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Technical feasibility of *Eremanthus erythropappus* (dc.) macleish coppice: critical factor for sustainable management

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SILVICULTURE

ABSTRACT

Background: This study aims to evaluate the technical feasibility of simple coppice system, in a planted stand of the native arboreal species *Eremanthus erythropappus* (DC.) MacLeish (candeia), according to different moments of soil scarification. The experiment is located in Baependi – MG (Brazil), where the mean altitude is 1,165 m and it´s under mild mesothermal climate. The first cycle was harvested under a clear-cutting system at 8 years after planting, with manual soil scarification and exposure of roots around the harvested trees stumps, at 5, 6, 7, and 8 weeks after cutting, i.e., four treatments with four repetitions of 50m^2 plots each. In the first months, adventitious buds sprouting from the roots have been observed inside and outside the perimeter around stumps. The area remained fenced, without thinning or application of fertilizers and, until the third year, the selective clearing was done to eliminate weed competition. Six years after the treatment, measurements of diameter at 1.30 m height (DBH), the height of the sprouts, and the circumference at soil height (CSH) of stumps were taken.

Results: After six years, the regenerated site under simple coppice system presented a density of established plants 216% higher than the harvested site using a high forest system (first cycle), but with only 4.3% of the commercial volume. The correlation between the density of sprouts and the density of stumps indicated that initial plant density can influence the number of sprouts after harvest.

Conclusion: It was verified the simple coppice system feasibility and that scarification technique can be applied up to eight weeks after tree cutting.

Keywords: Candeia. Natural regeneration. Silvicultural system

HIGHLIGHTS

The simple coppice system is feasible for candeia management.
Soil scarification is an essential technique for conducting candeia coppice.
Candeia stand under coppice system presented a plant density 216% higher than the initial planting density.
Candeia stand under coppice system attained, at six years old, 92% of the total volume of the initial cycle (but only 4.3% is commercial).

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INTRODUCTION

Eremanthus erythropappus (DC.) MacLeish (Asteraceae), popularly known as "candeia", is a Brazilian endemic specie found in the Cerrado and Atlantic Forest Domains (Flora do Brasil, 2020). Candeia is classified as a pioneer species (Ministério do Meio Ambiente, 2009) which occurs in ecotone zones between semi-deciduous forests and "campo aberto" (Cerrado grasslands) and also in "campos de altitude" (high altitude grasslands), and according to Pérez et al. (2004), the life cycle of candeia can reach more than fifty years. The species colonize poorly fertile soils and places hard to conduct crops or even other forest species (Araújo et al., 2018a).

As a heliophilous species, it benefits from the entry of light in the forests, provided by natural or anthropic disturbances, which is necessary for its germination and the establishment of its seedlings (Araújo et al., 2018a; Scolforo et al., 2012). Candeia presents great importance value among the species of tree communities in Litolic Neossol environments and, because its tendency to form monodominant stands, called "candeais", it leads to reduced local species richness (Dalanesi et al., 2004).

The small size seeds of *E. erythropappus* presupposes their ability to pass through the dense litter formed by species as *Pteridium aquilinum* (fern), reaching the soil, as reported by Ribeiro et al. (2013), who found a density of candeia of 266.6 plants.ha^{-1} in a natural regeneration site with the occurrence of ferns.

Araújo et al. (2014) evaluated the natural regeneration of *Eremanthus incanus* (Less.) Less, species ecologically and botanically similar to *E. erythropappus,* in a native "candeal" shortly after the fire occurrence and quantified the density of the regenerating stand in up to 26,125 plants.ha^{-1}. These results demonstrate a high regeneration capacity of candeia.

Candeia's main uses are in rural properties for rustic buildings, fence posts, and by the cosmetic and pharmaceutical industry for natural alpha-bisabolol production. Currently, in Minas Gerais state (Southeast Brazil), environmental legislation allows the analysis and approval of Sustainable Management Plans for the extraction of candeia wood in natural stands (Minas Gerais, 2013). One of the goals of sustainable management is to promote a possible increase in the candeia population through the conduct of natural regeneration.

In sites submitted to sustainable management by "seed tree silvicultural system", the occurrence of the natural regeneration of candeia was attributed to the intense dispersion of seeds throughout the site, after cutting and scarifying the soil (Araújo et al., 2018a; Silva et al., 2008; Andrade, 2009). After the exploration of the native candeal, the soil is cleaned, scarified by plowing and harrowing, and limestone and phosphate are applied using agricultural machinery (Silva et al., 2008; Andrade, 2009.

