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Article

Vegetative Propagation of Pequizeiro (*Caryocar brasiliense* Camb.) by Cuttings: Strategy for Conservation and Sustainable Use in the Cerrado

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ABSTRACT
The pequi tree (*Caryocar brasiliense* Camb.) is an emblematic native species of the Brazilian Cerrado, of great ecological and socioeconomic importance. Although widely used by traditional communities, it is still mainly propagated by seeds, which limits its production due to dormancy and low germination rates. The objective of this study was to evaluate the rooting of pequi cuttings as a function of the age of the parent plant, type of cutting, substrate, and influence of pruning. Two experiments were conducted in a greenhouse environment with intermittent misting. In the first experiment, the use of three substrates (Bioplant® , Amafibra® , and MecPlant®), two types of cuttings (herbaceous and semi-woody), and two plant ages (young and adult) were evaluated. In the second experiment, the effect of rejuvenation pruning on young and adult trees was evaluated. The variables analyzed were: live cuttings (EV), with callus (EC), with root primordia (PR), rooted (ER), and average root size (TR). The results showed that: (i) cuttings from young plants had higher survival and root primordia formation compared to those from adult plants; (ii) there was no significant difference between herbaceous and semi-woody cuttings, although herbaceous cuttings showed greater callus and RP formation; (iii) the Bioplant substrate® showed the best results in EV and EC, and (iv) rejuvenation pruning negatively influenced all parameters evaluated, regardless of plant age. Thus, we conclude that vegetative propagation of pequi trees by cuttings is feasible, especially with the use of cuttings from young plants in Bioplant substrate® , and that rejuvenation pruning is recommended after the removal of cuttings.
Keywords: pequi, seedling production, family farming.

ABSTRACT
The pequi tree (*Caryocar brasiliense* Camb.) is an emblematic native species of the Brazilian Cerrado, of great ecological and socioeconomic importance. Although widely used by traditional communities, its propagation is still primarily by seed, which limits its production due to dormancy and low germination rate. The objective of this study was to evaluate the rooting of pequi cuttings as a function of the age of the mother plant, cutting type, substrate, and the influence of pruning. Two experiments were conducted in a greenhouse environment with intermittent misting. The first experiment evaluated the use of three substrates (Bioplant®, Amafibra®, and MecPlant®), two types of cuttings (herbaceous and semi-hardwood), and two plant ages (young and mature). The , the second experiment evaluated the effect of rejuvenation pruning on young and mature trees. The variables analyzed were: live cuttings (EV), cuttings with callus (EC), cuttings with root primordia (PR), rooted cuttings (ER), and average root size (TR). The results showed that: (i) cuttings from young plants showed greater survival and root primordia formation compared to those from

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adult plants; (ii) there was no significant difference between herbaceous and semi-hardwood cuttings, although herbaceous cuttings showed greater callus formation and PR; (iii) the Bioplant® substrate presented the best results in LV and EC; and (iv) rejuvenation pruning negatively influenced all parameters evaluated, regardless of plant age. Therefore, we conclude that vegetative propagation of pequi trees by cuttings is viable, especially using cuttings from young plants in Bioplant® substrate, and that rejuvenation pruning is recommended after cuttings are taken.
Keywords: pequi, seedling production, family farming.

Introduction

The pequi tree (*Caryocar brasiliense* Camb.) is one of the most emblematic native species of the Cerrado, playing a fundamental ecological role as a food source for wildlife, a honey plant, and an important component in nutrient cycling in savanna and forest areas (Kuhlmann, 2012; Oliveira *et al.*, 2010).

In addition to providing ecosystem services, pequi is of great socioeconomic importance to traditional communities and family farmers, as it is a source of income and food security, especially in regions such as Goiás, Minas Gerais, Tocantins, and Bahia (Homma, 1993; Medeiros, 2011; Silva *et al.*, 2021). Its fruits are widely consumed fresh or processed, used in regional cuisine and in the food, cosmetics, and pharmaceutical industries due to their antioxidant and anti-inflammatory properties (Morais *et al.,* 2013; Faria *et al.,* 2014; Silva *et al.,* 2021).

