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Productivity and quality of sweet potato roots propagated by mini-cuttings with different trays and seedling ages

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ABSTRACT

The use of mini-cuttings is an option for obtaining sweet potato propagules of excellent quality. The objective of this research was to evaluate the production and quality of sweet potato roots propagated by mini-cuttings in different types of trays and ages of seedlings. Six treatments, resulting from the factorial 2x3, were evaluated: two types of trays (162 and 200 cells, with 31 and 18 mL of substrate per cell, respectively) and three ages of seedlings (39, 46 and 53 days after placement of mini-cuttings in trays), in a randomized block design, with five replications. Seedlings characteristics, production and quality of roots were evaluated. Higher number and dry weight of leaves per seedling were observed in the tray with 162 cells than in trays with 200 cells. The younger seedlings (39 days) had a lower number of leaves, dry weight of leaves, stem, roots ant total (leaves + stem + roots) than seedlings of other ages. There was no difference in root production depending on the type of tray, regardless of the age of the seedlings. For the 162-cell tray, the age of the seedlings did not affect the production of roots. On the other hand, for the 200-cell tray, higher roots production was observed on seedlings 39 days age compared to seedlings with 53 days. No differences were observed among the roots of different treatments for titratable acidity, and levels of sucrose, reducing sugars ant total sugars. It is recommended to avoid old seedlings, that is, it is recommended to use seedlings with a maximum of 43 days after planting of mini-cuttings for trays with 200 cells, while for trays with 162 cells no difference in root production was observed with the different ages of the seedlings.

Keywords: *Ipomoea batatas*, propagation, substrate.

RESUMO

Produtividade e qualidade de raízes de batata-doce propagada por mini-estacas em diferentes bandejas e idades de mudas

A utilização de mini estacas é uma excelente opção para a propagação de batata doce. Objetivou-se com esta pesquisa avaliar a produção e a qualidade de raízes de batata doce propagada por mini-estacas em diferentes tipos de bandejas e idades de mudas. Foram avaliados seis tratamentos, resultantes do fatorial 2x3, sendo dois tipos de bandejas (162 e 200 células, com 31 e 18 mL de substrato por célula, respectivamente) e três idades das mudas no dia do transplante (39, 46 e 53 dias após a colocação das mini estacas nas bandejas), no delineamento em blocos ao acaso, com cinco repetições. Foram avaliadas as características das mudas, a produção e a qualidade das raízes. Foram observados maior número e massa seca de folhas por muda na bandeja com 162 células em comparação à de 200 células. As mudas mais novas (39 dias) apresentaram menor número de folhas, massa seca de folhas, caule, raízes e total (folhas + caule + raízes) que as mudas das outras idades. Não se observou diferença de produção de raízes em função do tipo de bandeja, independentemente da idade das mudas. A idade das mudas não afetou a produção de raízes com o uso da bandeja com 162 células. Por outro lado, empregando a bandeja com 200 células, observou-se maior produção de raízes usando mudas com 39 dias em comparação às mudas com 53 dias. Não foram observadas diferenças entre as raízes dos diferentes tratamentos para a acidez titulável, teores de sacarose, açúcares redutores e açúcares totais. Recomenda-se evitar a utilização de mudas velhas, ou seja, utilizar mudas com no máximo 43 dias após o plantio em bandejas com 200 células, enquanto que para bandejas com 162 células não foi observada diferença na produção de raízes com as diferentes idades das mudas.

Palavras-chave: *Ipomoea batatas*, propagação, substrato.

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Sweet potato (*Ipomoea batatas*) is a vegetable of great economic importance in Brazil. It is a perennial plant grown as an annual, normally propagated using the mature branches obtained at the end of the cycle. However, this is not considered the best system, due to the high risk of spreading pests and diseases, mainly viruses, in the new crop (Rós *et al*., 2011, 2012).

The use of mini-cuttings is an option to obtain propagules of excellent quality, especially if virus-free matrices are used. This method presents a higher multiplication rate compared to the use of branches (Rós *et al*., 2011, 2012). Rós *et al*. (2011) reported a high post-transplant survival rate (98%) of seedlings obtained by this method.

