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Research Article

Production of *Pereskia aculeata* seedlings combining substrates and cutting diameters[1]

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ABSTRACT

Seedling production is one of the most important stages of plant cultivation, with quality mainly depending on the substrate and plant material used. This study aimed to evaluate the production of *Pereskia aculeata* seedlings combining substrates and cutting diameters. The experimental design was completely randomized, in a 5 x 3 factorial arrangement, corresponding to five substrate combinations (commercial, kapok, palm, commercial + kapok and commercial + palm) and three cutting diameter ranges (0.5-3.0, 3.1-5.5 and 5.6-8.0 mm). The following parameters were evaluated: plant height, leaf length and width, number of shoots and leaves, root length, shoot and root fresh mass, shoot and root dry mass, total fresh and dry mass and Dickson quality index. There was a significant interaction effect between substrates and cutting diameters on the seedlings formed, except for number of shoots, leaf length and root dry mass. Seedlings of higher quality can be achieved with larger cutting diameters combined with commercial substrate. The palm and kapok substrates can be used alternatively when combined with larger cutting diameters.

KEYWORDS: *Ora-pro-nobis*, plant propagation, non-conventional food plants.

RESUMO

Produção de mudas de *Pereskia aculeata* combinando substratos e diâmetros de estaca

A produção de mudas é uma das etapas mais importantes no cultivo de hortaliças, com qualidade dependendo principalmente do substrato e do material vegetal adotado. Objetivou-se avaliar a produção de mudas de *Pereskia aculeata* combinando substratos e diâmetros de estaca. O delineamento experimental foi inteiramente casualizado, em esquema fatorial 5 x 3, com combinação de cinco substratos (comercial, samaúma, palheira, comercial + samaúma e comercial + palheira) e três faixas de diâmetro de estaca (0,5-3,0; 3,1-5,5; e 5,6-8,0 mm). Foram avaliados a altura, comprimento e largura das folhas, número de brotos e de folhas, comprimento da raiz, massa fresca da parte aérea e raízes, massa seca da parte aérea e raízes, massa fresca e seca total, bem como calculado o índice de qualidade de Dickson. Houve interação significativa entre os substratos e diâmetros de corte nas mudas formadas, exceto para número de brotos, comprimento de folha e massa seca de raiz. Mudas de maior qualidade podem ser obtidas a partir de estacas de maior diâmetro em combinação com substrato comercial. Os substratos de palheira e samaúma podem ser uma alternativa, quando combinados com estacas de maior diâmetro.

PALAVRAS-CHAVE: *Ora-pro-nobis*, propagação vegetativa, plantas alimentícias não convencionais.

INTRODUCTION

Ora-pro-nobis (*Pereskia aculeata* Mill.) is a plant species of the Cactaceae family that stands out for its nutritional value and high protein, vitamin and mineral contents, being a source of bioactive substances (Silva et al. 2023). The species plays a potentially beneficial role in preventing diseases such as cancer, diabetes, osteoporosis and cardiovascular problems, and is highlighted as a functional food due to its potential chemical characterization benefits (Costa et al. 2012, Laverde Junior et al. 2022).

Pereskia aculeata Mill. is commonly propagated by cuttings, showing favorable characteristics that include easy rooting, fast reproduction, growth uniformity and the possibility of producing several cuttings from a single mother plant (Oliveira et al. 2019). Seedlings produced by this method show a better development when growing under full sunlight and an easy adaptation to different soil types (Barbosa et al. 2011, Madeira et al. 2013, Silva et al. 2022). However, aspects such as plant material, substrate, water, plant nutrition and cutting diameter should be considered in order to produce

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and obtain quality seedlings. In general, larger cutting diameters result in greater rooting and development capacities, as well as more shoots and adventitious roots, with the appropriate cutting diameter differing according to the species (Prieto et al. 2019, Gomes & Krinski 2020).

