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Article

MANUAL CROWNING VERSUS CARDBOARD IN FOREST RESTORATION: COSTS AND EFFECT ON SEEDLING DEVELOPMENT

Coroamento Manual Versus Papelão na Restauração Florestal: Custos e Efeito sobre o Desenvolvimento das Mudas

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ABSTRACT - Invasive grasses are one of the biggest obstacles to be overcome in restoration plantations. Thus, developing efficient and low-cost techniques to overcome this obstacle is a challenge for science and the ecological restoration practice. The objective of this study was to evaluate the effect of the use of cardboard for the crowning operation on the growth of forest tree species from the Atlantic Forest biome and on the operating costs of this technique in a reforestation implemented in Seropédica, Rio de Janeiro state. The predominant vegetation of the area was of *Andropogon bicornis* L. An experiment was installed in randomized blocks, with two treatments and 12 replications. The treatments consisted of crowning with cardboard and crowning with hoe. The used cardboard (50 x 50 cm) were pre-treated with a preservative solution with $CuSO_4$. Treatments were applied to 11 forest species from the Atlantic Forest biome: *Anadenanthera colubrina* var. cebil (Griseb.) Altschul, *Citharexylum myrianthum* Cham., *Enterolobium contortisiliquum* (Vell.) Morong, *Eugenia brasiliensis* Lam, *Eugenia uniflora* Lam, *Handroanthus chrysotrichus* (Mart. ex DC.) Mattos, *Hymenaea courbaril* L., *Inga laurina* (Sw.) Willd., *Plinia cauliflora* (Mart.) Kausel, *Plathymenia reticulata* Benth. e *Triplaris americana* L. Evaluations were carried out as for height, diameter at collar height (DCH) and survival rate, 6, 12 and 18 months after planting. The costs of each crowning method were also quantified. Overall, the height, DCH and growth rates did not differ between the crowning treatments for the species evaluated. However, the cardboard crowning treatment showed a higher survival rate (80%) of plants, compared with the hoe crowning (73%). The cost of the crowning with cardboard over a 12-month period was 40% lower than that of the crowning with hoe. These results show that the cardboard crowning technique can be a viable and a cost effective alternative to replace the crowning with hoe in reforestation areas with species from the Atlantic Forest biome.

Keywords: weed competition, *Andropogon bicornis*, reforestation, mulching.

RESUMO - Gramíneas invasoras são um dos maiores obstáculos a serem superados em plantios de restauração. Assim, desenvolver técnicas eficientes e de baixo custo para superar esse obstáculo é um desafio para a ciência e a prática da restauração ecológica. O objetivo deste trabalho foi avaliar o efeito do coroamento com papelão sobre o crescimento de espécies arbóreas e os custos operacionais dessa técnica em um reflorestamento implantado no município de Seropédica-RJ. A vegetação predominante do local era de ***Andropogon bicornis*** *L. Foi instalado um experimento em blocos casualizados com dois tratamentos e 12 repetições. Os tratamentos consistiram de coroamento com papelão e coroamento com enxada. Os papelões*

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utilizados (tampa de embalagem de papelão para pizza de 50 cm x 50 cm) foram previamente tratados com solução preservativa à base de $CuSO_4$. Os tratamentos foram aplicados a 11 espécies florestais do bioma Mata Atlântica: ***Anadenanthera colubrina*** *var. cebil (Griseb.) Altschul,* ***Citharexylum myrianthum*** *Cham.,* ***Enterolobium contortisiliquum*** *(Vell.) Morong,* ***Eugenia brasiliensis*** *Lam,* ***Eugenia uniflora*** *Lam,* ***Handroanthus chrysotrichus*** *(Mart. ex DC.) Mattos,* ***Hymenaea courbaril*** *L.,* ***Inga laurina*** *(Sw.) Willd.,* ***Plinia cauliflora*** *(Mart.) Kausel,* ***Plathymenia reticulata*** *Benth. e* ***Triplaris americana*** *L. Foram feitas avaliações de altura, diâmetro à altura do coleto (DAC) e taxa de sobrevivência aos 3, 9 e 15 meses após o plantio. Também foi realizada a quantificação dos custos de cada técnica de coroamento. Em geral, altura, DAC e taxas de crescimento não diferiram significativamente entre tratamentos de coroamento para todas as espécies avaliadas. O tratamento de coroamento com papelão apresentou maior taxa de sobrevivência de plantas (80%) em relação ao tratamento com coroamento com enxada (73%). O custo do coroamento com papelão durante 12 meses foi 40% inferior ao do coroamento com enxada. Esses resultados demonstram que a técnica de coroamento com papelão pode ser uma alternativa viável e de menor custo para substituir o coroamento com enxada em áreas de reflorestamento com espécies do bioma Mata Atlântica.*

Palavras-chave: matocompetição, *Andropogon bicornis*, reflorestamento, *mulching*.