Araújo et al. (2018b) collected data from 46 plots, in five sites submitted to the seed tree silvicultural system and it was concluded that the natural regeneration of candeia occurs differently in each fragment, depending on the environmental conditions, being mainly influenced by the altitude and predominance of the species before management. In these sites, the soil scarification was done manually, in a circular form.

Since the publication of Ordinance No. 01 of January 5, 2007, mechanized soil operation is no longer allowed in areas under sustainable management. Since then, the manual technique of scarification with a circular form made with hoes was adopted (Instituto Estadual de Florestas - IEF, 2007). Meanwhile, the efficiency of this technique has been put to test by entrepreneurs and rural producers, as natural regeneration does not occur uniformly using this methodology.

The results obtained by Melo et al. (2012) indicated significant sprouting from roots of candeia after root exposition through soil scarification. In this way, the proposal for the management of stands using the simple coppice system was considered potentially viable.

The present work aims to evaluate the technical feasibility to conduct *Eremanthus erythropappus* (DC.) MacLeish under the simple coppice system, using different time intervals between the harvesting and the root exposition through manual soil scarification around the stumps, in a commercial planted stand. We expect the sooner the scarification is done after the harvesting, the more sprouts are likely to be accounted.

MATERIAL AND METHODS

This study was carried out in a 3,916 m² commercial planted stand of *Eremanthus erythropappus*, located on Citróleo Indústria e Comércio de Óleos Essenciais Ltda farm. This farm is located at the municipality of Baependi-MG (21°58'06.8"S and 44°45'01.6"W), mean altitude of 1,165 m, region of Serra da Mantiqueira Environmental Protection Area ("APA") and next to Serra do Papagaio State Park.

The predominant original vegetation is "campo de altitude" (altitude field) and the soil is a Dystrophic and Alic Cambisol (medium texture). The region's climate is classified as mild mesothermal, semi-humid during four to five months and present B3 humidity index according to Spatial Data Infrastructure of the State System of Environment and Water Resources IDE-Sisema (2020). The annual temperature varies between 14 and 22° C and the annual rainfall average is 1,581 mm.

The implantation of the candeal was carried out in January 2005. To prepare the soil, grooves were made approximately 30 cm deep, in level, with an implement attached to the tractor. The spacing used was 2.5 x 2.0 m, and the planting fertilization was done with 150 g of NPK 08-28-16 applied in the groove. We also controlled weeds, leaf-cutting ants, and we carried out the maintenance of roads and firebreaks.

In 2012, all individuals with a diameter equal or larger than 5 cm (at least one stem) at 1.3 m in height (diameter at breast height, DBH) had their total height and DBH of each stem recorded.

The Declaration of Harvesting and Marketing of Planted Forests was emitted on September 25, 2012, by the State Forestry Institute of Minas Gerais (IEF), a historic landmark in the management of candeia plantations, as it was the first commercial planting to have their harvest authorized.

The harvest was carried out between October and November 2012, during the rainy season, and around 700 trees were cut down, at approximately eight years old, by the clear-cut system. Stumps remained between 5 and 10 cm in high, to carry out the coppice management. Part of the harvest residues was removed from the site to make the soil cleaner and to facilitate soil scarification. The soil scarification operation promotes the superficial cleaning of the soil, exposing the superficial roots of the candeia stumps. Scarifications were made manually with a hoe, in a circular shape with a radius of 80 cm, at a depth of approximately 5 cm, exclusively around harvested tree stumps (Figure 1).

After scarification, the site remained fenced and, periodically, until the third year, manual and selective clearing, performed with a scythe, was done to eliminate weed competition. No fertilizers or pesticides were applied, keeping only the resources generated by the remaining plant decomposition resulting from soil clearing. We took care to don't eliminate any sprouts, and during the development of the shoots, we didn't any shoot thinning.

To assess the best time interval between felling the tree and carrying out the scarification, the harvested area was divided into four treatments, varying the time between harvest and soil scarification: five, six, seven, and eight weeks (four treatments). Within each treatment we randomly placed four repetitions, i.e., four 5 x 10 m plots) Therefore, out total sampling area was 800 m^2 (16 plots of 50 m^2).

We observed established candeia sprouts and stumps within the plots, some of which were already deteriorated, covered by termites or undergrowth. We used an ultrasound measuring tape to obtain the correct information on the positioning of these elements.