The seedling success and quality may depend on how the plant material interacts with substrates (Arantes et al. 2021). In this scenario, the high costs of commercial substrates may be financially unfeasible for family farmers, justifying the search for alternative substrates, instead of conventional ones. Any material used as an alternative substrate must be made organically through the decomposition of plant residues and have proper density, water retention capacity and nutritional balance (Brito et al. 2017).

Alternative substrates have received increased attention and are now being employed to produce seedlings of some species. Organic leftovers found in the Amazon rainforest that can be used as substrate include decomposed stems of the kapok tree (*Ceiba pentandra* L.) and urucuri palm (*Attalea phalerata*), both native to the Amazonian region. For centuries, traditional peoples have used these residues through natural decomposition to grow ornamental and food species, which could also be an alternative to produce seedlings of several species of interest (Araújo Neto et al. 2017, Costa et al. 2017, Siqueira et al. 2020).

The success of seedling production and the high yields of some unconventional food plants have already been reported in the literature for some species when using alternative substrates such as *Alternanthera sessilis* L. (Silva et al. 2022) and *Talinum triangulare* (Jacq.) Willd. (Arantes et al. 2021), in most cases favoring the plant performance, with emphasis on vegetable crops, and showing promising results at affordable costs (Freitas et al. 2013, Siqueira et al. 2020).

In the Brazilian state of Acre, following the overall pattern of the North region of Brazil, the *P. aculeata* cultivation is mostly limited to backyards and small vegetable gardens, and no commercial production records have been found. However, the seedling production may facilitate the cultivation of this species (Lage 2015). From this perspective, considering the availability of easily accessible alternative materials in Acre and the predominant production by cuttings, this study aimed to assess the production of *P. aculeata* seedlings in a variety of substrates and cutting diameters.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse at the Universidade Federal do Acre, in Rio Branco, Acre state, Brazil (9º57’34”S, 67º52’13”W and mean altitude of 170 m), from October to November 2022. The climate in the region is hot and humid, fitting the Am type, according to the Köppen classification, with mean temperature of 25.4 ºC and relative humidity of 88.4 %.

Alternative materials included kapok substrate produced from decomposed kapok tree stems (*Ceiba pentandra*) and palm substrate produced from decomposed urucuri palm tree stems (*Attalea phalerata*) acquired from rural family farms. The substrates and mixtures used in the experiment were subjected to chemical and physical analyses, and the commercial substrate Mecplant®, made of pine bark, dolomitic limestone, NPK Fertilizer, single superphosphate and vermiculite, was used for cultivation.

The experimental design was completely randomized, in a 5 x 3 factorial arrangement, corresponding to five substrate combinations [commercial, kapok, palm, commercial + kapok (1:1) and commercial + palm (1:1)] and three cutting diameter ranges [0.5-3.0, 3.1-5.5 and 5.6-8.0 mm], standardized with a 10-cm length, totaling 15 treatments with 6 replications.

For the chemical and physical analyses, 500 g samples were dried in the shade for 15 days and sent to the laboratory. The findings of this analysis are shown in Table 1.

The plant material used for propagation (cuttings) was provided by an organic vegetable producer in the rural area of Rio Branco (9º53’17”S, 67º49’04”W and altitude of 167 m). The cuttings were sectioned and selected in the morning, when they concentrate ideal levels of abscisic acid and ethylene (0.01 $\mu L\ L^{-1}$), according to the methodology proposed by Andrade (2012). Abscisic acid and ethylene promote and facilitate plant rooting.

Healthy adult plants were selected for the experiment. Then, uniform cuttings measuring 10 cm in length were taken from the middle part of tender branches and bevel-sectioned (Ribeiro Júnior et al. 2021). The cuttings were then sectioned and

Table 1. Chemical and physical analyses of the substrates used in the production of *Pereskia aculeata* seedlings.

