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How does the season and the tree diameter affect the shoot emission of *Anadenanthera peregrina* by trunk girdling?

Como a estação e o diâmetro da árvore afetam a emissão de brotações de *Anadenanthera peregrina* por anelamento de tronco?

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Abstract:

The induction of sprouting for vegetative rescue needs to be better studied, especially in tropical native species of commercial interest such as *Anadenanthera peregrina*. The objective was to know the influence of the season of the year and the diameter class of the trees on the girdling of the trunk in the emission of *A. peregrina* buds. The population, pure and uneven, was divided into six diametric categories ranging from 5 to 30 cm in diameter at breast height (DBH) and girdling occurred in two seasons, autumn and spring. The experiment was conducted in a randomized block design, with six replications, containing one plant per plot. Girdling was efficient in inducing shoots in *A. peregrina*. The diameter class influenced the number of trees that sprout and the average number of sprouts. The season of the year influences the emission of shoots and the number of trees that sprout. Trunk girdling in *A. peregrina* trees has a greater potential for sprouting when performed in May (autumn) in trees with DBH up to 25 cm.

Keywords: angico, rainforest species, vegetative propagation, sprounting

Resumo:
A indução de brotação para o resgate vegetativo precisa ser melhor estudado, principalmente em espécies nativas tropicais de interesse comercial como *Anadenanthera peregrina* . Objetivou-se conhecer a influência da estação do ano e da classe diamétrica das árvores no anelamento do tronco na emissão de brotos de *A. peregrina*. A população, pura e inequiânea, foi dividida em seis categorias diamétricas variando de 5 a 30 cm de diâmetro à altura do peito (DAP), e o anelamento ocorreu em duas estações, outono e primavera. O experimento foi conduzido em delineamento em blocos casualizados, com seis repetições, contendo uma planta por parcela. O anelamento foi eficiente na indução de brotos em *A. peregrina*. A classe diamétrica influenciou no número de árvores que brotam e o número médio de brotações. A estação do ano influencia a emissão de brotos e no número de árvores que brotaram. O anelamento do tronco em árvores de *A. peregrina* apresenta maior potencial de emissão de brotações quando realizado em maio (outono) em árvores com até 25 cm de DAP.

Palavras-chave: angico, espécies da floresta tropical, propagação vegetativa, brotação

1. Introduction

Among the existing techniques of vegetative rescue, tree cutting is the one widely used in *Eucalyptus* spp., however, to induce the shoot the tree is cut down (Xavier *et* al., 2013). Cutting trees is problematic for rescuing native species since it is unwise to cut individuals in natural populations where the genetic basis may be compromised, in addition to the fact that many of these species are law-protected. Test other forms of vegetative rescue are essential to native species, especially non-destructive forms of inducting sprouts.

Trunk girdling is a viable alternative to the native species because it induces epicormic shoots without the need to kill or cause tree death once the technique is correctly applied (Alfenas *et al*., 2009). Examples of success are reported in yerba mate rescue (Stuepp *et al*., 2016; Bisognin *et al.*, 2018).

The induction of shoots happens because the incision applied to the trunk results in a disruption of the auxin/cytokinin ratio (Taiz *et al.*, 2017). When the technique is applied, a reduction in auxin concentration occurs with an increase in cytokinin concentration in the region below the girdling (Hartmann *et al.*, 2011). In this condition also occurs the stress caused by the cut of the flow of photoassimilates and other metabolites to the roots, as the plant uses a mechanism that aims to maintain its survival, which is the emission of shoots (Nascimento *et al*., 2018).

Physiological and environmental factors influence plant sprouting ability. Some species are incapable of emitting shoots in the adult phase, due to the aging and tissue maturity, which reduce or completely lose the competence of undergo adventitious rooting (Wendling, *et al*., 2014b; Stuepp *et al*., 2017).

About the environmental factors, atmospheric conditions, such as temperature, humidity, and precipitation, affect the physiological behavior of the individuals, and thus can influence the capacity of shooting (Nascimento *et al.*, 2018). Light and plant nutrition are a well-documented environment conditions associated with sprouting ability being required for shoot regeneration in some plant species (Ikeuchi *et al*., 2016; Nascimento *et al*., 2019).