Data from IBGE (2022) indicate that national pequi production exceeded 74,000 tons, with the states of Minas Gerais, Goiás, and Tocantins as the main producers. According to Silva *et al.* (2021), pequi represents a significant source of income for family farmers and extractivists in the Cerrado, but because it is predominantly sourced from extractivism, it is subject to climatic variations and availability, which compromises the consistency of supply and the predictability of income.

According to Cardoso *et al.* (2020), agroforestry systems that incorporate native species such as pequi trees promote not only productive diversification but also the conservation of plant resources associated with the Cerrado biome. Pequi can also be used in silvopastoral systems, which consist of raising cattle on pasture intercropped with tree species, in landscaping in parks, squares, residences, in nurseries for the supply of seedlings, wood production, in rural backyards, among others (Ribeiro, Amorim, and Barros, 2020; Siqueira *et al.,* 2021; Vieira *et al.,* 2014; Silva Júnior, 2005; Kuhlmann, 2012; Silva *et al.,* 2001).

Although the species is not threatened with extinction (BGCI, 2019), several studies point to the need for attention to its conservation. Recent research shows growing threats, mainly due to climate change and agricultural expansion in the Cerrado (Strassburg *et al.*, 2017; Nabout *et al.*, 2011). In addition, its physiological characteristics of difficult seed germination and reproductive age, the occurrence of pests that are difficult to control (Vieira *et al.,* 2014; Carvalho and Castro, 2016; Santos, Lima, and Silva, 2005), and the loss of native dispersing fauna (Silva and Scariot, 2013) are also threats.

Therefore, given the ecological, economic, and sociocultural importance of pequi, measures and strategies that promote its appreciation should be encouraged through the formulation of public policies that favor sustainable use, allowing for income generation and associated conservation (Silva *et al.*, 2021). Carneiro *et al.* (2014), in a study of plant species in the central-western region of Brazil, emphasize that extractive pressure on some species should receive special attention, in the sense of seeking cultivation techniques, as well as raising public awareness of the need for sustainable use and conservation of these species.

Increasing the availability of seedlings and promoting continuous and sustainable production to supply the market may be a good strategy for the valorization, dispersion, and conservation of pequi. Most pequi seedlings are produced from seeds, which, despite their low germination rate due to natural dormancy (Santos *et al.,* 2006;

Leão *et al.,* 2012; Tsuda and Almeida, 2012), is essential for maintaining genetic variability (Naves *et al.,* 2010; Dias *et al.,* 2012).

The propagation of native Cerrado species through cuttings is a promising technique that can reduce the cost of seedling production by increasing the scale of production (Martins *et al.*, 2015) and allows the fixation of selected genotypes (Dias *et al.*, 2012). In addition to contributing to the establishment of commercial crops, it conserves genetic resources, minimizing the risks of extinction and the impacts of predatory extractivism (Oliveira *et al.,* 2013). Another advantage of vegetative propagation through cuttings is that it can reduce the juvenility of the pequi tree. This phase is characterized by prolonged vegetative development with no flowering or fruiting (Betanin and Nienow, 2010).

For the development of cuttings protocols, several factors must be observed, including the species' suitability for cuttings, age and nutritional aspects of the propagule donor matrix, production of endogenous hormones promoting rhizogenesis, consistency of the cutting, propagule collection period, and substrate type (Dias *et al.*, 2012; Petry *et al.,* 2012; Xavier *et al.,* 2013). According to Dias *et al.* (2015), several factors limit the propagation of native species, mainly the absence of efficient methodologies for rejuvenating adult material in the field. Pruning branches or twigs from mature trees can restore the youthfulness of these propagule-producing organs, yielding herbaceous or semi-woody cuttings with greater rooting potential (Xavier *et al.,* 2013, Guimarães *et al.* (2019).