INTRODUCTION

Areas for forest restoration in Brazil are generally pastures dominated by exotic grasses, which are difficult to eliminate and replaced by a biodiverse and multi-layered forest vegetation. Grasses found in these areas mostly belong to the Poaceae family, mainly including forage species from the genera *Urochloa*, *Panicum* and *Andropogon* (Souza et al., 2010). These species present survival mechanisms that make them very aggressive, due to the high production capacity of seeds with high viability and longevity, which can germinate in different types of soil, with high or low fertility. They can also reproduce vegetatively and have a great ability to regenerate their clumps after they have been cut (Durigan et al., 1998). Therefore, regular controls of these grasses are required to ensure the growth of introduced forest plants, minimizing weed competition (competition for light, water and nutrients).

There are several methods of grass control in reforestation, but the most consolidated ones are manual crowning with hoes and mechanized trimming (Toledo et al., 2000). These methods have a high operating cost and require a lot of manpower, in a physically exhausting activity. Because of this, it is important to develop alternatives to control weed competition in areas of forest restoration that are efficient and do not harm planted species.

The use of cardboard for the crowning of plants has been proposed as an alternative to traditional crowning with a hoe (Martins et al., 2004; Palhares, 2011; Silva, 2014). This technique consists of covering an area around the planted seedling with cardboard. Cardboard is expected to inhibit seed germination and also lead to the senescence and death of undesirable existing vegetation, in order to control competition.

Authors such as Martins et al. (2004) evaluated the cardboard crowning of the peach-palm (*Bactris gasipaes*) as an alternative to the conventional hoe crowning and showed that cardboard crowning increased the yield of palm hearts. Palhares (2011) used cardboard for the crowning of seedlings introduced in the reforestation of a riparian forest in the Atlantic Forest biome. For the authors, cardboard crowning was more profitable compared to the conventional hoe crowning. Silva (2014) evaluated the durability on the field of cardboard sheets, treated or not with different preservatives, in a crowning simulation using bamboo stakes in an area dominated by *Urochloa humidicola* in the state of Rio de Janeiro and showed that cardboard was able to maintain its effectiveness in controlling weed competition for up to one year without any additional treatment, or for an even longer period when treated with copper sulphate solution.

However, although the use of cardboard has proved to be efficient, there are no reports in literature about studies on the silvicultural and economic viability of crowning with this material in newly implanted multispecies reforestations. Thus, this study aims at evaluating the costs and the effect of cardboard crowning on forest species in a forest restoration area of the Atlantic Forest, in Seropédica - Rio de Janeiro.

MATERIAL AND METHODS

Area characterization

The experiment was conducted in an area of approximately 6 hectares, belonging to Embrapa Agrobiologia, located in Seropédica - Rio de Janeiro state (UTM 23K 635182 E, 7483547 S), meant for reforestation with native species. The soil of the area is classified as Argisol (soil fertility analysis of the area: pH = 5.9; total carbon = 1%; Al = 0 $cmol_c.dm^{-3}$; H+Al = 2.8 $cmol_c.dm^{-3}$; Ca = 2 $cmol_c.dm^{-3}$; Mg = 1 $cmol_c.dm^{-3}$; K = 91 mg L^{-1}; P = 5.7 mg L^{-1}; N = 0.1%). The relief of the place is slightly wavy, tending to flat in some places, between 24 m and 38 m of altitude. The predominant vegetation is *Andropogon bicornis* (West Indian foxtail). The area remained fallow for at least 30 years, having suffered burnings and periodic grazing. There is no record of previous crops in the area. The climate of the region is Aw, characterized by a dry season in winter (especially from June to September) and a humid one in summer. The records of the municipality of Seropédica between January 2009 and December 2013 indicate an annual rainfall of 1,370 mm, with average monthly temperatures ranging from 16 °C to 36 °C and an annual average around 24 °C. The annual mean relative air humidity in the same period was 81% (INMET, 2014).