In this context, we aimed to know the influence of tree diameter at the breast hight and season of tree girdling on the potential of shooting in adult trees of *Anadenanthera peregrina* (L.) Speg.

2. Material and Methods

The experiments occurred at a pure and uneven age population of *Anadenanthera peregrina* in the southern Minas Gerais. The climate, according to Köppen's climatic classification, is Cwa. It presents an average annual temperature of 19.3 ºC, varying between 22.1 ºC to 15.8 ºC, annual precipitation of 1530 mm, and average annual relative humidity of 76%.

Sartori *et al*. (2014) inventoried the population in 2011 and separated it into six classes of diameter at breast height (DBH): (A) composed of trees from 0 to 5 cm; (B) from 5.1 to 10 cm; (C) from 10.1 to 15 cm; (D) from 15.1 to 20 cm; (E) from 20.1 to 25 cm; and (F) from 25.1 to 30 cm (Figure 1).

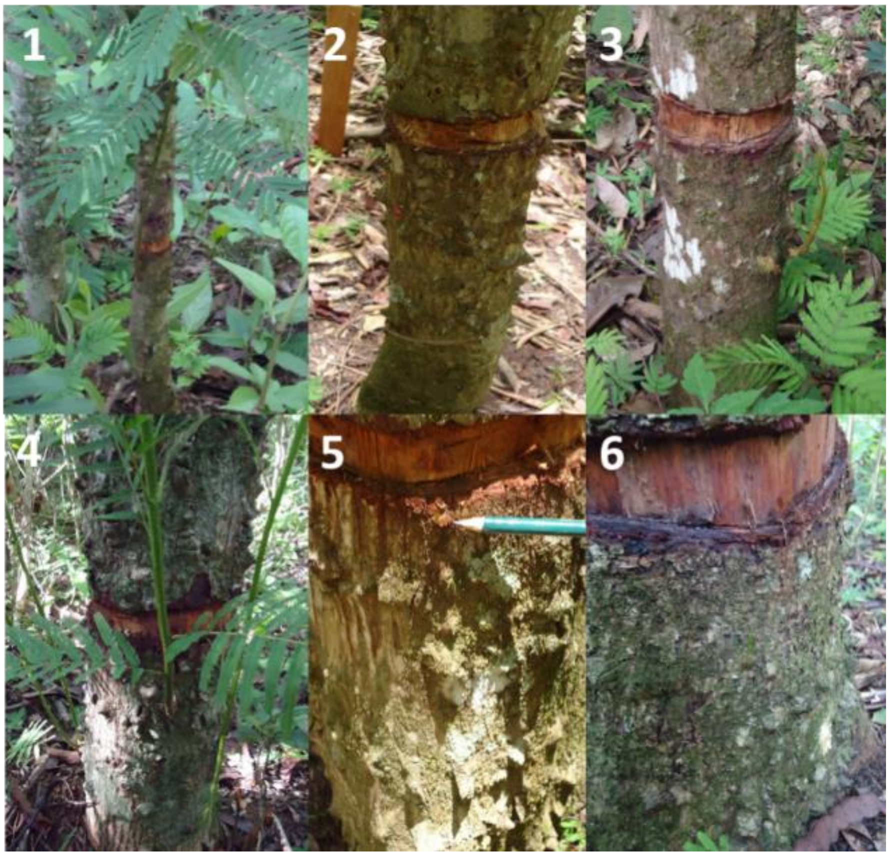


Figure 1. Girdling and shoots in different diametric classes of *Anadenanthera peregrina*. 1: class A (0 to 5 cm); 2: class B (5.1 to 10 cm); 3: class C (10.1 to 15 cm); 4: class D (15.1 to 20 cm); 5: class E (20.1 to 25 cm); 6: class F (25.1 to 30 cm).

