer periods to finish nursery tree production. Five-liter containers evaluated in two dimensions (20 cm × 40 cm and 25 cm × 32 cm) did not affect nursery tree growth, although 25 cm × 32 cm containers led to wider plant spacing in the greenhouse.

Five months after budding, 36% of plants cultivated in 5.8-L containers (25 cm × 35 cm) did not reach satisfactory development for commercialization, according to the nurseryman's standards. These plants presented problems, such as short and not erect shoots, thin stems (under the average) or dormant buds. On the other hand, 64% of plants cultivated in 3.0-L containers (20 cm × 32 cm) did not reach satisfactory development for commercialization at the same moment. Therefore, smaller container volumes lead to slower plant growth rate and therefore longer periods of time would be required for adequate vegetative development. The higher costs in this alternative system would probably suppress profits gained by greater production densities. Moreover, root damage could appear in nursery trees produced in greater densities due to the use of smaller containers; thus negative consequences could be expected on plant setting and development in the field.

4. Conclusions

The container volume range used in this experiment did not affect the development of Rangpur lime rootstocks until budding, 6 months after sowing.

Larger container volumes induced faster and more vigorous vegetative growth of Pera sweet orange nursery trees budded on Rangpur lime rootstock, using controlled-release fertilizer proportionally incorporated into the substrate.

Five-liter containers are recommended for the commercial production of well-developed Pera sweet orange nursery trees budded on Rangpur lime.

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Crecimiento vegetativo de plantones cítricos debido al volumen de recipiente.

Resumen — Introducción. La determinación de un volumen de recipiente adecuado que combine el uso racional de substratos con la maximización del crecimiento vegetativo es muy importante para la optimización de la producción de plantones cítricos. Esta investigación evaluó la influencia de diferentes volúmenes de recipientes en el crecimiento vegetativo de plantones cítricos. **Materiales y Métodos**. Plantones de naranja dulce Pera [*Citrus sinensis* (L.) Osbeck] injertados sobre Lima Rangpur (*Citrus limonia*, Osbeck) fueron producidos en seis diferentes volúmenes de recipientes (3.0, 3.8, 4.5, 4.6, 5.0 y 5.8) L, con las siguientes dimensiones: (20 × 32, 20 × 35, 22 × 32, 22.5 × 35, 25 × 32 y 25 × 35) cm. Se utilizó también otro recipiente de 5,0 L con las dimensiones de 20 cm × 40 cm. Fue empleado un substrato comercial compuesto de cáscara de pino y fertilizante de liberación lenta. Las evaluaciones comenzaron después que los patrones fueron transferidos de las bandejas a los recipientes plásticos, 3,5 meses después de la siembra, y terminaron cuando los plantones alcanzaron un año de edad. Los datos biométricos que se colectaron fueron los siguientes: altura, diámetro y área foliar de patrones y plantones injertados, porcentaje de prendimiento del injerto, materia seca de raíces y parte aérea de los plantones y análisis foliar. **Resultados y discusiones**. El desarrollo de la lima Rangpur no fue afectada por ninguno de los tratamientos hasta la injerta. Los mayores volúmenes de recipientes inducirán crecimientos vegetativos mas rápidos y vigorosos en los plantones de naranja dulce Pera injertados sobre limas Rangpur. El recipiente con capacidad de 5,0 L puede ser indicado como una opción técnica y económica para la producción de plantones cítricos en recipientes.

Brasil / *Citrus sinensis* / *Citrus limonia* / propagación de plantas / viveros / plantación en contenedor / crecimiento / medicon