Preparation of the planting area

Before planting, the entire area was trimmed with backpack brushcutter; this step was followed by marking of planting furrows, in 2 m x 2 m spacing. Crowns of approximately 1.0 meter of diameter were made around each furrow using a hoe. Furrows were opened in a mechanized way, using a planting hole digger with a drill, having the size of 0.3 m in diameter x 0.5 m in depth. Each planting furrow received 200 grams of formulated N-P-K 06:30:06 and 2 liters of previously hydrated hydrogel.

Planting was done in July 2014, using seedlings produced in 14 x 20 x 20 cm bags (8.5 cm in full diameter). Inside and around the experimental area, the control of leafcutter ants was carried out before and after planting.

Preparation of the cardboard used for crowning

Kraft cardboard B-wave sheets were used, measuring 50 cm x 50 cm, pre-cut to make pizza boxes. On each sheet, a perpendicular cut to the cardboard structure was made, from the center to the edge of the sheet, with the help of a cutter.

The paperboard was treated with a $CuSO_4$-based solution (Galvão et al., 2004), following the procedure performed by Silva (2014). This solution was applied to both sides of the cardboard with the help of a spray pump, so as to soak the cardboard. The sheets were air dried before being taken to the field.

Experiment design and conduction

The experimental design was in randomized blocks, with 2 treatments and 12 replications. The 12 blocks were marked in different positions over the planting area, so as to cover an average of 100 seedlings per block. Treatments consisted in manual crowning and cardboard crowning. One third of the seedlings from each block were treated with cardboard crowning, and the rest with manual crowning. The following 11 species of the Atlantic Forest biome were planted: *Anadenanthera colubrina*, *Citharexylum myrianthum*, *Enterolobium contortisiliquum*, *Eugenia brasiliensis*, *Eugenia uniflora*, *Handroanthus chrysotrichus*, *Hymenaea courbaril*, *Inga laurina*, *Plinia cauliflora*, *Plathymenia reticulata* and *Triplaris americana*. Not all species were found in all blocks; each one was found at least in 7 blocks and at most in 11 blocks.

Treatments were applied after three months, when the first crowning was necessary after planting. The hoe crowning was made by removing all the regenerating vegetation within a radius of 50 cm around the seedling collar. On the other hand, cardboard crowning was carried

out by placing it on the ground, "fitting" the seedling to the center through the previously made cut (Figure 1). To avoid the displacement of the cardboard by the action of the wind, it was fixed to the ground with the help of five clips made from galvanized wire with a gauge of 2.77 mm and 20 cm in length, folded in a U-shape. The clips were fixed to the four corners of the cardboard, and a last one was fixed next to the cut made to fit the seedling. The second manual crowning was not made before the cardboard was placed; it was placed on the vegetation found in the crown region (Figure 1).

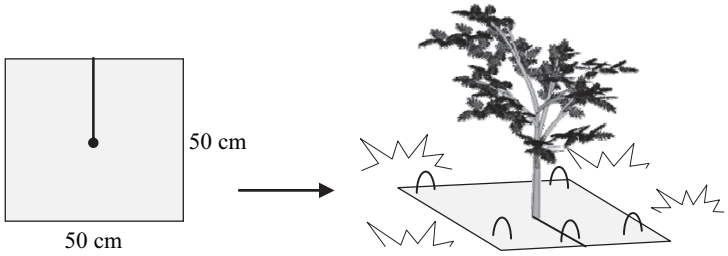


Figure 1 - Cutting scheme of the cardboard and layout in the field for plant crowning. Please observe the position of the clips used to attach the cardboard to the ground surface.

The hoe crowning was repeated 6, 9, 12 and 15 months after planting. The cardboard crowns were replaced 12 months after planting because some of them (about 15%) had been damaged during trimming operations. The replacement cardboard received the same treatment and was placed on the field in the previously described way.

After three months from the application of the treatments, topdressing was performed with 80 g of N-P-K 20-05-19 per plant. In the treatment with manual crowning, little holes were made for the application of the fertilizer, with the help of a hoe, under the projection of the crown of plants, within a radius of approximately 30 cm; soon after fertilization, they were closed. In the treatment with cardboard crowning, the fertilizer was applied under the cardboard, under the projection of the crown of plants. Six months after the application of the treatments, the second topdressing was performed, repeating the first one.