Thus, this article seeks to contribute more information on the vegetative propagation of pequi through cuttings, verifying the influence of pruning, types of cuttings, and substrates on the rooting process of the pequi tree.

Materials and Methods

The experiments were carried out in the Horticulture Sector of the School of Agronomy (Federal University of Goiás – Goiânia/GO), in a 42 m² greenhouse with 90% relative humidity maintained through intermittent misting.

All cuttings used in the experiments were harvested in the morning from the School of Agronomy arboretum and transported to the greenhouse in buckets of water to prevent dehydration. To ensure that the cuttings could express their rhizogenic potential, no fungicide treatment was used. In the greenhouse, each cutting was placed in a 12 cm long plastic tube with a capacity of 260 cm³ ([3], properly filled with the substrate appropriate for the experiment.

The data collected in the experiments were submitted to analysis of variance and the means were compared using the Scott-Knott test at 5% probability, using the ASSISTAT software (Silva, 2008).

EXPERIMENT 1. INFLUENCE OF AGE, TYPES OF CUTTINGS, AND SUBSTRATES ON THE CUTTING OF PEQUI.

In this experiment, woody and semi-woody cuttings were collected from 8 adult trees aged 22 years and 46 young trees aged 6 years, and their viability was evaluated in three commercial substrates with different compositions and physical and chemical characteristics, as described in the table below (Table 1).

Cuttings with six leaflets reduced to half their original size were collected. The cuttings were between 7.5 and 22 cm long and 5 to 13 mm in diameter, contained between one and two buds, and were harvested from branches of the first flush of sprouting in the middle and basal regions of the canopy ( ). Thirty-two days after the experiment was set up, the percentage of live cuttings (EV), cuttings with callus (EC), and root primordia longer than 1 mm (PR) were evaluated.

Table 1. Composition and chemical and physical characterization of the Amafibra®, Bioplant®, and MecPlant® substrates used in the propagation of Caryocar brasiliense. EC = electrical conductivity; Dens = density; WRC = water retention capacity.

Substrate	Composition	pH	EC mS. Cm^{-1}	Density kg/m ^{3}	CRA
Bioplant®	Pine bark and rice husks, manure, sawdust, coconut fiber, vermiculite, ash, agricultural gypsum, yoorin thermophosphate, and fertilizers	6.0	0.7	190	55
Amafibra®	Coconut fiber mesocarp	6.0	0.6	85	55
MecPlant®	Bio-stabilized pine bark and vermiculite	5.5	1.0	360	60

Source: Author

The experimental design adopted was completely randomized, in a 3 x 2 x 2 factorial scheme, with three types of substrates, two types of cuttings, and two ages, with four replicates and three cuttings per plot, for a total of 144 cuttings.

EXPERIMENT 2. INFLUENCE OF AGE AND PRUNING ON PEQUI CUTTINGS

For this experiment, 11 adult trees aged 22 years and 30 young trees aged 6 years were selected, and among them, 3 adults and 17 young trees were randomly selected for rejuvenation pruning (median and basal pruning between 5 and 10 mm of the apical branches).

One hundred forty-four days after rejuvenation pruning, herbaceous cuttings with two pairs of leaves were selected from pruned and unpruned trees. Their leaflets were reduced to half their original size, and the cuttings were between 9.5 and 31.5 cm long and between 5 and 15 mm in diameter. The experiment was set up in the greenhouse as described above, using only Bioplant substrate® .

Sixty-six days after the experiment was set up, the percentage of live cuttings (EV), cuttings with calluses (EC), cuttings rooted with roots longer than 5 mm (ER), and average root size (TR) were evaluated. Root length was measured using a ruler graduated in cm, and the average was calculated from the three largest roots of each cutting.

The experimental design adopted was completely randomized, in a 2 x 2 factorial scheme, with two ages (young and adult) and two types of pruning (with and without pruning), with four replicates and ten cuttings per plot, totaling 160 cuttings.