The production of seedlings in trays allows better use of the propagating material, facilitates the initial cultural treatments, provides greater homogeneity to the plants, reducing the possibility of failures in the area and guaranteeing the desired population (Neumann *et al*., 2017; Ichikawa *et al*., 2019) and, depending on the type, allows the reuse of trays. However, the age of the seedling obtained in trays is a factor that can influence the plant's performance in the field, as its root development depends on the volume of available substrate. If kept for a long period in the tray, it may result in low quality seedlings (Seabra Júnior *et al*., 2004; Godoy & Cardoso, 2005; Salata *et al*., 2011) being necessary a supplemental fertilization of the substrate (Ichikawa *et al*., 2019) or to use biostimulants (Neumann *et al*., 2017). The ideal seedling age can vary with the species and type of tray, because trays with larger cells allow the seedling to be kept for longer time in the nursery and to be transplanted with a larger size and number of leaves, increasing the competitiveness of the plants and reducing the time the plant remains in the field (Seabra Júnior *et al*., 2004). On the other hand, it increases the cost of each seedling.

However, the use of trays for the production of seedlings is usually restricted to species propagated by seeds, and little has been studied for species with vegetative propagation, such as sweet potatoes. In the case of nurseries, when there is a small number of matrice plants for the production of branches, the production of mini-cuttings in a tray can be used, resulting in a greater number of seedlings (Rós *et al*., 2011). In this way, propagation with the use of trays in protected nurseries increases the possibility to propagate and commercialize virus-free seedlings, which favors significant increases in productivity (Rós *et al*., 2012; Montes *et al*., 2015).

Considering the existence of little researches about the use of trays for vegetative propagation of sweet potato, this research aimed to evaluate the production and quality of sweet potato propagated by mini-cuttings in different tray types (162 and 200 cells) and ages of seedlings.

MATERIAL AND METHODS

The experiment was carried out under field conditions, at São Manuel Experimental Farm, located in the municipality of São Manuel-SP (22°46'28''S, 48°34'37''W, 750 m altitude), at São Paulo State University (UNESP), *campus* Botucatu-SP.

The soil of the experimental area was classified as typic distrophic Red Latosol, sandy texture. Chemical analysis (0-20 cm) showed: pH $_{(CaCl2)}$= 5.8; organic matter = 10 g dm^{-3}; P= 168 mg dm^{-3}; H+Al= 19 mmol$_c$ dm^{-3}; K= 1.3 mmol$_c$ dm^{-3}; Ca= 31 mmol$_c$ dm^{-3}; Mg= 8 mmol$_c$ dm^{-3}; sum of bases (SB)= 40 mmol$_c$ dm^{-3}, CEC= 59 mmol$_c$ dm^{-3} and base saturation (V%)= 68%. Based on the chemical analysis of the soil, 20 kg ha^{-1} of N, 60 kg ha^{-1} of P_2O_5 and 60 kg ha^{-1} of K_2O were applied, using urea, triple superphosphate and potassium chloride, respectively, according to recommendation of Peressin & Feltran (2014).

The seedlings were produced in a nursery with an arch type structure, 7.0 m wide, 20.0 m long and 2.5 m high, covered with 150 µm thick transparent low density polyethylene film and protected with anti-aphidic screen on the sides.

Rigid polypropylene trays and Carolina® substrate were used. Young branches of cv. Uruguaiana, virus-free, were used to obtain mini-cuttings with three nodes. The leaves were removed and a segment of the mini-cutting with one node (the most basal) was inserted in the substrate, leaving two nodes above the substrate, according to Nasser *et al*. (2020).

Six treatments, resulting from the factorial 2x3, were evaluated, two types of trays (162 and 200 cells, with 31 and 18 mL of substrate per cell, respectively) and three ages of seedlings (39, 46 and 53 days after placing the mini-cuttings in the trays), in a random blocks design, with five repetitions.

The mini-cuttings were placed in the trays on January 5, 2017 and the seedlings were transplanted with different ages, according to the treatment, in 0.90 m spacing between lines and 0.40 m between plants. Irrigation was carried out by sprinkling system. In the top dressing fertilization, 60 kg ha^{-1} of N (urea) was applied, 45 days after planting the seedlings, according to recommendation of Peressin & Feltran (2014).