Substrate	WHC	P	N	C/N	OC	EC	OM	Ashes	pH
	%					dS m^{-1}	%		
CS	212	0.50	0.77	42.30	32.60	683.0	66.98	33.02	5.53
KS	216	0.11	0.76	46.03	35.20	144.9	78.25	21.75	4.02
PS	456	0.23	2.28	14.20	32.40	1,922.0	83.57	16.43	4.29
CS + KS (1:1)	218	0.23	0.45	74.10	29.60	446.0	67.16	32.84	5.18
CS + PS (1:1)	288	0.31	1.10	61.03	31.70	1,314.0	64.46	35.54	4.92

* WHC: water holding capacity; P: phosphorus; N: nitrogen; C/N: carbon to nitrogen ratio; OC: organic carbon; EC: electric conductivity; OM: organic matter; pH: potential of hydrogen; CS: commercial substrate; KS: kapok substrate; PS: palm substrate.

categorized into three diameter ranges, after which they were placed on the substrates.

Polystyrene containers with volumetric capacity of 200 cm^3 were used to carry out the experiment. The seedlings were grown in a greenhouse with a metallic structure, arched roofs, sides closed with a shading screen and covered with a transparent 100-microns-thick polyethylene sheet. The overall structure measured 6.9 x 22 m, with a ceiling height of 2.0 m and a central height of 3.5 m. Irrigation was performed daily using a watering can.

Morphometric evaluations were performed after 35 days of seedling growth, when stabilization was observed in the number of shoots in six seedlings per treatment. Leaf and root development were evaluated using the following parameters: seedling height, leaf width and length, total number of shoots and leaves, root length, shoot and root fresh mass, shoot and root dry mass, total fresh and dry mass, and the Dickson quality index (DQI).

The leaf length and width, as well as root length, were measured using a digital caliper graduated in mm. The seedling height was measured using a ruler graduated in cm, from the substrate to the longest shoot. The total number of leaves and shoots were determined by simple counting. A precision scale was used to weigh the shoot and root fresh mass. Subsequently, the material was packed in kraft paper bags and oven-dried at 65 ºC, for 48 h, to obtain the shoot and root dry mass.

The DQI was calculated to assess the seed quality. The collected data were checked for the presence of discrepancies using the Grubbs test, for normality of residuals using the Shapiro-Wilk test and for variance homogeneity using the Cochran test. Following that, analysis of variance was performed using the F-test, with comparison of means with the Tukey test, when statistical significance was established (at 5 % of probability). Statistical analyses were performed using the System for Analysis of Variance software (Ferreira 2011).

RESULTS AND DISCUSSION

According to the F-test, there was a significant interaction ($p < 0.05$) between the combined factors of substrate and cutting diameter on plant height, leaf width, total number of leaves, shoot and root dry mass, root length, total dry mass and DQI.

The 5.6-8.0 mm diameter achieved higher mean values for plant height in all the substrates, followed by 3.1-5.5 mm in the commercial and kapok substrates. Only in the commercial + kapok substrate the 5.6-8.0 mm diameter differed individually from the other diameters studied (Table 2).

The diameter range did not affect the leaf width. However, there was a significant effect for substrates within the diameter treatment. The commercial, palm and commercial + palm substrates resulted in the highest means for leaf width. The 5.6-8.0 mm diameter showed the best results for the palm and commercial + palm substrates, resulting in a larger leaf size, followed by 0.5-3.0 mm. In agreement with what was observed for plant height, 5.6-8.0 mm stood out in the commercial + kapok substrate, resulting in the highest leaf width mean among the diameters tested. No difference was observed for the total number of leaves among the substrates in all the studied diameters, except for kapok and commercial + kapok, which showed the lowest mean values for the 0.5-3.0 and 3.1-5.5 mm diameters (Table 2).

In all the diameter ranges tested, the commercial, palm and commercial + palm substrates were determinants of high root growth. In the commercial + kapok, commercial + palm, palm and kapok substrates, the larger diameters ranging from 5.6 to 8.8 mm resulted in higher shoot dry

Table 2. Plant height (H), leaf width (LW), total number of leaves (TNL), root length (RL), shoot dry mass (SDM), total dry mass (TDM) and Dickson quality index (DQI) of *Pereskia aculeata* seedlings as a function of cutting diameters combined with substrates.