Results and Discussion

Plant age, types of cuttings, and substrates in pequi propagation

There was no interaction between the factors plant age, types of cuttings, and substrates, so the results will be discussed separately for each of the factors in this experiment.

The age of the plants from which the cuttings were taken influenced survival and root primordia formation. Cuttings from young trees had 76.3% EV and 6.9% PR, while cuttings from adult plants had 49.9% EV and no root formation. The values related to callogenesis did not show a statistically significant difference (Table 2).

Regarding the types of herbaceous and semi-woody cuttings, although positive results were observed in all parameters evaluated (EV, EC, and PR), none of these values showed a significant difference (Table 2).

The results referring to substrates indicate an influence on EV and EC, where the commercial product Bioplant® showed a statistical difference for EV with 77% and 45.8% for EC in relation to Amafibra® 62.4% EV and 27% EC and MecPlant® 49.9% EV and 12.4% EC (Table 2).

Table 2. Percentage of live cuttings (EV), with callus (EC) and root primordia (PR) of *Caryocar brasiliense* as a function of different biological ages, types of cuttings, and substrates. Means followed by the same letter do not differ from each other according to the Scott-Knott test (p>0.05). *e** = significant at the 5% and 1% probability levels, respectively; ns = not significant.

	Treatments	% EV	% EC	% PR
Plant age	Adult	49.96 b	22.30a	0.00 b
	Young	76.35 a	34.69a	6.93 a
	F-test	11.38 **	3.42 ns	5.00 *
Types	Herbaceous	58.29	33.30	4.1
	Semi-woody	68.02	23.58	2.77
	F-test	1.54 ns	2.07 ns	0.20 ns
Substrates	Amafibra®	62.45 b	27.05 b	4.16 a
	Bioplant®	77.06 a	45.80 a	4.16 a
	Mec Plant®	49.96 b	12.48 b	2.08 a
	F test	4.01	8.15	0.20 ns
	CV	42.86	82.22	309.84%

Source: Author

The results of this study show that the age of the parent plants used to obtain cuttings influences the survival of the cuttings and root formation. Dias *et al.* (2012), in studies on cuttings and mini-cuttings of woody forest species in Brazil, report that the age of the parent plant supplying the propagules is a determining factor in the rooting process of the cuttings. Frazon, Carpenedo, and Silva (2010) state that cuttings from young plants root more easily. Guimarães *et al.* (2019), in a study with pequi cuttings at different levels of foliage and pruning, found that cuttings from young plants have a greater capacity for rooting and survival than those from adult plants.

Studies with different tree species have also reached similar results. Hernández *, et al.* (2012), studying *Piptadenia gonoacantha* cuttings*,* found a higher survival and rooting rate in cuttings from young material. Bastos *et al.* (2009) found in their studies with *Averrhoa carambola* that biological age influences the survival and rooting of cuttings. The authors report that young plants have a higher content of rooting cofactors and a lower content of inhibitors. Lima (2021), working with baruzeiro (*Dipteryx alata)* cuttings, emphasizes that cuttings taken from adult plants are difficult to root.

Adult matrices reduce their ability to form roots as they age, and with advancing ontogenetic age, the concentration of endogenous auxins in mature branches gradually decreases (Dias *et al*., 2012). Xavier *et al.* (2013) report that cuttings from mature plants root sporadically, taking longer than cuttings from young plants.

Although we did not observe root primordia formation in cuttings from adult plants, it is important to note that we obtained nearly 50% viability and callus formation in 22.3%, suggesting that root formation in these plants could take longer than in cuttings from young plants. Guimarães *et al.* (2019) observed root primordia formation in 5% of pequi cuttings from adult trees at 42 days, i.e., 10 days longer than in the present study. Carvalho, Ribeiro, and Souza (2020) state that the presence of calluses at the base of pequi cuttings indicates the possibility of natural rooting stimulation.