The eight and diameter at collar height (DCH) of the seedlings were measured and the survival rate for each species was calculated. The first evaluation occurred at the time of application of the treatments, after three months from planting, and later, 9 and 15 months from planting in the field. In the data collection about height a telescopic pole and a digital caliper were used to measure the diameter of the neck.

Data analysis

Height growth and DCH data were used to monitor growth in three seasons. However, height and DCH data at 3 and 15 months were used to calculate the growth rates for each species; these variables were expressed as cm month^{-1} and mm month^{-1}, respectively.

All variables were evaluated as for variance homogeneity, through residual graphs (residuals vs. fit plot), and as for normality, using the q-q plot. Survival rate data were transformed by the square root function of the sine-wave. After that, each variable was analyzed by analysis of variance, considering as variation sources the block and crown type, separately for each species. For the mean comparison between the two crown treatments, the result of the F test was considered. All analyses were performed using the S-Plus® 8.0 software (Insightful Corp).

Evaluation of the costs of the crowning techniques

The costs involved in the use of each crowning method were evaluated in the 12 month period after planting. To evaluate the cost involved in the use of cardboard as a crowning method, data were collected on the purchase cost, preparation (treatment application and cutting) and cardboard installation on the field. The labor cost of R$ 80.00/man/day was considered for

operations involving crowning with hoe or with cardboard. All costs were estimated based on the area of 1 hectare.

RESULTS AND DISCUSSION

Growth and survival

The measurements of the height and diameter at collar height (DCH) of plants, made three months after planting, had the objective to define a reference point, from which the effects of the crowning treatments were evaluated. At the moment, which preceded the application of the treatments, for the great majority of the species, the mean height and DCH did not differ among treatments, reflecting the proper distribution of the experimental units (Figures 2 and 3). However, there were exceptions: *T. americana* presented a significantly higher average height in the experimental units allocated in the treatment with hoe crowning (difference of 14%), and *C. myrianthum* and *H. courbaril* presented a higher DCH in the same treatment (differences of 45% and 14%, respectively) (Figures 2 and 3).

The follow-up done at 9 and 15 months did not show a significant effect of the crowning type on the growth in the DCH of any of the species, except for *I. laurina*, which presented a significantly higher mean in the treatment with hoe crowning at 15 months (difference of 29%) (Figure 3). The same evaluation made for height did not show any difference between treatments, except for *H. courbaril*, which had a higher mean when crowned with a hoe, at the age of 9 and 15 months (24% and 15%, respectively) (Figure 2). It is important to notice that the difference in height of *T. americana* and in DCH of *H. courbaril* and *C. myrianthum* in the hoe crowning treatment at the application date (three months after planting) was not maintained at subsequent evaluation.

The use of cardboard crowning did not affect the height growth rate or DCH of most of the 11 forest species, in relation to the treatment with hoe crowning, although growth rates varied considerably between species (Table 1). The only exception was *C. myrianthum*, which presented a significantly higher growth rate in DCH when crowned with cardboard ($p<0.05$).

Although the monitoring results of the growth of forest species showed few differences between treatments, the crowning type influenced the survival of plants on the field. After 18 months from planting, the survival rate of *H. chrysotrichus* and *M. cauliflora* were significantly higher, at the significance level of 5.8% and 8.7%, respectively, when these species were crowned with cardboard than when they crowned with a hoe (Table 2). As for the other species, there was no significant difference between treatments. However, when considering the overall mean of planting survival, regardless of the species, plants crowned with cardboard had a survival rate of 80.7%, significantly higher than the 73.1% survival rate of the plants crowned with a hoe (Table 2).