Substrate	Diameter (mm)	H (cm)	LW (mm)	TNL	RL (cm)	SDM (g)	TDM (g)	DQI
CS	0.5-3.0	13.30 Ba*	35.93 Aa	12.00 Aa	35.93 Aa	0.380 Ca	0.403 Ca	0.016 Bab
	3.1-5.5	15.78 ABa	38.20 Aa	13.50 Aa	38.20 Aa	0.655 Aa	0.693 Aa	0.033 Aa
	5.6-8.8	18.45 Aa	39.63 Aa	14.50 Aa	39.63 Aa	0.518 Ba	0.543 Ba	0.023 ABa
KS	0.5-3.0	7.53 Bb	12.85 Ab	6.33 Bb	12.85 Bb	0.080 Bb	0.092 Bb	0.008 Bb
	3.1-5.5	8.88 ABb	17.63 Ac	6.83 Bb	17.63 Bb	0.088 Bd	0.105 Bb	0.014 ABc
	5.6-8.8	10.88 Ab	12.85 Aa	13.00 Aa	23.67 Ab	0.235 Ac	0.255 Ac	0.019 Aa
PS	0.5-3.0	15.78 Aa	37.27 Aa	11.33 Aa	37.27 Aa	0.408 Aa	0.443 Aa	0.021 Aa
	3.1-5.5	12.60 Ba	34.77 Aab	11.16 Aa	34.77 Aa	0.310 Ac	0.332 Ac	0.019 Abc
	5.6-8.8	15.56 Aa	34.62 Aa	12.50 Aa	34.62 Aa	0.427 Aab	0.453 Ab	0.025 Aa
CS + KS (1:1)	0.5-3.0	7.88 Bb	18.15 Ab	6.17 Bb	18.15 Bb	0.117 Bb	0.142 Bb	0.013 Aab
	3.1-5.5	9.20 Bb	19.92 Abc	8.00 Bb	19.62 Bb	0.165 Bd	0.178 Bb	0.012 Ac
	5.6-8.8	12.15 Ab	27.50 Aa	11.67 Aa	27.50 Ab	0.293 Abc	0.315 Ac	0.020 Aa
CS + PS (1:1)	0.5-3.0	15.60 ABa	38.45 Aa	14.00 Aa	38.45 Aa	0.478 Aa	0.508 Aa	0.020 Aab
	3.1-5.5	13.68 Ba	35.07 Aab	11.17 Aa	35.07 Aa	0.463 Ab	0.498 Ab	0.030 Aab
	5.6-8.8	16.70 Aa	39.60 Aa	12.17 Aa	39.60 Aa	0.460 Aa	0.488 Aa	0.026 Aa

* Means followed by the same uppercase letter in the column do not differ ($p \geq 0.05$) by the Tukey test in relation to the cutting diameters within the substrates; means with different lowercase letters in the column differ ($p \leq 0.05$) by the Tukey test in relation to the substrates within the cutting diameters. CS: commercial substrate; KS: kapok substrate; PS: palm substrate.

mass means. The combination between commercial substrate and 3.1-5.5 mm diameter, on the other hand, resulted in a higher shoot dry mass accumulation.

In general, the kapok and commercial + kapok substrates had the lowest mean values for all the studied morphological properties, what could be due to the substrate porosity and low electrical conductivity levels of 144.9 and 446.0 dS m^{-1}, respectively. These values are below the detection limit that the substrate or soil cannot exceed (4,000 dS m^{-1}). As a result, the transport of essential solutes for plant growth was insufficient (Cavalcante et al. 2010).

Another crucial consideration refers to the nutritional value of the substrates. The *P. aculeata* seedlings produced in the commercial, palm and commercial + palm substrates showed the highest means for most variables, with 0.77, 2.28 and 1.10 % of nitrogen (N), respectively. According to Kratz et al. 2013, substrate N concentrations should range from 0.70 to 2.50 %, in order to favor leaf expression.