All the sprouts found within the plots, with a height greater than 1.5m, had its diameter of 1.30 m height (DBH) recorded using a digital caliper. We measured the sprouts high with a telescopic stick with a graduation every 10 cm.

We carried out an exploratory analysis of the data, accessing sprouts density, number of stems per sprout, and descriptive statistics (calculation of the mean, standard deviation, and coefficient of variation) for the number and height of stems, DBH or equivalent DBH (plants with more than one stem), basal area and wood volume with bark.

To calculate the equivalent diameter at breast height, we used the equation 1:

$$DBH_{eq} = \sqrt{\sum DBH^2} \quad [1]$$

To calculate the sectional area, equation 2 was used, where: Gi: sectional area expressed in m^2; DBH: Diameter at 1.3 m height

$$G_i = \frac{\pi . DBH^2}{40{,}000} \quad [2]$$

To calculate the basal area, equation 3 was used, where: the inventoried area is expressed in m².

$$G = \frac{\sum(G_i).10{,}000}{inventory\ area} \quad [3]$$

To calculate the total volume with bark, we used a specific equation for planted stands of the species in the Baependi region, obtained using the Smalian Method, performed in 2012, during the harvest of the first cutting cycle (Páscoa et al., 2014).

The results obtained from different times of soil scarification with root exposure were analyzed using the Analysis of Variance - ANOVA method.

The correlations between the mean diameter of the stumps per plot and the frequency and basal area of the regenerating plants were verified using Pearson's correlation and scatter plots. The interpretation criterion used is comprised between the values: 0 ≤ Poor <0.20; 0.20 < Bad ≤ 0.40; 0.40 < Regular ≤ 0.60; 0.60 < Good ≤ 0.80; 0.80 <Excellent ≤ 1.0 (Araújo et al., 2018a).

The significance criterion was defined using the Pareto principle, which states that for many events, approximately 80% of the effects come from 20% of the causes.

RESULTS

At eight years after planting, the calculated yield after harvest was 35.55 $m^3 \cdot ha^{-1}$, from branches up to 3 cm in diameter.

On average, 32.2% of the area of each plot was scarified. In the studied area, the sprouts occurred after the tree was felled and, subsequently, exposure and wounding of the roots to stimulate the sprouting of adventitious buds (Figure 2).

Fig. 1 Partial view of the harvested area after scarification around stumps.

Within the 16 plots of the study area, 307 sprouts were found, corresponding to 2.16 plants per stump, considering the initial planting density of 1,780 plants·ha^{-1}. Of the total sprouts density, 81 (26.4%) occurred exclusively within the scarified circular area around the stump (radius of 80 cm) and 226 (73.6%) in the remaining area of the plot (Table 1). It indicates that sprouting can occur outside the area directly affected by scarification.

The quantitative results demonstrate that six years after cutting and scarifying the soil around the stumps, it was possible to reestablish the population density, with an increase of 216% in individuals number. The density of sprouts, still under development, under the simple coppicing system was 3,838 plants·ha^{-1}, while in the planting site, without coppicing, it was 1,780 plants·ha^{-1}.

Comparing the volume and basal area values calculated from the inventory of the population under development by simple coppice system, with the pre-cut forest inventory of the first cycle, respectively, the volume was 32.86 m^3·ha^{-1} and 35.55 m^3·ha^{-1}, which the second volume represents 92% of the initial one, and the basal area was 4.89 m^2·ha^{-1} and 11.44 m^2·ha^{-1}, representing only 43%. It proves that, although the stand has recovered almost the entire volume of the first cutting cycle, new individuals have not yet developed in diameter. Although the new population has a lot of individuals, many of these have no commercial value.

The mean height was 3.80 m, compared with 5.36 m of the population of the first cutting cycle, which represents a recovery of 71% in high, which corroborates with Smith et al. (1986) who claim that new individuals grow surprisingly fast in height, producing straight stems.

The calculated mean equivalent DBH was 3.66 cm, compared with 8.63 cm of the first cutting cycle stand. It indicates that the regenerating plants reached 42% in diameter, compared to the first cutting cycle stand. It needs to grow 37% more to achieve the minimum cut diameter commercially accepted by the industry. Only eleven regenerating individuals with a DBH equal to or greater than 5 cm were found.