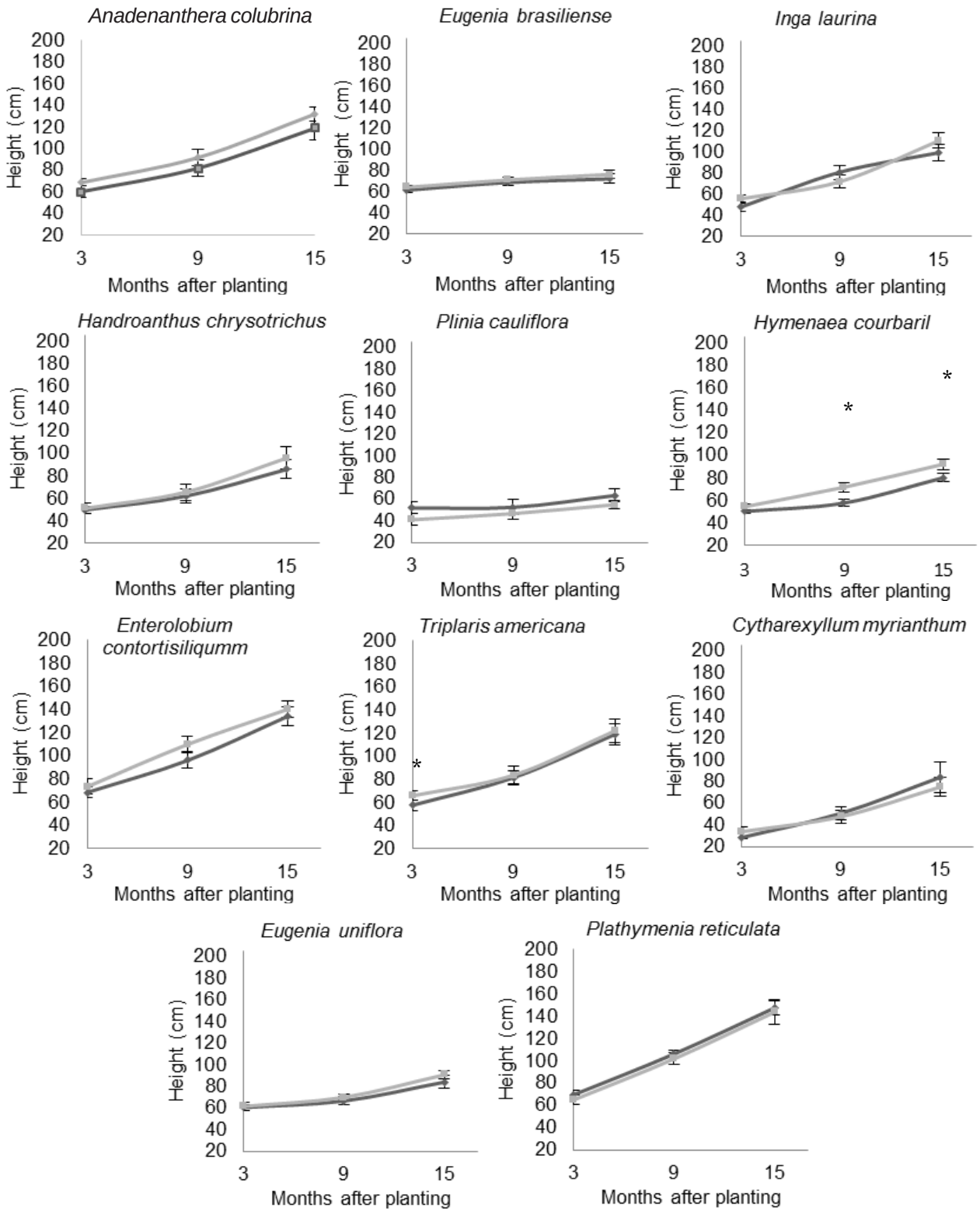
The higher survival rate of seedlings crowned with cardboard may be related to the "mulching effect" of cardboard, which leads to less exposure of the crown area to sunshine, reducing the temperature in the soil profile and better preserving moisture during periods of drought. It is worth mentioning that, during the evaluations between January and May 2015, no rainfall was recorded during 77 of the 121 days in this period. The maximum temperatures recorded in January and February 2015 were higher than 35 °C.

No studies have been found in literature evaluating the effect of cardboard crowning on the growth and survival of native species. On the other hand, it is possible to draw a parallel with studies that evaluated the mulching technique in systems of agricultural and forestry production. Some studies have shown that the use of soil covering can increase crop productivity (Resende et al., 2005; Ferreira et al., 2013) and reduce soil temperature (Ribas et al., 2015).

Barajas-Guzmán and Barradas (2013) evaluated the use of mulching in reforestation with tropical native species in a degraded area in Mexico. The mulch types tested were alfalfa straw, forest plant litter, white polyethylene film and exposed soil. The results showed that the growth and survival rate of the evaluated species was much higher when polyethylene mulching was used. The lowest survival rates occurred in the treatment with exposed soil.