Guimarães et al. (2019) found similar results for leaf width, when evaluating morphological attributes of arugula, observing an increase in leaf width and other agronomic parameters when N-rich materials were used as substrate. Dias et al. (2022) discussed the significance of organic matter incorporation, stating that minimum concentrations of 40 % are required to enable appropriate plant development and nourishment.

The organic matter concentrations observed in the palm and commercial + palm (83.57 and 64.46 %) substrates, combined with larger cutting diameters (5.6-8.0 mm), implying in greater carbohydrate reserves, favored the passage of electric currents, directly influencing the uptake of nutrients present in the solution of the substrates used in the experiment.

In addition to the high organic matter and electric conductivity concentrations in these substrates, the high values of organic carbon, water retention capacity and pH (Table 1) also stood out, showing similar values to the commercial substrate used as the reference treatment in this experiment, demonstrating their potential application as alternative sources for seedling production.

Araújo Neto et al. (2017) noticed that, in terms of plant height, the alternative straw substrate, either in its natural composition or mixed with the commercial substrate, produced plants with better initial development and greater vigor, a result similar to that obtained in this experiment for the formation of *P. aculeata* seedlings.

The substrate is extremely important in the seedling production stage. In a study with *P. aculeata*

Plum., Santos et al. (2019) evaluated the biotic factors related to the type of substrate that could influence the seedling development, verifying that the cuttings used in seedling formation showed a better development when in a mixture of commercial and alternative substrates.

The DQI is a tool widely used to indicate seedling quality, calculating the correlation between the robustness variables (height and diameter) and the ratio of shoot to root dry biomass. Thus, the higher the DQI value, the higher the quality standard of the produced seedling (Maekawa et al. 2020).

The combination of the commercial substrate with the cuttings of intermediate diameter (3.1-5.5 mm) resulted in seedlings with the highest DQI. There was no difference in the association of diameters within each substrate when the palm, commercial + kapok and commercial + palm substrates were evaluated. However, there was a difference in each isolated diameter with regard to the substrate, showing that the 5.6-8.0 mm diameter had a higher mean value than the others. These results indicate that the thicker the diameter, the better the quality of the obtained seedlings.

The total number of shoots, leaf length and root dry mass did not indicate a significant interaction between the parameters substrate and cutting diameter (Table 3).

The total number of shoots showed no statistically significant differences between substrates or cutting sizes. The commercial, palm and commercial + palm substrates had an isolated effect that encouraged an increase in the leaf length and root dry mass parameters. The diameters of *P. aculeata* cuttings had no effect on these factors. These findings are comparable with those of Guerra et al. (2020), who demonstrated the effectiveness of adopting alternative N-rich sources (e.g., palm substrate and its combination with commercial substrate), in the development of agricultural seedlings.

Table 3. Total number of shoots (TNS), leaf length (LL) and root dry mass (RDM) of *Pereskia aculeata* seedlings as a function of cutting diameters combined with substrates.

Substrate	TNS	LL (mm)	RDM (g)
CS	2.166 a*	79.66 a	0.2889 a
KS	2.333 a	36.63 c	0.1611 b
PS	2.277 a	73.76 a	0.2778 ab
CS + KS (1:1)	2.111 a	47.46 b	0.2000 ab
CS + PS (1:1)	2.166 a	83.12 a	0.3110 a
Diameter (mm)	**TNS**	**LL (mm)**	**RDM (g)**
0.5-3.0	2.167 a	2.167 a	2.000 a
3.1-5.5	2.333 a	2.000 a	2.500 a
5.6-8.8	2.000 a	2.833 a	2.333 a

* Means followed by different lowercase letters in the column differ ($p \leq 0.05$) by the Tukey test. CS: commercial substrate; KS: kapok substrate; PS: palm substrate.

CONCLUSIONS

1. A higher *Pereskia aculeata* seedling quality can be obtained from larger cutting diameters combined with commercial substrate;
2. Palm and kapok can be used as alternative substrates when combined with larger cutting diameters.

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