In a study to aid the domestication and genetic improvement of pequi, Silva *et al.* (2012) verified that significant results can be achieved through the vegetative propagation of pequi trees selected in the field for the physical characteristics of their fruits. According to the authors, the age of the matrix has no effect on the expression of physical variables in pequi fruits, allowing young plants to be selected for vegetative propagation of pequi.

Regarding the types of cuttings (herbaceous and semi-woody), although we did not find a statistically significant difference in any of the parameters evaluated, the results found show similarities with other studies. Hartmann *et al.* (2011) report that herbaceous and semi-woody cuttings have less lignified tissues compared to woody cuttings and therefore share similar characteristics such as greater potential and speed of rhizogenesis.

In the experiment, herbaceous cuttings showed higher mortality with visible tissue deterioration at the base of the cut. Similar observations were found in the studies by Xavier *et al.* (2013) and Santos *et al.* (2014), who stated that herbaceous cuttings are more susceptible due to the deterioration of less lignified tissues. Although their viability was lower, herbaceous cuttings presented more individuals with calluses and root primordia. These results corroborate Xavier *et al.* (2013), Frazon, Carpenedo, and Silva (2010), and Zem *et al.* (2015), who associate herbaceous cuttings with greater rooting capacity.

In the literature, it is possible to note that there are advantages and disadvantages in choosing between herbaceous, semi-woody, and woody cuttings. These may vary according to the species, cultivar, and part of the plant from which it was taken (Frazon, Carpenedo, and Silva, 2010). It is assumed that, for pequi trees, herbaceous cuttings provide faster and higher levels of rooting, while semi-woody cuttings show lower levels of deterioration.

The choice of substrate is crucial to the success of the cutting, especially in species that are difficult to root, such as the pequi tree. Well-structured substrates promote physical and chemical conditions suitable for root development, such as aeration and balanced water retention (Frazon, Carpenedo, and Silva, 2010; Oliveira *et al.,* 2012; Amaro *et al.,* 2013). In this study, the Bioplant substrate® showed superior performance, with 77.0% of cuttings alive and 45.8% callogenesis, surpassing the Amafibra® and MecPlant® substrates. This result may be related to its physical structure and nutritional composition, which favor oxygenation of the base of the cutting and stimulate callus formation (Santos *et al.,* 2012; Xavier *et al.,* 2013; Yamamoto *et al.,* 2013; Mattana *et al.,* 2009).

For the root primordia variable, there was no significant difference between the substrates, but the Bioplant® and Amafibra® substrates showed higher rooting percentages, indicating better physical conditions for the rhizogenesis process. Santos *et al.* (2012), comparing different commercial substrates in the vegetative propagation of *Passiflora cincinnata,* found greater rooting when using the Bioplant substrate® . The authors associated this result with the high phosphorus content of the substrate.

However, the result found in this study may be better associated with the presence of more fibers in these two substrates, providing a more suitable environment for root respiration. Da Silva *et al.* (2012), in a study with cuttings of *Eucalyptus urophylla and* E. *grandis,* report that substrates with higher total porosity enable better root system quality, as oxygen is essential for root respiration. Porosity was mainly observed in substrates containing coconut fiber, allowing for higher rooting percentages (Ristow *et al.,* 2012). In addition, the MecPlant substrate was used for the cuttings® , which had the highest density and water retention capacity, resulting in water accumulation and lower survival rates. Lima *et al.* (2008) state that the absence of oxygenation at the base of the cutting causes deterioration of the cuttings, and Frazon, Carpenedo, and Silva (2010) highlight that one of the factors affecting the success of cuttings is a substrate that does not maintain a balance between moisture and aeration.

INFLUENCE OF AGE AND PRUNING ON PEQUI CUTTINGS

Based on the results of the previous experiment, the substrate and type of cuttings used in this experiment were selected. Despite the low rooting of cuttings from adult plants verified in this study and in Xavier *et al.* (2013), it was decided to maintain this variable, since collecting cuttings from adult plants in the field is essential for the production of clones with desirable characteristics.