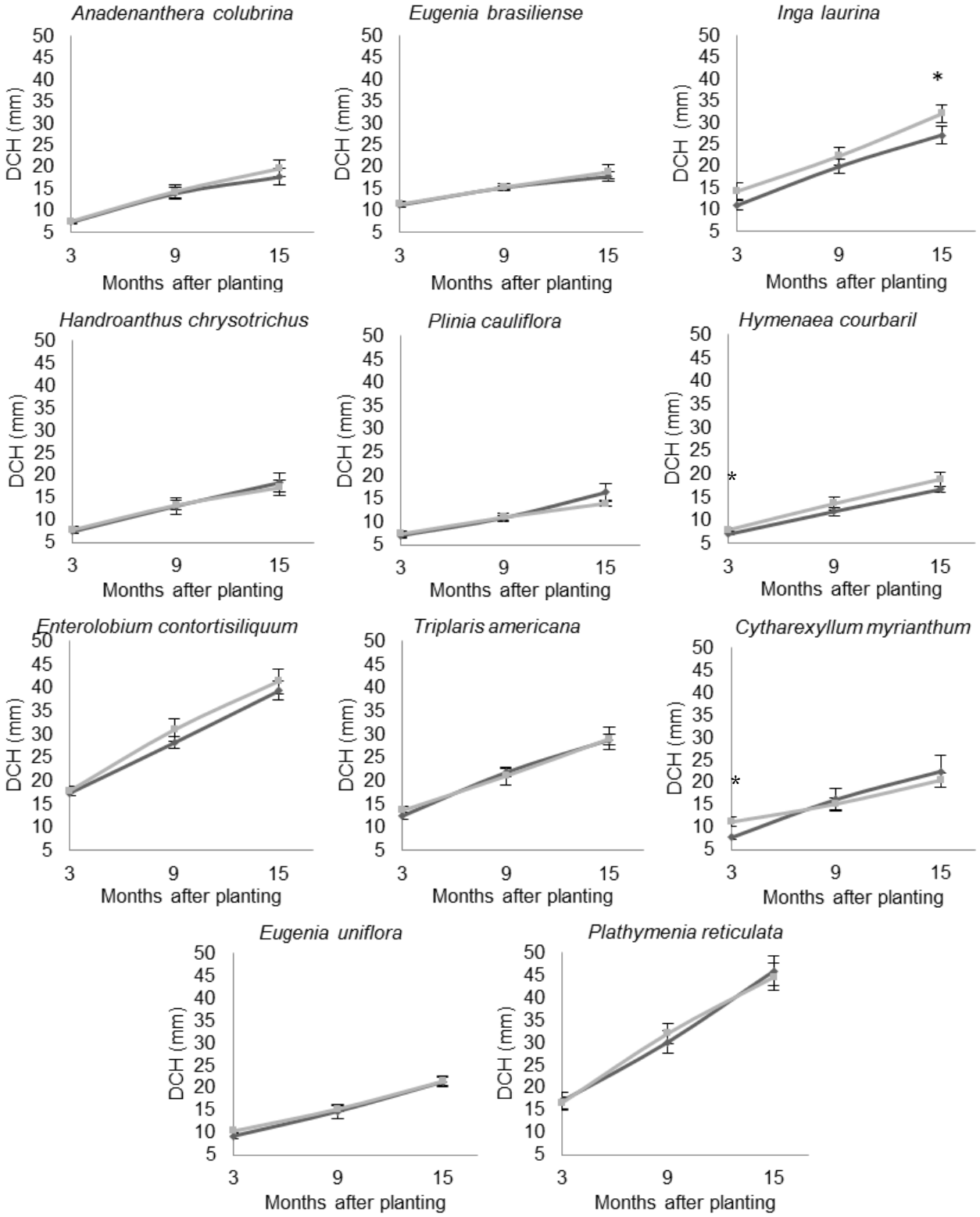
The results of this study showed that cardboard, although not favoring the growth of forest species, did not negatively affect their growth, either. However, the higher survival rate of plants

crowned with cardboard is relevant to the practice of forest restoration, considering the possibility of reducing the costs of replanting and the greater speed in the forest recovery of the area, which also reduces the costs of reforestation due to the lower maintenance needs of the area with weeds and crowns.



* Indicate difference between treatments (F test, $p<0.05$) for the evaluation date.

Figure 2 - Height of 11 forest species treated with cardboard or hoe crowning crowning at three ages, after planting.