On the day of transplanting the seedlings, the following vegetative characteristics were evaluated: number of leaves and primary roots per plant, dry matter weight of the leaves, stem, roots and total per plant. To obtain the dry weight, the samples (leaves, stem and roots) were placed in paper bags, identified and taken to dry in an oven with forced air circulation at 65°C, for 72 hours, until reaching constant weight. Then they were weighed on a digital scale (0.001 g).

Plants were harvested on July 18, 2017, being evaluated the total production of roots and the production of commercial roots, using a digital scale (0.1 g). Roots were considered commercial when weighting between 80 and 500 g, with no apparent defects (rot, cracks and insect damage) and an elongated and uniform shape, according to Nasser *et al*. (2020). Based on production per plot, yield (t ha^{-1}) was estimated.

After harvest, the commercial roots were washed to evaluate the following chemical characteristics: levels of reducing sugar, sucrose, total sugar, starch, total soluble solids, pH, titratable acidity and proteins. Sugars and starch were determined by the method described by Somogyi and adapted by Nelson (1944), with the results expressed in percentage. The soluble solids were determined using the Atago digital refractometer; the results were expressed in °Brix. The pH was measured in the aqueous extract, in a Micronal potentiometer model B-221, according to the standards of the Adolfo Lutz Institute, published in Brasil (2005). For titratable acidity, the titration was done with NaOH 0.1N, and expressed as percentage, according to the standards of the Adolfo Lutz Institute published in Brasil (2005).

The obtained data were subjected to analysis of variance and when significance was verified by the F test, the treatment means were compared by the Tukey test (5%). The Sisvar statistical software was used (Ferreira, 2011).

RESULTS AND DISCUSSION

For the characteristics number of roots and leaves and dry weight of leaves per seedling, the interaction between the factors type of tray and age of seedlings was not significant by the F test. On the other hand, for the characteristics dry weight of stem, roots and total per seedling the interaction between these factors was significant by the F test.

Higher number and weight of leaves per seedling were observed in the tray with 162 cells compared to 200 cells, regardless of the age of the seedlings (Table 1). Lower dry weight of roots and total per seedling were obtained in the tray with 200 cells only for older seedlings, 46 and 53 days old, while for younger seedlings (39 days) there was no difference between the trays (Table 2). Seedlings produced in trays with lower volume cells restrict seedling growth due to less substrate and space for root growth (Seabra Júnior *et al*., 2004; Pêgo *et al*., 2019), even if the number of roots is not restricted (Table 1), as observed in this work. Cells with less volume may restrict the availability of nutrients, oxygenation, water and other essential elements for seedling growth (Seabra Júnior *et al*., 2004). For seedlings 39 days old no restriction was observed on its growth, probably due to the fact that the roots had not occupied all the available space in the cells yet. At the time when the roots occupy the entire cell space, growth restriction began, which occurred first in the 200 cells tray. According to Seabra Júnior *et al*. (2004), the greater the volume of available substrate, the greater the vigor of the seedlings, with better balance in the aerial part / roots ratio, which can provide better development after transplantation. Seedlings with higher weights in trays with greater volume per cell were also observed in other vegetables (Seabra Júnior *et al*., 2004; Piovesan & Cardoso, 2009; Costa *et al*., 2013; Lima *et al*., 2018).

Regarding the age of the seedlings, the youngest (39 days) had a lower number and dry weight of leaves (Table 1), and lesser dry weight of stem, roots and total (Table 2) than seedlings of other ages, regardless of the tray type, probably because they were still developing. Seedlings 46 days old showed higher values of leaf dry weight than seedlings with 53 days, regardless of the tray (Table 1) and greater dry weight of stem and total, only for the

Table 1. Number of primary roots and leaves and dry weight of leaves (DWL) of sweet potato seedlings obtained by mini cuttings depending on the type of tray and the ages of the seedlings. Botucatu, UNESP, 2017.

Number of cells per tray	Number of primary roots	Number of leaves	DWL (g)
162	13.7 a	5.2 a	0.708 a
200	13.5 a	4.4 b	0.622 b
Seedlings age (days)			
39	13.5 a	3.6 b	0.171 c
46	13.3 a	5.4 a	0.959 a
53	14.0 a	5.4 a	0.865 b
CV (%)	18.1	17.1	11.9

Averages followed by the same letter, in columns, do not differ from each another, by the Tukey test at 5% probability. CV = coefficient of variation.