For biological age, a significant difference was found only for live cuttings (Table 3), with cuttings from young plants achieving 37.5% survival and adult plants only 16.2%. Callogenesis was 21.2% in young plants and 7.5% in adult plants, and rooting was 3.7% in young plants and 2.5% in adult plants.

A significant difference was found in live cuttings, callogenesis, and rooting for pruning of plants supplying cuttings. Unpruned plants provided 38.7% live cuttings, 22.5% callogenesis, and 6.25% rooting, differing from pruned plants with 15.0% live cuttings, 6.2% callogenesis, and 0.0% rooting (Table 3).

Table 3. Live cuttings (EV), callus (EC), rooted cuttings (ER), and average of the three largest roots (NR) of *Caryocar brasiliense* as a function of biological age in pruned and unpruned trees. Means followed by the same letter do not differ from each other according to the Scott-Knott test (p>0.05). *e** = significant at the 5% and 1% probability levels, respectively; ns = not significant.

	Treatments	% EV	% EC	% ER	NR
Age of plant	Adult	16.25b	7.50a	2.50a	0.48a
	Young	37.50	21.25a	3.75a	0.14a
	Test F	8.10 *	3.74ns	0.42ns	1.39ns
Pruning	With pruning	15.00b	6.25b	0.00b	0.00
	Without pruning	38.75a	22.50a	6.25a	0.62a
	Test F	10.12 **	5.22	10.71**	4.62ns
	CV (%)	55.55	98.89	122.2	186.04

Source: Author

The analysis of variance revealed that there was no interaction between biological ages and pruning for the EV, EC, and ER variables. For the variable length of the three largest roots, we found interaction between biological ages ( ) and pruning (Table 4), where apical bud pruning did not result in root development in young and adult plants, and only unpruned young and adult plants obtained rooted cuttings with equal average lengths of 0.32 cm. Therefore, collecting cuttings from the basal and median regions of the pequi tree canopy in unpruned trees in the field may be a strategy for the vegetative propagation of selected genotypes.

Table 4. Length of the three largest roots of Caryocar brasiliense, as a function of biological age in pruned and unpruned trees. Means followed by the same lowercase letter in the column and uppercase letter in the rows do not differ from each other according to the Scott-Knott test (p>0.05). *= significant at the 5% probability level and ns = not significant.

Length of the three largest roots (cm)		
Plant age (I)	**With pruning**	**Without pruning**
Adult	0.00aA	0.32aB
Young	0.00aA	0.32aB
Interaction (I X P)	0.001*	
CV	163.03	

Source: Author

Regarding plant age, this study showed that in adult pequi trees, the survival, callogenesis, and rooting rates of cuttings decreased. According to Ferreira *et al.* (2010), in most woody species, cuttings obtained from adult plants do not root or have low rooting percentages. Hernández *et al.* (2013)*,* working with vegetative propagation of *Cariniana estrellensis,* found that cuttings obtained from juvenile trees had a 100% survival rate and concluded that young plants provide cuttings with a higher chance of survival and rooting, associating these results with the high rate of endogenous auxins present in cuttings from young plants.

Santos *et al.* (2011), studying the cuttings of 20 native forest species, collected cuttings from the last vegetative flush of adult plants in the field, observing after 45 days in the greenhouse that species such as *Inga marginata* did not root and *Sebastiania scothiana* had a 6% rooting rate. According to the authors, several factors hinder rooting in adult plants, including the degree of tissue maturation. Adult plants may contain lower levels of endogenous auxins, reducing rooting percentages. Dias *et al.* (2012) emphasize that increasing tree age has a negative correlation with root formation in cuttings. According to the authors, due to the greater ontogenetic age and maturation of the branches, the concentration of auxin decreases, reducing adventitious rooting rates.

