

Artigos

Ecological restoration in pasture areas with direct seeding

Restauração ecológica em área de pastagem por semeadura direta

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ABSTRACT

The use of direct seeding in projects for the recovery of degraded areas has stood out in some regions of the country because of its effectiveness, lower operating costs, and ease of implementation. Thus, the present study aimed to evaluate the potential of direct seeding the haul in ecological restoration of a deactivated pasture dominated by *Urochloa brizantha*, here characterized by an invasive weed plant. The experiment consisted of eight treatments resulting from different combinations of seeds (tree and herbaceous cover crops), the use of treatments to break the dormancy of tree species seeds (with and without), and the use of different types of substrates (clay and sawdust). The tested treatments did not affect seedling emergence, survival, or initial growth. The most established species in the study area were *Piptadenia gonoacantha*, *Mabea fistulifera*, *Dalbergia nigra*, and *Senegalia polyphylla*, which could potentially compose the list of species to be used in forest restoration projects through the use of direct sowing techniques. Plant survival at the end of the evaluation period every three months until the 14 months of experiment implementation corresponded to a density equivalent to 4300 plants per hectare, this result compared to other techniques, shows muvuca as a seeding technique viable direct for the area under study. However, further studies using higher seed densities of cover species are necessary to control the invasive grass *Urochloa brizantha* effectively.

Keywords: Biosphere reserve; Serra do Espinhaço; Atlantic Forest; Degraded pasture

RESUMO

O uso da muvuca de sementes em projetos de recuperação de áreas degradadas vem se destacando em algumas regiões do país devido sua eficácia, menor custo de operação e facilidade na implantação. Neste sentido, o presente estudo teve como objetivo avaliar o potencial da semeadura direta por meio do uso da muvuca de sementes na restauração ecológica de uma pastagem desativada e dominada por *Urochloa brizantha*, aqui caracterizada como planta invasora infestante. O experimento consistiu em oito tratamentos resultantes de diferentes combinações de sementes (espécies arbóreas e herbáceas de cobertura), uso de tratamentos para quebra de dormência das sementes de espécies arbóreas (com e sem) e tipos de substratos (argila e serragem). Os tratamentos testados não apresentaram efeito na emergência, sobrevivência e crescimento inicial das plântulas. As espécies com maior estabelecimento na área em estudo foram *Piptadenia gonoacantha*, *Mabea fistulifera*, *Dalbergia nigra* e *Senegalia polyphylla*, sendo estas, potenciais para comporem a lista de espécies a serem utilizadas em projetos de restauração florestal por meio do uso da técnica de muvuca. A sobrevivência das plantas ao final do período de avaliação a cada três meses até os 14 meses de implantação do experimento, correspondeu a uma densidade equivalente a 4300 plantas por hectare, este resultado comparado ao de outras técnicas evidencia a muvuca como uma técnica de semeadura direta viável para a área em estudo. Todavia, faz-se necessário novos estudos utilizando maiores densidades de sementes de espécies de cobertura a fim de se obter um controle efetivo da gramínea invasora *Urochloa brizantha*.

Palavras-chave: Reserva da biosfera; Serra do Espinhaço; Mata Atlântica; Pastagem degradada

1 INTRODUCTION

In Brazil, agricultural activity has converted complex ecosystems into cultivated areas, areas that, in large part, have been degraded as a result of the adoption of inappropriate practices. According to data from Embrapa (2019), the country has approximately 200 million hectares of pasture, and more than half of this land extension has some level of degradation, and most of the land is already at an advanced stage of degradation. Currently, Minas Gerais is the state with the most deforestation of the Atlantic Forest in Brazil. In this state, livestock occupy large tracts of land without proper management (ROCHA JÚNIOR *et al.*, 2017).

Although there is a great loss of forest area with the advancement of agriculture, the greatest threat to ecological restoration has been biological invasion, mainly by African grasses, and the changes brought about in the fire regime (BARBOSA *et al.*, 2015). Invasion by exotic species represents a problem worldwide; however, some territories are more susceptible to invasion than others (MARCHANTE, 2011).

The *Urochloa* genus, which includes some of the most aggressive invasive grasses, has favorable characteristics that contribute to its invasion in Brazilian biomes, among which the following stand out: high photosynthetic efficiency and use of nutrients, high rates of growth, regrowth, and regeneration, high reproductive efficiency because of the fast reproductive cycle, and intense production of seeds with high viability (DAMASCENO *et al.*, 2018).