Table 2. Dry weight of stem (DWS), roots (DWR), and total (DWT) of sweet potato seedlings obtained by mini cuttings depending on the type of tray and the ages of the seedlings. Botucatu, UNESP, 2017.

Seedlings age (days)	DWS (g)		DWR (g)		DWT (g)	
	Number of cells per tray					
	162	200	162	200	162	200
39	0.10 Ac	0.11 Ab	0.22 Ab	0.17 Ab	0.50 Ac	0.44 Ab
46	0.85 Aa	0.62 Ba	0.82 Aa	0.71 Ba	2.71 Aa	2.23 Ba
53	0.63 Ab	0.60 Aa	0.87 Aa	0.70 Ba	2.41 Ab	2.14 Ba
CV (%)	8.1		8.3		7.1	

Averages followed by the same letter, uppercase in lines and lowercase in columns, do not differ from each other, by the Tukey test at 5% probability. CV = coefficient of variation.

Table 3. Total and commercial yield of sweet potato roots according to type of tray and ages of the seedlings obtained by mini cuttings. Botucatu, UNESP, 2017.

Type of tray	Seedlings age (days)		
	39	46	53
	Total yield of roots (t ha^{-1})		
162 cells	11.0 Aa	9.9 Aa	8.8 Aa
200 cells	14.4 Aa	11.5 ABa	7.9 Ba
CV (%)	30.7		
	Commercial yield of roots (t ha^{-1})		
162 cells	9.5 Aa	7.7 Aa	6.9 Aa
200 cells	12.9 Aa	9.3 ABa	6.2 Ba
CV (%)	35.4		

Averages followed by the same letter, uppercase in lines and lowercase in columns, do not differ from each other, by the Tukey test at 5% probability. CV = coefficient of variation.

tray with 162 cells, while for the tray with 200 cells there was no difference between seedlings 46 and 53 days old for these characteristics (Table 2). According to Ichikawa *et al*. (2019), in situations in which the seedlings need to stay for a longer period in the trays, the supplemental fertilization of the seedlings is also essential for the maintenance of their quality.

Regarding production of roots (total and commercial) characteristics, the interaction between the factors type of tray and age of seedlings was significant by the F test.

There was no difference in root production (total and commercial) depending on the type of tray, regardless of the age of the seedlings (Table 3). He *et al*. (2000) also did not observe difference in the production of sweet potato roots by testing two types of seedling production containers, with 35 and 55 mL, that is, with greater volumes of substrate than those used in this research (18 and 31 mL).

For the 162-cell tray, the age of the seedlings did not affect the production of roots (total and commercial). On the other hand, for the 200-cell tray, higher root production (total and commercial) was observed on seedlings 39 days old compared to seedlings with 53 days (Table 3). Seabra Júnior *et al*. (2004) also observed that older seedlings produced in trays with greater number of cells and, consequently, less substrate volume per cell, resulted in cucumber plants with less productive potential. Probably, these older seedlings (53 days) have already passed the ideal stage for transplanting, and even though they had higher values for number of leaves and dry weight (leaves, stem, roots and total) than the younger seedlings (39 days) this does not mean that they are of better quality, which shows the importance of evaluating not only the seedling phase, but also the development after the transplant until the end of the cycle and, consequently, the production. Godoy & Cardoso (2005) also observed that cauliflower seedlings, transplanted after the ideal stage, can impair productivity. In the only research with sweet potatoes found in the literature that studied the age of seedlings produced in containers, Islam *et al*. (2006) found no difference. However, the age difference between treatments studied by these authors was only 4 days (seedlings 11 and 14 days old).

No differences were observed among the roots of the different treatments for titratable acidity, with an average of 0.089 g of citric acid/100 g (Table 4), a value similar to those reported by Gouveia *et al*. (2014) and Corrêa *et al*. (2015), who obtained, on average, 0.079 and 0.091 g of citric acid/100 g, respectively. Acidity is attributed to the presence of organic acids that are dissolved in the vacuoles of cells in free form or combined with esters' salts. These organic acids are some of the responsible for the characteristic aroma, considering that some components are volatile and can serve as an energy reserve, through their oxidation in the Krebs cycle (Chitarra & Chitarra, 2005; Gouveia *et al*., 2014).