Figura 1. Anelamento e brotações em diferentes classes diamétricas de *Anadenanthera peregrina* . 1: classe A (0 a 5 cm); 2: classe B (5,1 a 10 cm); 3: classe C (10,1 a 15 cm); 4: classe D (15,1 a 20 cm); 5: classe E (20,1 a 25 cm); 6: classe F (25,1 a 30 cm).

The girdling was applied at six trees per DBH class and consisted of an incision approximately 5 cm thick around the entire stem circumference at 40 cm high from the ground, with a machete and a hammer. The depth of the cut was enough to remove the bark without damaging the wood. It is worth noting that we protected the shoots against the attack of ants through the application of adherent paste throughout the circumference of the stem, below the girdling, and formicide bait applied in the total area.

The girdling procedure was applied in two different seasons, in May during autumn (dry season) and November during spring (raining season). The seasons were considered different experiments and analyzed separately. Both used a randomized block design with six replications, six treatments (diametric categories), and one plant per plot.

We evaluated the percentage of trees that presented shoots and the number of epicormic gems present in each as a function of days after girdling. For the girdling performed in May, evaluations were at 207, 224, 251, 279, 303, and 365 days, and for the girdling prepared in November, we evaluated at 42, 68, 96, 120, and 182 days.

The data were processed by the analysis of variance ($p < 0.05$). When a significant difference was observed a regression analysis was conducted selecting the equations with a significance at 5% and the best fitted to the data distribution. All statistical analyses were executed at SISVAR (Ferreira, 2019).

3. Results and Discussion

All DBH categories of the girdling performed in May (autumn) showed shoots, with classes A, B, C, and D presenting shoots in all individuals. In November (spring), no category showed 100% of the trees with shoots, with category F did not present shoots (Table 1).

Table 1. Percentage of *Anadenanthera peregrina* trees that sprouted during the experimental periods, as the diameter category, after the application of the girdling in May or November.

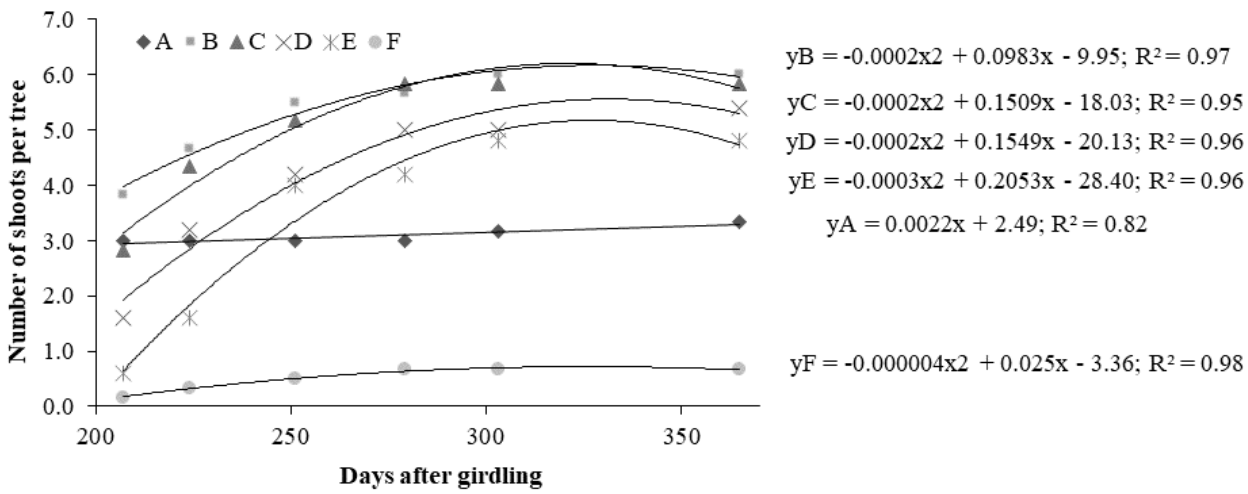
Tabela 1. Percentual de árvores de *Anadenanthera peregrina* que brotaram durante os períodos experimentais, conforme categoria de diâmetro, após a aplicação do anelamento em maio ou novembro.