The species *Urochloa brizantha*, which is widespread in the study region, alters the intrinsic and extrinsic characteristics of the combustible material, retaining moisture, and increasing the vertical distribution of the combustible material, which are characteristics that alter the fire regime in the areas where this species occurs (GORGONE-BARBOSA *et al.*, 2015). Additionally, its high biomass acts as a barrier for the arrival of propagules and light in the soil, which consequently prevents or reduces the establishment of native species from natural regeneration or causes high mortality of seedlings of tree species used in planting for forest restoration in these areas.

Faced with the challenges of restoring pasture areas, it is necessary to use effective and low-cost techniques, as well as to know when and where to use them. Among the techniques that show promise in ecological restoration, direct sowing stands out (PALMA; LAURANCE, 2015), which is a cheap and versatile procedure. In addition to reducing costs, it eliminates the entire seedling production phase in a nursery and can be carried out in areas with difficult access and significant declivity. There is also the possibility of mechanization for use in large areas (CAMPOS-FILHO *et al.*, 2013), as long as they present a flat relief.

One way to use direct seeding is *muvuca*, which consists of mixing different species of native seeds together with some substrate (earth, sand and sawdust, for example), avoids the separation between pioneers and other non-pioneer species (SILVA *et al.*, 2015). To accelerate the process of soil covering and to create the microclimatic conditions necessary for the development of native species, seeds of non-invasive annual exotic species, such as pork beans, pigeon peas, and/or crotalaria, are added to the mixture (RAUPP *et al.*, 2020).

Although the muvuca technique has been standing out in some regions of the country, it is still a little known technique, despite its high potential. In the literature, studies using this restoration technique are scarce, especially in the biome under study.

Therefore, the goal of the present study was to evaluate the potential of direct sowing through direct seeding in the ecological restoration of a pasture of *Urochloa brizantha*. To improve the technique in the region, the influence of different substrates associated with seeds was tested along with the overcoming of dormancy in seed germination and initial seedling development.

2 MATERIAL AND METHODS

2.1 Characterization of the study area

The experiment was implemented in an area of deactivated pasture located at Fazenda Pitangueiras, belonging to the Anglo American mining company. The farm is located on the eastern edge of the Serra do Espinhaço Meridional, in the municipality of Conceição do Mato Dentro, MG.

The climate of the region is of the Cwa type (humid temperate climate with dry winter and hot summer) according to the Köppen classification. The average altitude is 735 m and has an average annual temperature of 20°C and average annual precipitation of 1,450 mm, with rainfall concentrated from November to March. The predominant vegetation in the study area comprises pastures surrounded by fragments of seasonal semi-deciduous forests in an intermediate stage of succession (AYOADE, 1996). The soils occurring at the site are the Cambisols, occurring in relief, varying from wavy to mountainous.

2.2 Implementation and conduct of the experiment

The experiment was conducted during the rainy season in December 2017. The experiment was a randomized block with eight treatments and four replications

each. Four blocks were implanted along a gentle slope, each containing nine plots of 4 m × 4 m (16 m²) with 1 m spacing between them.

The experiment consisted of the respective treatments: trees with dormancy break + clay (T1), trees without dormancy break + clay (T2), trees + herbaceous with dormancy break + clay (T3), trees + herbaceous without dormancy break + clay (T4), trees with dormancy break + sawdust (T5), trees without dormancy break + sawdust (T6), trees + herbaceous with dormancy break + sawdust (T7), trees + herbaceous without dormancy break + sawdust (T8).

About three days before sowing, the soil was prepared by plowing and harrowing the area. Subsequently, direct broadcast sowing was carried out manually of the mix of seeds of tree species belonging to different ecological groups (pioneers, early secondary and late secondary) occurring in forest remnants in the study region, together with cover herbaceous seeds or green adubation. The seed density used in the composition of the mix was six seeds/species/m². For treatments that presented dormancy break (T1, T3, T5, and T7), this was done only for the species that presented this requirement (Table 1). The exotic species *Tamarindus indica* was added to the seed mixture to act as a bait plant to avoid damage caused by the attack of leaf-cutting ants on the other species used. According to the Instituto Socioambiental (ISA) the species is consumed by ants, which is preferred over seedlings of other species. Therefore, tamarind seeds are used in the seed mixture to compose the mixture that will serve as bait to attract ants and, thus, interrupt the consumption of the seedlings of the species of interest.