By restricting to only eleven individuals commercially accepted, the volume goes down to 1.52 m^3·ha^{-1} and the basal area to 0.52 m^2·ha^{-1}. Comparing with the volume of 35.55 m^3·ha^{-1} and the basal area of 11.44 m^2·ha^{-1} calculated in the pre-cut forest inventory of the first cycle, the population submitted to the coppice system, still under development, reached 4.3% in volume and 4.5% of the basal area, with only 23.1% (1.6 years) left to match in age the trees of the first cycle.

Regarding the tested treatments, there are no significant differences between the time after felling the tree and the roots scarification for all the variables of interest related to the regenerating plants: frequency, total height, DBH, sectional area, and volume per plot (Table 2).

The correlation between the mean stump diameter per plot and the frequency and sectional area of the regenerating plants showed results classified as "Good" with a positive trend (Figure 3). It shows that the density of planting, which affects the diameter of the plants, is a factor that can influence the number and diameter of sprouts.

DISCUSSION

The simple coppice system proved to be effective in conducting the candeia regeneration. Regarding the shoot production, we observed that the sprouts were in the form of clumps where the soil was scarified distant from the stumps and rarely coming directly from it. We believe that it occurred due to exposed and injured roots during the soil scarification procedure, as already showed by Melo et al. (2012).

Fig. 2 Evolution of *E. erythropappus* regeneration after cutting: a) scarification around the stump; b) sprouts around the stump after eight weeks of scarification; c) regeneration, 18 months after scarification; d) regeneration, 30 months after scarification.

Tab. 1 Number of *E. erythropappus* sprouts after cutting the planted forest and managed under Simple Coppice System. Abbreviations: N: number; ∑: summation $\bar{X}$: mean; σ: standard deviation; VC: variation coefficient.

Treatment	Sprouts inside the area around stump		Sprouts outside the area around stump		Total	
(time after cutting)	N	$N \cdot ha^{-1}$	N	$N \cdot ha^{-1}$	N	$N \cdot ha^{-1}$
5 weeks	22	1,100	35	1,750	57	2,850
Plot 1	12	2,400	14	2,800	26	5,200
Plot 2	2	400	2	400	4	800
Plot 3	7	1,400	7	1,400	14	2,800
Plot 4	1	200	12	2,400	13	2,600
6 weeks	20	1,000	61	3,050	81	4,050
Plot 5	5	1,000	26	5,200	31	6,200
Plot 6	11	2,200	11	2,200	22	4,400
Plot 7	3	600	17	3,400	20	4,000
Plot 8	1	200	7	1,400	8	1,600
7 weeks	19	950	63	3,150	82	4,100
Plot 9	6	1,200	24	4,800	30	6,000
Plot 10	6	1,200	18	3,600	24	4,800
Plot 11	5	1,000	13	2,600	18	3,600
Plot 12	2	400	8	1,600	10	2,000
8 weeks	20	1,000	67	3,350	87	4,350
Plots 13	8	1,600	30	6,000	38	7,600
Plots 14	5	1,000	6	1,200	11	2,200
Plot 15	4	800	18	3,600	22	4,400
Plot 16	3	600	13	2,600	16	3,200
∑	81	-	226	-	307	-
$\bar{X}$	5.1	1,013	14.1	2,825	19.2	3,838
σ	3.3	651.0	7.7	1,547.3	9.2	1,848
VC%	64.30	64.30	54.77	54.77	48.15	48.15

Tab. 2 Summary of the analysis of variance (ANOVA) for the candeia stand submitted to simple coppice system, six years after cutting the first cycle.

Variation source	Freedom degrees	Mean square				
		Plants per plot	Height (m)	DBH (cm)	G ($m^2 \cdot ha^{-1}$)	Volume per plot (m^3)
Treatments	3	45.0625^{ns}	0.0313^{ns}	0.4127^{ns}	4.0969^{ns}	0.0032^{ns}
Error	12	95.4375	0.4211	0.5882	11.4159	0.0054
$\bar{X}$	-	19.19	3.80	3.66	4.89	0.16
σ	-	9.24	0.58	0.74	3.15	0.07
VC %	-	48.15	15.40	20.32	64.52	42.85

Where: ns - not significant, considering the error probability of 0.05. DBH: Diameter at the height of 1.3 m. G: Basal area. CV%: Coefficient of variation.