Category	Percentual of trees with at least one shoot	
	May (autumn)	November (spring)
A (0 – 5 cm)	100.0	83.3
B (5.1 – 10 cm)	100.0	83.3
C (10.1 – 15 cm)	100.0	83.3
D (15.1 – 20 cm)	100.0	50.0
E (20.1 – 25 cm)	80.0	16.7
F (25.1 -30 cm)	50.0	0.0
Average	88.2	51.4

The girdling performed in May (autumn) showed an average of 4.3 shoots per tree if we consider all diametric categories. The highest number of shoots per tree were the Category B (6.0 shoots) and C (5.8 shoots) (Figure 2). Category A after the first evaluation showed almost no new shoots (Figure 2), and trees in F did not present shoots at all.

Figure 2. Average number of shoots per *Anadenanthera peregrina* tree, as days after the girdling in May (autumn).

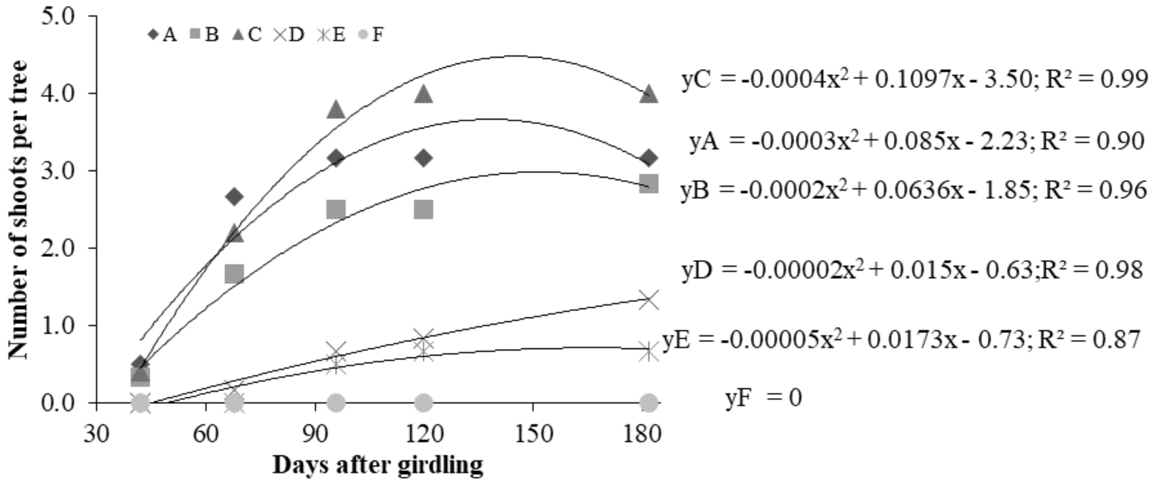
Figura 2. Número médio de brotações por árvore de *Anadenanthera peregrina*, em dias após o anelamento em maio (outono).



On the other hand, the girdling in November (spring) showed an average of 1.9 shoots per tree. At that time, the category A, B, and C stood out with greater yields of shoots per tree, while the categories D, E, and F had fewer. The category with the largest DBH (F) showed no bud during the whole experimental period (Figure 3).

Figure 3. Average number of shoots per tree of *Anadenanthera peregrina* as a function of the days after the girdling performed in November (spring).

Figura 3. Número médio de brotações por árvore de *Anadenanthera peregrina* em função dos dias após o anelamento realizado em novembro (primavera).



In the November girdling, we found the first shoots at 42 days, and after 182 days did not show any new shoots (Figure 3). In the May girdling, the start and finishing of new shoots occurred from 207º to 365º day (Figure 2).

The probability of a stump would produce a sprout after harvesting decrease with the increasing of stump diameter, and for some species, such *Quercus* spp., with the increasing tree age (Ward & Williams, 2018). Despite different methods, the same phenomenon was observed with girdling trees where the F category showed a lower percentage of trees that sprouted and a smaller number of shoots per tree (Table 1, Figure 2, Figure 3).