The seeds were collected from matrices located on the premises of the Anglo American mining company in the year before the implementation of the experiment, except for the species *Cordia trichotoma*, *Handroanthus ochraceus*, and *Machaerium nyctitans*, which were collected about six months before the experiment. Seeds were beneficiaries and stored later. The seeds of the following species: *Cassia ferruginea*, *Anadenanthera colubrina*, *Piptadenia gonoacantha*, *Mabea fistulifera*, *Senegalia polyphylla*, and *Tamarindus indica* remained stored in a cold chamber at the Center

for Propagation of Forest Species (CIPEF) at UFVJM, at a temperature of 6 °C and relative humidity of 40%.

Table 1 – Seed species used in the muvuca mixture, together with herbaceous coverage or green manure seeds

Family	Specie	Form of growth
Araliaceae	<i>Didymopanax morototoni</i> (Aubl.) Decne. & Planch.	Tree
Bignoniaceae	<i>Cybistax antisyphilitica</i> (Martius) Martius	Tree
Bignoniaceae	<i>Handroanthus chrysotrichus</i> (Mart. ex DC.) Mattos	Tree
Bignoniaceae	<i>Handroanthus ochraceus</i> (Cham.) Mattos	Tree
Bignoniaceae	<i>Jacaranda puberula</i> (Cham.)	Tree
Boraginaceae	<i>Cordia trichotoma</i> (Vellozo) Arrabida ex Steudel	Tree
Brassicaceae	<i>Raphanus sativus</i> L.	Herb
Erythroxylaceae	<i>Erythroxylum pelleterianum</i> A.St.-Hil.	Herb
Euphorbiaceae	<i>Mabea fistulifera</i> Mart.	Tree
Euphorbiaceae	<i>Maprounea guianensis</i> Aubl.	Tree
Fabaceae	<i>Anadenanthera colubrina</i> (Vell.) Brenan var. <i>cebil</i>	Tree
Fabaceae	<i>Cassia ferruginea</i> (Schrad.) Schrad. ex DC.	Tree
Fabaceae	<i>Dalbergia nigra</i> (Vell.) Allemão ex Benth.	Tree
Fabaceae	<i>Machaerium brasiliensis</i> Vogel.	Tree
Fabaceae	<i>Machaerium nyctitans</i> (Vell.) Benth.	Tree
Fabaceae	<i>Piptadenia gonoacantha</i> (Mart.) J. F. Macbr.	Tree
Fabaceae	<i>Senegalia polyphylla</i> (DC.) Britton & Rose	Tree
Fabaceae	<i>Tamarindus indica</i> L.	Tree
Fabaceae	<i>Cajanus cajan</i> (L) Hunth	Tree
Fabaceae	<i>Canavalia ensiformes</i> L. DC	Herb
Fabaceae	<i>Crotalaria ochroleuca</i> L.	Herb
Fabaceae	<i>Dolichus lablab</i> L.	Herb
Fabaceae	<i>Mucuna pruriens</i> L. DC	Herb
Malvaceae	<i>Luehea grandiflora</i> Mart. & Zucc.	Tree
Melastomataceae	<i>Miconia</i> sp.	Herb
Poaceae	<i>Sorghum bicolor</i> (L.) Moench	Herb
Primulaceae	<i>Cybianthus brasiliensis</i> (Mez) G. Agostini.	Herb
Rutaceae	<i>Dictyoloma vandellianum</i> Adr. Juss.	Tree

Source: Authors (2020)

The variables evaluated were emergence, survival, establishment, growth of tree species, and soil cover by *Urochloa brizantha* and herbaceous species. In the first three months, the evaluation was carried out every two weeks, and after that, it was conducted monthly. The seedlings were marked with a numbered plate; thus, enabling their identification and counting for emergence and survival. The evaluation of the increase in height (cm) and diameter (mm) of the seedlings began 184 days after the implementation of the experiment (End of rainy season), using a measuring tape and a digital caliper, respectively. The growth evaluation was carried out every three months until 14 months after the implementation of the experiment.