In addition to the age of the parent plant, the time of collection of the cuttings also has a significant influence on the rooting process of the pequi tree. In this study, it was observed that cuttings from young six-year-old plants had a 37.5% survival rate, 21.2% callus formation, and 3.7% rooting. During the collection period, these plants exhibited sporadic fruiting, which may indicate a higher concentration of auxins and carbohydrates in the leaves, essential elements for the induction of rhizogenesis. On the other hand, adult plants were in a phase of intense flowering and fruiting, a time that demands greater nutritional investment, possibly compromising the allocation of reserves for rooting the cuttings. As a result, cuttings from these adult plants had lower survival rates (16.2%), callus formation (7.5%), and rooting (2.5%). These findings corroborate Santos et al. (2011), who highlight the influence of nutritional factors of the parent plant on the success of adventitious rooting.

In a study with *Campomanesia adamantium*, a species native to the Cerrado, Martins *et al.* (2015) also found that cuttings harvested during the fruiting period had lower percentages of survival and rooting (5% and 10%, respectively). The authors emphasize that the high nutritional requirements of the parent plants influence the low percentages of survival and rooting. Oliveira and Ribeiro (2013), evaluating the rooting of the native Cerrado species *Euplassa inaequalis,* emphasize that flowering and fruiting are periods in which hormones and carbohydrates are directed to these phenological phases, impairing the rhizogenic process.

In addition to the nutritional aspect, the collection period also affects the physiological quality of the cuttings. According to Oliveira and Ribeiro (2013), the collection period of the cuttings is decisive for the formation of adventitious roots. According to the authors, *E. inaequalis* cuttings collected during the rainy season had a survival rate of 0.42%, with no callus or root formation observed. They report that cuttings collected at the end of the dry season lose fewer leaves and have higher carbohydrate levels, achieving survival and rooting rates of 42.0% and 5.42%, respectively. Sarmiento *et al.* (2015), working with cuttings from adult

Ficus cestrifolia plants, achieved 50% rooting after collecting cuttings in September, during the dry season. According to the authors, this is one of the best periods for collecting cuttings, as the plants are in full metabolic activity and the cuttings have lower rates of rooting inhibitors.

For the pequi research, cuttings were collected at the end of November, on days of excessive humidity due to heavy rainfall. During this period, a reduction in the physiological quality of the cuttings was observed, causing high deterioration of young and adult cuttings. Therefore, higher percentages of pequi rooting can be obtained by collecting cuttings in drier periods from August to October, a time of intense vegetative sprouting, higher concentration of nutrients in the parent trees, and better physiological quality of the cuttings.

Regarding the influence of pruning, it has been found that several techniques are used to reverse the juvenility of a plant, such as apical bud pruning, girdling, semi-girdling, and coppicing (Badilla *et al.*, 2016; Xavier *et al.,* 2013), all of which enable the recovery of the juvenile characteristics of adult material (Rickli *et al.,* 2015). However, obtaining juvenile basal cuttings from trees in the field without cutting down the parent plant is a challenge to be overcome (Wendling *et al.,* 2013). For Dias *et al.* (2015), the absence of efficient techniques for the rejuvenation of adult species limits the propagation of native species.

In addition to reversing juvenility, pruning, according to Xavier *et al.* (2013), can be characterized as one of the main forms of vegetative rejuvenation, producing cuttings with greater rooting potential and physiological vigor. In this study, the rejuvenation strategy was to prune apical buds from the middle and basal regions of the crown to induce juvenile sprouting. This technique increased and standardized the production of cuttings, but resulted in lower survival rates, 15% in pruned trees, statistically differing from unpruned trees with 38.7% live cuttings.

The callogenesis process was also lower in pruned trees (6.25%), differing significantly from unpruned plants (22.5%). Callus formation indicates that a longer stay in the greenhouse would increase rooting percentages (Oliveira and Ribeiro, 2013). Pruned tree cuttings did not root after 66 days of research, while unpruned trees showed 6.25% rooting and an average number of 0.62 of the three largest roots.