Although the larger trees have a large amount of energy reserve for the sprouting investment, they lost the ability to sprout over time, as explained by Xavier *et al*. (2013); Wendling *et al*. (2014a); Ikeuchi *et al*. (2016). These authors report that age reduces the capacity and quantity of shoots due to the reduction of the vegetative vigor and the dormant buds. Morphological and physiological changes occur in the transition from juvenile to mature phase (Ahsan *et al*. 2019), resulting in a decrease in sprouting capacity.

The trees of category A in the girdling carried out in May was the second category with the least number of shoots per tree (Figure 3). This possibly happens due to the dry season and the low temperatures of autumn. Another possibility is that small trees are dominated and grow under the canopy shade this environment may have had a negative influence on shoot induction. Ward & Williams (2018) explains that lower canopy trees are more stressed, resulting in low levels of carbohydrate, affecting their likelihood of sprouting, because there is a positive correlation between levels of carbohydrate and sprouting.

The scenario changed in November (spring) when group A showed a higher percentage of trees with sprouts and plentiful shoots per tree. In spring, water and nutrients were not limiting factors, and categories A, B, and C were able to express their sprouting ability (Figure 2).

The best results on average of shoots per tree and percentage of trees that sprouted were in the girdling of May (autumn), despite the longer time of emission of the first shoots. This result is probably due to the trees entering a vegetative rest. The fall in temperature, lower air humidity, and drier soil are drivers of this vegetative rest, as highlighted by Stuepp *et al*. (2017). The same phenomenon happened in *Robinia pseudoacacia* L., which emitted more shoots when cut in the winter and autumn (Masaka *et al*., 2015).

In the period of vegetative rest, the trees with the capacity to sprout present vast storage of reserve substances in the root system, stimulating the number of shoots produced (Shibata *et* al., 2016; Mosseler *et* al., 2022). When the girdling was done in November (spring), trees sprouted rapidly, 42 days, stimulated by high temperature and humidity. However, November begins the period of vigorous growth, when the carbohydrate reserve of the roots is towards the aerial parts (Ceulemans *et al*., 1996). Thus, it is possible that the lower carbohydrates reserves in the roots may caused the lower average of shoots per tree and a lower percentage of trees that sprouted in the girdling performed at that time.

Another factor that contributed to the best result of the girdling in May (autumn) was that in the later months, during the dry season, the *Anadenanthera peregrina* trees presented strong deciduousness, thus increasing light entry. In November (spring), the first rains had already occurred when the girdling was performed, causing the leafing of the trees and resulting in less luminosity overall. The light, on dormant buds at the stump of the trees, increase sprout production, in addition to other factors (Meier *et al*., 2012).

The early stopping in shooting emission that happened in November coincided with the girdling cuts cicatrization. The cicatrization jointed the upper and lower extremities of the cuts covering the removed area, resulting in the reestablishment of phloem, normalizing the flow of photoassimilates, and auxin-cytokinin balance (Taiz *et al.*, 2017), thus ending the physiological conditions for shoots emission.

According to Perranto & Corder, (2006), the seasons of the year influence the emission of shoots. For *Acacia mearnsii*, the best period for the girdling is between autumn and spring in the Cfa region (Perranto & Corder, 2006). For *Ilex paraguariensis*, winter was the most favorable season for girdling in the Rio Grande do Sul (Stuepp *et al*., 2016).

Considering the two seasons, the girdling had about 70% of trees sprouted. This technique has also made possible the induction of shoots in other Brazilian native species such as *Anadenanthera macrocarpa* (Dias *et al*., 2015), *Calophyllum Brasiliense* (Kratz *et al*., 2016), *Ilex paraguariensis* (Stuepp *et al*., 2016), and the latter two presented 83% and 90% of trees that sprout, respectively.

4. Conclusion

The girdling was efficient for the sprouting of *Anadenanthera peregrina*. The DBH size of the trees influenced the number of trees that sprout and the average number of shoots per tree. The season influence how fast the shoots appear, the number of trees that sprouted, and the number of shoots per tree. The girdling of the trunk on *Anadenanthera peregrina* trees shows a higher potential for vegetative propagation when carried out in May (autumn) in trees with up to 25 cm of DBH.

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