Table 4. Titratable acidity, pH, levels of reducing sugars, total sugars, sucrose, total soluble solids and starch from commercial sweet potato roots depending on the type of tray and age of the seedlings obtained by mini cuttings. Botucatu, UNESP, 2017

Type of tray	Seedlings age (days)		
	39	46	53
	Titratable acidity (g citric acid $100g^{-1}$)		
162 cells	0.091 Aa	0.088 Aa	0.096 Aa
200 cells	0.082 Aa	0.092 Aa	0.086 Aa
CV (%)	9.0		
	pH		
162 cells	6.4 Ab	6.4 Aa	6.5 Aa
200 cells	6.6 Aa	6.5 Ba	6.5 Ba
CV (%)	0.6		
	Reducing sugars (%)		
162 cells	0.61 Aa	0.69 Aa	0.49 Aa
200 cells	0.72 Aa	0.65 Aa	0.55 Aa
CV (%)	32.0		
	Total sugars (%)		
162 cells	1.25 Aa	1.84 Aa	1.17 Aa
200 cells	1. 95 Aa	1.42 Aa	1.28 Aa
CV (%)	42.3		
	Sucrose (%)		
162 cells	0.61 Aa	1.09 Aa	0.64 Aa
200 cells	1.16 Aa	0.74 Aa	0.69 Aa
CV (%)	52.8		
	Total soluble solids (°Brix)		
162 cells	6.3 Aa	5.8 Aa	5.7 Aa
200 cells	5.3 Ab	5.6 Aa	5.4 Aa
CV (%)	8.2		
	Starch (%)		
162 cells	15.3 Aa	15.3 Ab	16.4 Aa
200 cells	16.8 Aa	17.9 Aa	13.9 Bb
CV (%)	9.8		

Averages followed by the same letter, uppercase in lines and lowercase in columns, do not differ from each other, by the Tukey test at 5% probability. CV = coefficient of variation.

Also for levels of sucrose, reducing sugars and total sugars, no differences were observed among the roots of the different treatments, with averages of 0.82%, 0.62%, and 1.48%, respectively (Table 4). These values of reducing sugars are lower than those obtained by Corrêa *et al*. (2016, 2018) who reported average levels between 2.52% and 3.25%. For starch levels, although some significant differences were obtained, a trend was not observed, with an average of 15.9%, a value much higher than that reported by Corrêa *et al*. (2018) (8.94%) and Nobrega *et al*. (2019) (8.97%). Corrêa *et al*. (2016) highlight that the levels of sugars and starch can vary a lot according to the cultivar studied, in addition to fertilization, conservation, among other factors, which may explain the great differences between the values obtained by different authors.

For total soluble solids (TSS) content, the only difference observed was the lower value observed for roots of treatment in trays with 200 cells compared to plants in the tray with 162 cells only for the youngest seedlings, 39 days old (Table 4), with no difference between ages or between trays for other ages (46 and 53 days), with a general average of 5.7ºBrix. This value is lower than that of Gouveia *et al*. (2014) and Corrêa *et al*. (2015), who obtained averages of 6.62ºBrix and 6.48ºBrix, respectively. According to Gouveia *et al*. (2014), soluble solids consist mainly of sugars. Therefore, the lower values obtained in the present research must be due to the lower values of sugars observed. Still according to these authors, this characteristic, TSS, is one of the main ones in determining the sweet taste of the roots.

The roots obtained from seedlings, 46 and 53 days old, in the tray with 200 cells showed lower pH than those obtained with younger seedlings (39 days). However, although significant, the difference was only 0.1 units (Table 4) and the overall average was 6.5, a value similar to that reported by Gouveia *et al*. (2014, 2015), (average of 6.39).

It is recommended to avoid old seedlings, that is, seedlings are recommended with a maximum of 43 days after planting of mini-cuttings on trays with 200 cells, while for trays with 162 cells no difference in root production was observed with the different ages of the seedlings.

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