* Indicates difference between treatments (F test, $p<0.05$) for the evaluation date.

Figure 3 - Diameter at collar height (DCH) of 11 forest species treated with cardboard or hoe crowning at three ages, after planting.

Cost evaluation

The cost of crowning through traditional techniques (hoe crowning) and using cardboard were calculated based on the planting of seedlings spaced 2 m x 2 m in an area of 1 hectare.

Table 1 - Growth rate in height and diameter at collar height (DCH) of 11 forest species crowned with cardboard or hoe between 6 and 18 months after planting

Specie	Family	Height (cm month^{-1})		DCH (mm month^{-1})	
		Cardboard	Hoe	Cardboard	Hoe
Anadenanthera colubrina	Leguminosae	4.89 (0.69)	5.28 (0.51)	0.86 (0.16)	1.01 (0.12)
Citharexyllum myrianthum	Verbenaceae	2.94 (1.28)	2.80 (0.65)	1.04*(0.34)	0.61 (0.14)
Enterolobium contortisiliquum	Leguminosae	5.48 (0.68)	5.58 (0.42)	1.83 (0.14)	1.96 (0.16)
Eugenia brasilienses	Myrtaceae	0.89 (0.41)	1.01 (0.24)	0.54 (0.10)	0.82 (0.27)
Eugenia uniflora	Myrtaceae	1.96 (0.52)	2.43 (0.31)	1.01 (0.13)	0.93 (0.06)
Handroanthus chrysotrichus	Bignoniaceae	3.01 (0.76)	3.73 (0.55)	0.91 (0.18)	0.78 (0.11)
Hymenaea courbaril	Leguminosae	2.50 (0.35)	3.15 (0.29)	0.81 (0.05)	0.88 (0.10)
Inga laurina	Leguminosae	4.30 (0.71)	4.59 (0.44)	1.25 (0.13)	1.37 (0.18)
Plinia cauliflora	Myrtaceae	0.96 (0.86)	0.58 (0.76)	0.77 (0.17)	0.40 (0.15)
Plathymenia reticulata	Leguminosae	6.50 (0.42)	6.56 (0.67)	2.32 (0.35)	2.33 (0.15)
Triplaris americana	Polygonaceae	5.12 (0.60)	4.69 (0.56)	1.36 (0.11)	1.29 (0.12)
Média geral		3.50	3.67	1.15	1.12

Values in parentheses represent the standard error of the mean. * Indicates difference between treatments for the indicated variable according to the F test ($p<0.05$).

Table 2 - Percentage of average survival of 11 studied forest species crowned with cardboard or hoe after 18 months of planting

Specie	Family	% Survival		
		Cardboard	Hoe	*p* (F test)
Anadenanthera colubrina	Leguminosae	85	84	ns
Cytharexyllum myrianthum	Verbenaceae	68	67	ns
Enterolobium contortisiliquum	Leguminosae	82	82	ns
Eugenia brasilienses	Myrtaceae	74	63	ns
Eugenia uniflora	Myrtaceae	80	76	ns
Handroanthus chrysotrichus	Bignoniaceae	86	69	0.058
Hymenaea courbaril	Leguminosae	81	73	ns
Inga laurina	Leguminosae	83	71	ns
Plinia cauliflora	Myrtaceae	85	44	0.087
Plathymenia reticulata	Leguminosae	88	77	ns
Triplaris americana	Polygonaceae	82	83	ns

ns – not significant.

Eight hundred grams of copper sulphate were used to treat 2,500 cardboard sheets measuring 50 cm x 50 cm and 111 kg of 2.77 mm galvanized flat wire to make five clips per crown.

The time to install the cardboard on the field comprised the placement of the cardboard around the seedlings, the preparation of the clips and its placement on the ground. The average time spent fixing each cardboard on the field was 1.25 minutes. Taking into consideration a workday of eight hours daily and discounting 10 minutes from each working hour for rehydration and rest, it is possible to install 320 units per worker. Therefore, to install 2,500 units on the field, there was an estimate of 7.81 man day^{-1} per hectare.

The hoe crowning was performed on four occasions during the first year after planting (3, 6, 9 and 12 months). Each worker made approximately 175 crowns per working day. Thus, there was an estimate of 14.3 man day^{-1} per hectare for the crowning of 2,500 seedlings ha^{-1}.