The Braun-Blanquet scale was used to assess the *Urochloa brizantha* coverage in the plot and the coverage of herbaceous species, which is a subjective measure that visually estimates the coverage in percentage values (BRAUN-BLANQUET, 1979). Values from 1 to 5 were assigned to cover species in the area, where 1: individuals covering less than 5% of the plot, 2: individuals covering 5%–25% of the plot, 3: individuals covering 25%–50% of the plot, 4: individuals covering 50%–75% of the plot, and 5: individuals covering >75% of the plot.

2.3 Data analysis

Data were tested for normality and homogeneity and, when necessary, transformed according to Box and Cox, using the MASS package (VENABLES; RIPLEY, 2002), and then submitted to analysis of variance (ANOVA), with trough of the package ExpDes.pt (FERREIRA *et al.*, 2018). The significance of the data was detected ($p < 0.05$), and the Tukey's test was performed to compare the means. The data were analyzed with the aid of the statistical program R version 3.5.0 (2018).

3 RESULTS

3.1 Emergency

Of the 21 tree species sown in the area, only seven emerged. These include *Anadenanthera colubrina*, *Cassia ferruginea*, *Dalbergia nigra*, *Mabea fistulifera*, *Piptadenia gonoacantha*, *Senegalia polyphylla*, and *Tamarindus indica*.

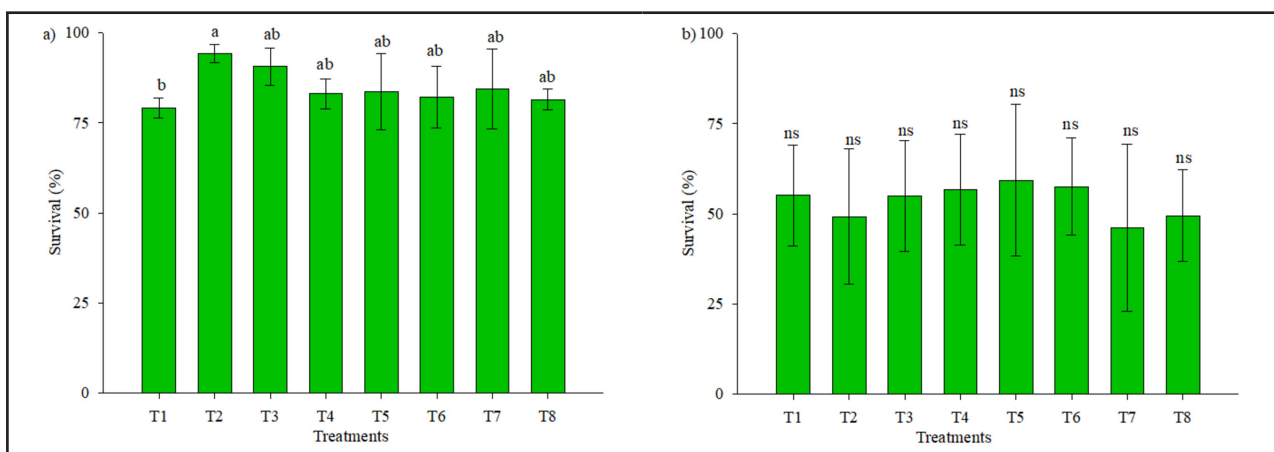
The ANOVA of the emergency data did not result in a statistically significant difference between the treatments tested ($p > 0.05$). However, the descriptive analysis of the data showed that the treatments in which dormancy breaking techniques were not applied obtained slightly higher averages than the treatments in which the techniques were applied. As for the tree/herbaceous association, the treatments with this association showed higher averages in comparison with treatments using only tree species. The substrate factor of the seed mixture resulted in the highest averages for the treatments in which sawdust was used.

The species *Tamarindus indica* had the greatest emergence, followed by *Piptadenia gonoacantha*. The species with the least emergence was *Anadenanthera colubrina*.

3.2 Plant survival

The overall average survival of the plants in the treatments was 82% and 54% at 7 and 14 months, respectively. The ANOVA of the data showed statistically different averages at 5% significance for the treatments tested at 7 months (Figure 1A), which were not significant at 14 months (Figure 1B).

Figure 1 – Survival of plants from different treatments at 7 (a) and 14 (b) months after the implementation of the direct sowing experiment in the ecological restoration of a pasture area in Conceição do Mato Dentro, Minas Gerais-Brazil



Source: Authors (2020)

In where: *Bars followed by the same letters do not differ based on Tukey's test at 5% significance.