Melo et al. (2012), found that scarification is an efficient practice to enhance root sprouts, which justifies its usage. The authors also found that sprouting occurred after cutting only in naturally exposed roots showing that scarification is a practice that must be done. However, it still lacks information about the best time interval between the cut and scarification. Also, a series of other activities inherent to the exploration process must be made before making the area clear for scarification.

The present study showed that among the tested intervals, up to 8 weeks there is no difference in sprouting density. It can be inferred that due to the characteristics of the site, where the soil type is an alic and dystrophic Cambisol with medium texture, many roots were already

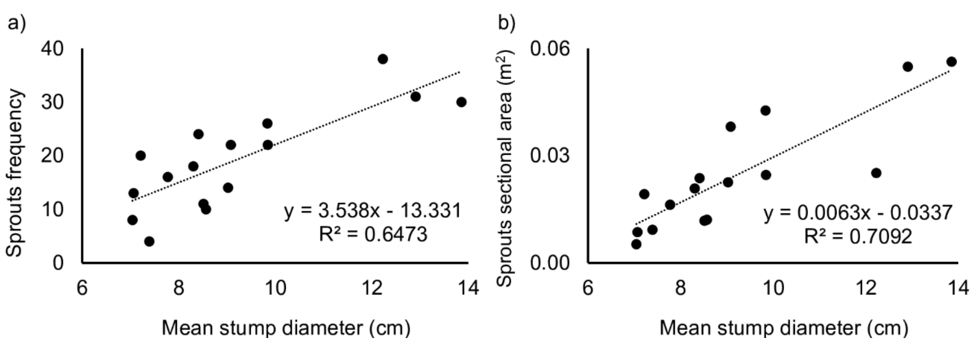

Fig. 3 Correlations between the mean diameter of stumps and (a) the sprouts frequency and (b) sectional area of a candeia plantation in the spacing of 2.5 x 2.0 m, at six years old, under the simple coppice system.

naturally exposed. They probably suffered the impacts of harvesting activities, culminating in a good sprouting potential outside the scarified area.

Smith et al. (1986) state that shoots can also arise from adventitious buds that develop in the callus tissue formed on injuries or in the root cambium of a limited number of tree species. Sometimes, if the shoots of dormant buds are cut, new sprouts can arise from adventitious buds that re-form in the injured callous tissue.

Another factor that should be noted, given its impact on competition among plants, is the number of stems per plant. On average, each regenerating individual had 2.07 bifurcated stems below 1.30 m height. The high number of sprouts favors competition among plants for the resources available in the environment, and an intervention in the site through thinning is recommended.

Therefore, it is clear that the number of sprouts is high and the survival of the sprouts seems to be high, even though it was not evaluated. The high density of trees together with the absence of thinning led to a substantial reduction of the commercial volume after the coppice. So, the correct management is crucial to enable a better increase in diameter, mainly through thinning.

For example, a native population of *E. incanus* submitted to five thinning treatments, evaluated between 23 and 100 months, obtained the best growth rate in diameter at the lowest density treatments (Araújo et al., 2014). The tree's diameter is linearly correlated with the canopy area and the planting spacing can limit the growth of individual trees as it is an obstacle to canopy growth. The densities equal to and below 3,333 plants.ha^{-1} produced the best results over 10 years of evaluations (Páscoa et al., 2019).

Under climatic conditions similar to those in the first months after harvest, the results show that regardless of when scarification was done, regeneration was sufficient to reestablish the initial number of plants of the first cycle without significant differences. Depending on the dimensions of the planting area and the material and human resources available to carry out the activities, the soil scarification may occur concurrently with other activities up to the eighth week after the beginning of the harvest.

CONCLUSIONS

Our initial hypothesis was rejected, once there was no significant difference in sprouts number related to time between the havesting and the soil scarification. Soil scarification, with exposed roots around *Eremanthus erythropappus* (DC.) MacLeish (candeia) stump, can be done up to eight weeks after the tree is felled.

The simple coppice system for *Eremanthus erythropappus* showed, in six years, a density of established plants 216% higher than high forest planting, but only 4.3% of the commercial volume obtained in the first cycle.

The mean diameter of stumps can influence the number of sprouts and their basal area under the simple coppice system.

The simple coppice system for *Eremanthus erythropappus* is technically feasible, as long as the soil is scarified to promote root sprouting, and thinning is done as a way to reduce competition among sprouts.

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AUTHORSHIP CONTRIBUTION

Project Idea: AJP,

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Processing: AJP, VMMP, MCNST

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