Bitencourt *et al.* (2009), studying the rooting of *Ilex paraguariensis* cuttings, compared cuttings from the current year's shoots of 13-year-old trees with cuttings from rejuvenated shoots of 17-year-old plants. After 90 days in a greenhouse, the authors found higher percentages of live cuttings (32.5%) and callus (17.7%) in cuttings from the current year's shoots. Similar results were observed for pequi, which after 66 days of study showed 38.7% live cuttings and 22.5% calluses in the current year's shoots on unpruned trees.

Wendling and Brondani (2015), evaluating the effectiveness of vegetative rescue methods for cuttings in *Araucaria angustifolia,* used coppicing and pruning of branches to obtain cuttings. Twenty-six-year-old trees were coppiced, and twenty-year-old plants had their primary branches in the upper third of the crown pruned. The authors report that rooting rates were low, ranging from 12-30% for coppiced shoots and 0-28% for canopy branch shoots. Despite the low rooting rates of the cuttings, the authors emphasize the importance of rescue studies for species of economic, social, and environmental importance.

The survival and rooting of cuttings obtained from basal and median regions of the crown without pruning indicate the potential of the pequi tree for rooting, making it a sustainable strategy for vegetative propagation of this species, without causing damage or mortality to the trees, since the cuttings are collected from apical shoots of the year. However, further studies are needed to define the best rooting protocol for the pequi tree.

Unlike apical bud pruning for the rejuvenation of cuttings, the cutting of the pequi tree could induce the production of juvenile shoots, presenting greater callogenesis and rooting. Cuttings collected from the basal region of the trunk have a higher degree of juvenility, unlike cuttings collected from the basal and median regions of the canopy, which reduce their rooting potential. According to Hartmann *et al.* (2011), woody trees have a maturation gradient from the base to the apex of the plant due to ontogenetic aging, so coppicing, girdling, and semi-girdling are growing techniques in the vegetative rescue of woody species and can be applied to pequi trees.

These techniques are also recommended by Dias *et al.* (2015), who, after 150 days of study with the native Brazilian species *Anadenanthera macrocarpa*, found that basal herbaceous cuttings from coppicing and girdling provided 65.3% and 63.8% survival, 57.1% and 56.2% callus formation, and 25.5% and 26.7% rooting, respectively. The authors report that these are efficient methodologies for rescuing adult trees in the field, highlighting the juvenility of basal cuttings, which have greater rooting potential.

Developing a rooting protocol for pequi is essential for commercial production and preservation of the species. The survival of 37.5% and rooting of 6.25% of cuttings obtained from basal and median regions of the crown indicate the potential of pequi trees for rooting. According to Endres *et al.* (2007), higher survival rates and lower rooting levels indicate that cuttings should remain under misting for longer periods.

It should be noted that no rooting hormones were used in the study of pequi tree rooting, and both young and adult plants rooted, so cuttings may be a promising alternative for pequi propagation. Pruning increased and standardized the supply of propagules in C. *brasiliense* matrices in the field, which is an important characteristic of the pequi tree, but presented 6.25% callogenesis, initiating the rooting process. It should be noted that the cuttings were collected at the end of November, a period of high rainfall, reducing the physiological quality of the cuttings. Bringing forward the pruning season to collect cuttings in drier periods can enhance the rooting of pequi cuttings, contributing to the maintenance of this native Cerrado species.

Final Considerations

Cuttings from young plants are more suitable for propagation, presenting greater viability and callus and root formation. The Bioplant substrate® is the most suitable for pequi propagation. Pruning can reduce the viability and callus and root formation processes in pequi cuttings.

Based on the results of this study, we can conclude that further studies should be conducted to verify the influence of the seasonal period in which the cuttings were collected, since the physiological quality and viability of the cuttings may be associated with the flowering and fruiting season of pequi. Likewise, to define the rooting period, since the low number of cuttings that initiated rhizogenesis in relation to viable plants may indicate that the root formation process in pequi cuttings is longer than the evaluation period used in this study.

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