Tamarindus indica had a mortality rate higher than 90%, due to herbivory of leaf-cutting ants. It is noteworthy that this was the only species to be attacked by ants during the experiment. This fact converges with the observation of the local population regarding the attraction of the species to ants, which motivated its choice to be part of the seed mix used for the restoration of the area. Survival rates ranged from 24% to 64% for *Cassia ferruginea* and *Anadenanthera colubrina*, respectively. *Piptadenia gonoacantha* had the highest number of plants per plot, followed by *Mabea fistulifera* (Table 2).

Table 2 – Species establishment and survival rate

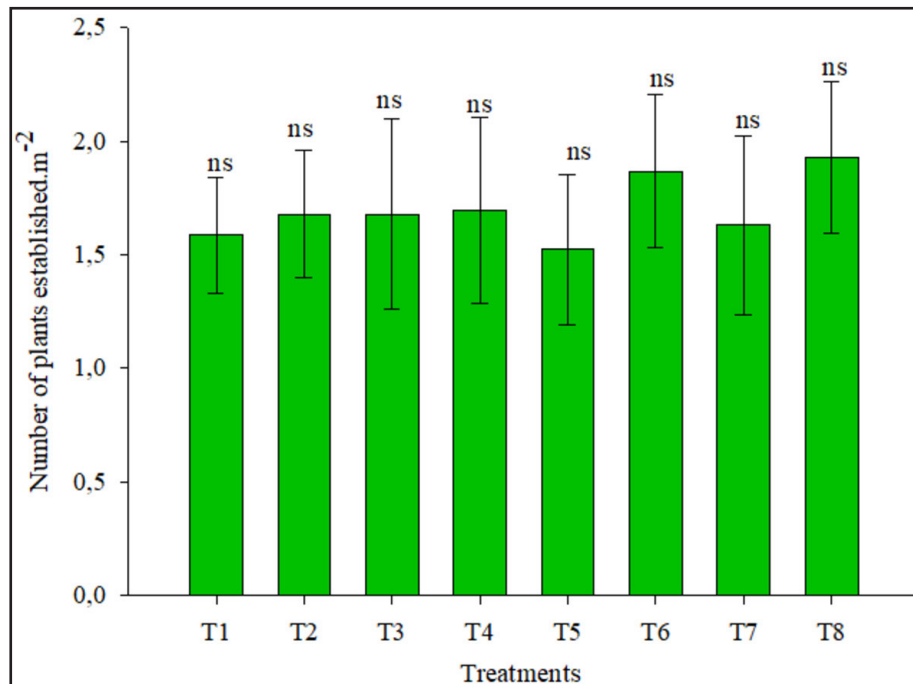
Species	Establishment (plants/m ²)	Establishment (plants/ha)	Survival (%)
<i>Senegalia polyphylla</i>	0.05	500	32.5
<i>Anadenanthera colubrina</i>	0.018	180	64.3
<i>Cassia ferruginea</i>	0.016	160	23.5
<i>Mabea fistulifera</i>	0.072	720	43
<i>Dalbergia nigra</i>	0.05	500	60.5
<i>Piptadenia gonoacantha</i>	0.219	2,190	59.9
Total	0.43	4,300	
CV%		22%	

Source: Authors (2020)

3.3 Establishment of plants

The ANOVA of data on the number of plants established at 14 months did not show distinct means at 5% significance for treatments (Figure 2). However, treatments T8 (1.93 plants m⁻²) and T6 (1.87 plants m⁻²) showed the highest averages of established plants.

Figure 2 – Number of plants established in different direct seeding treatments in the ecological restoration of a pasture area in Conceição do Mato Dentro, Minas Gerais-Brazil within 14 months



Source: Authors (2020)

3.4 Growth and increment of established plants

At 14 months after the implementation of the experiment, the plants showed an average growth of 1.5 mm in diameter and 11.5 cm in height. The ANOVA did not result in a significant difference between the treatments tested for height, diameter, and increment ($p > 0.05$). The descriptive analysis of the data showed the highest averages for the treatments in which sawdust was used as a substrate for seed release, especially for the averages of the height variable (Table 3).