During the first year after planting, the costs of material and labor employed in crowning with cardboard were equivalent to about 57% of the costs of the manual hoe crowning over 12 months (Table 3). Thus, the total cost of crowning with cardboard without the trimming activity was R$ 3,273.30 ha^{-1}. The total cost of exclusive hoe crowning over the first year was R$ 5,714.29 ha^{-1}. Although it was not included in the cost tables, both for cardboard crowning and

Table 3 - Costs of cardboard and hoe crowning during the first year after planting

Cardboard crowning (5 fixing clips and without plantation crowning)				
	Unit	Quantity	Price (R$)	Value (R$)
Copper sulphate (prep. of preservative solution)	kg	0.8	12.00	9.60
Cardboard (0.5 x 0.5 m sheets)	unit	2500	0.60	1,500.00
Wire (clips)	kg	111	9.90	1,098.90
Labor – copper sulphate application	man day^{-1} per hectare	0.5	80.00	40.00
Labor – cardboard placement on the field*	man day^{-1} per hectare	7.81	80.00	624.80
			Total:	3,273.30
Hoe crowning				
Labor – plantation crowning	man day^{-1} per hectare	14.3	80.00	1,142.86
Labor – After-planting crowning (4/year)	man day^{-1} per hectare	57.1	80.00	4,571.43
			Total:	5,714.29

* Estimated calculation.

manual crowning, mechanized trimming was performed in both treatments on four occasions in the first year of planting (0, 4, 8 and 12 months after planting), at the cost of labor plus fuel equivalent to R$ 696.00 ha^{-1} per operation.

As for hoe crowning, it is important to notice that the number of operations required during the first 12 months after planting may vary depending on several factors, such as the type of vegetation found in the area, the soil quality and the climatic conditions of the region. These variables can therefore influence the costs of the crowning operation, changing the cost difference between the two methods in other competitive conditions.

A significant difference in the cost composition of the two crowning methods is due to the fact that 100% of hoe crowning costs refer to manpower, whereas in cardboard crowning, labor represents only 38% of the total cost. Another important point is that the acquisition of cardboard corresponds to the component with the greatest impact on the total cost of this management option. This cost can be reduced by purchasing cardboard in large volumes or by reusing used cardboard, which is widely available on the market. Cardboards have different weights, but the preliminary treatment to increase durability is the same and the duration time on the field is similar.

Palhares (2011) used cardboard for the crowning of plants in a reforestation of riparian APP and concluded that this practice required half the time demanded in the hoe crowning with hoe; however, he did not quantify the costs of each crowning method.

Several studies have evaluated other techniques to reduce the costs of controlling weed competition in reforestation. Nascimento (2007) evaluated the influence of spacing on the growth of six forest species in the Rio Guandu Basin, in the city of Seropédica - Rio de Janeiro, and the implantation and maintenance costs up to the age 25 months. This author verified that in crops with a spacing starting from 2.0 m x 1.5 m, the weed competition control cost becomes higher than the price of implantation. Toledo et al. (1996) compared the costs of four control methods of *Urochloa decumbens* (trimming, disking, herbicide and weeding) on *Eucalyptus grandis* plantations and found that the cost of manual weeding, despite being the most efficient technique, was around 2.6 times higher than the other methods, during the first 12 months after planting.

Forest restoration projects usually consider three years of area maintenance after planting. In this study, costs were monitored for only 12 months. However, a three-year estimate could not be made simply by multiplying by three the values found in the first 12 months, since maintenance costs tend to decrease over time. With the growth of the forest species on the field, there is a progressive decrease in weed competition, due to the growth of plants and the shading of herbaceous plants, reducing the need for regular hoe crowning. As for cardboard crowning, replacement would probably be necessary over time. However, a study conducted under similar conditions as this study (Silva, 2014) demonstrated that cardboard treated with copper sulphate solution showed longevity and effectiveness in controlling *A. bicornis* for more than 12 months.

This indicates that cardboard replacement may be postponed or even unnecessary, although long-term monitoring studies are needed to test this hypothesis.

This study demonstrated that manual crowning of seedlings, usually carried out in forest restoration plantations, can be replaced by cardboard crowning, without damages to growth and even reducing seedling mortality. For the conditions of the study area, the costs of cardboard crowning are considerably lower than those of manual crowning, reinforcing the recommendation of this technique in forest restoration initiatives.

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