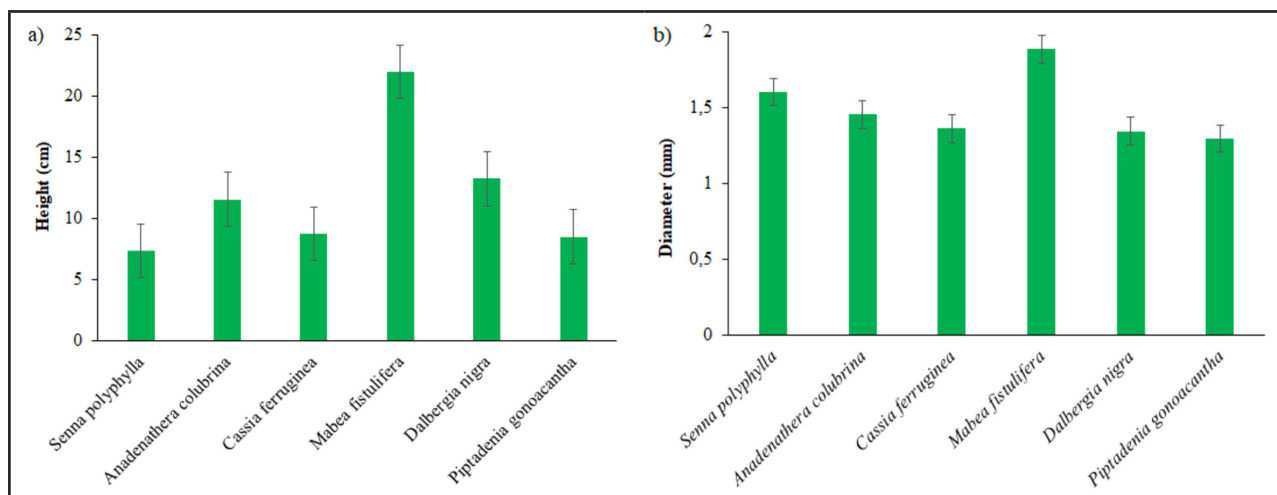
Table 3 – Growth of plants in diameter and height at 14 months after implementation of the no-tillage experiment in the ecological restoration of a pasture area in Conceição do Mato Dentro, Minas Gerais-Brazil

Treatment	Diameter (mm)	Height (cm)
Clay		
1) Tree with break	1.29 ^{ns}	8.36 ^{ns}
2) Tree without breaking	1.38 ^{ns}	10.88 ^{ns}
3) Tree + herbaceous with breaking	1.37 ^{ns}	9.88 ^{ns}
4) Tree + herbaceous without breaking	1.47 ^{ns}	12.46 ^{ns}
Sawdust		
5) Tree with break	1.49 ^{ns}	9.98 ^{ns}
6) Tree without break	1.56 ^{ns}	12.45 ^{ns}
7) Tree + herbaceous with breaking	1.65 ^{ns}	16.01 ^{ns}
8) Tree + herbaceous without breaking	1.40 ^{ns}	11.72 ^{ns}
CV%	11.2%	25.6%

Source: Authors (2020)

The species with the highest growth and overall average increase was *Mabea fistulifera*, and the species with the lowest growth was *Cassia ferruginea* (Figure 3).

Figure 3 – Growth of species in diameter and height at 14 months of implementation of the no-tillage experiment in ecological restoration of a pasture area in Conceição do Mato Dentro, Minas Gerais-Brazil



Source: Authors (2020)

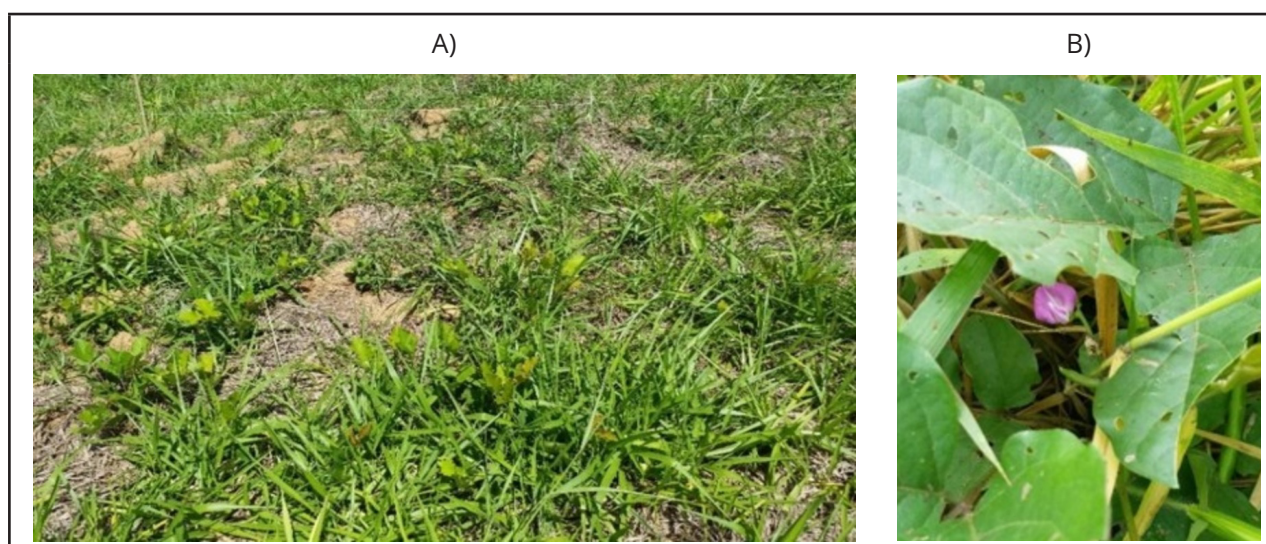
In where: *Bars followed by the same letters do not differ based on Tukey's test at 5% significance.

3.5 Covering of *Urochloa brizantha* and herbaceous species used for sowing

Three months after the implementation of the experiment, the area had approximately 50% of its coverage composed of *Urochloa brizantha*, which persisted until the end of the evaluations of the experimental area. In the same period of three months, the herbaceous species sown in the plots reached a maximum coverage of 25%, and at six months, the total area already had more than 75% of grass cover. Among the cover species, *Canavalia ensiformes* was the one that stood out, presenting the largest number of individuals in the plots in relation to the other species sown in the area (Figure 4).

The high percentage of coverage of the invasive grass *Urochloa brizantha* persisted until the end of the evaluations of the experimental area.

Figure 4 – Species of coverage in the experimental area at two months after implementation of the experiment



Source: Authors (2020)

In where: A) Individuals of *Canavalia ensiformes* distributed in one of the experimental plots; B) A flowering plant.

4 DISCUSSION

Only seven of the 21 species used for sowing emerged in the study area. However, the estimated population density of individuals in treatments T8 (1.93 plants m⁻²) and T6 (1.87 plants m⁻²) showed the highest plant averages established at the end of 14 months. The seeds that did not germinate were precisely the seeds stored under controlled conditions of temperature and humidity, which may have affected their viability. Six of the seven germinated species were stored in a cold chamber at the CIPEF at UFVJM.

The ANOVA of the data carried out at 7 months showed different averages at 5% significance, however, for the seedling emergency data at the end of 14 months, there were no significant differences between the treatments tested. Some authors have obtained better conditions for establishing tree species in response to the decrease in competition between native and invasive exotic species resulting from the consortium between tree species and herbaceous cover species (NUNES *et al.*, 2015; FERREIRA *et al.*, 2018). Beltrame and Rodrigues (2008) obtained better results with respect to survival and increase in the basal area of native species in consortium with *Cajanus cajan*; however, it was observed that the positive results of this consortium depended on the planting density of *Cajanus cajan* and the length of the intercropping. As in this study, the coverage of herbaceous species did not exceed 25% of the plots, and the absence of influence of this treatment may be related to the low sowing density of these species in the plots.

Results similar to those found in the present study were obtained by Pietro-Sousa and Silva (2014), who studied the sowing of seed mixture for ecological restoration of degraded permanent preservation areas. These authors did not find any influence of *Canavalia ensiformis* as a cover plant on the emergence and survival of native species in the evaluated plots. Alves (2016), when testing different densities of *Stylosanthes capitata* and *Stylosanthes macrocephala*, found no differences in the density of native planted species.

Another treatment evaluated in the present study was of breaking the dormancy of the seeds of the species for which this was needed. It was observed that of the nine species that received dormancy-overcoming treatments, only *Cassia ferruginea* and *Tamarindus indica* emerged. However, *Cassia ferruginea* was the species with the lowest survival rate (23.5%), leaving only one individual per treatment, except for the first treatment in which no individual of the species survived. The final establishment was 0.02 plants m⁻² or 200 plants ha⁻¹.

Dormancy-overcoming studies of *Cassia ferruginea* have revealed good germination results under controlled conditions (PAIXÃO *et al.*, 2017; CRUZ *et al.*, 2019). However, dos Santos *et al.* (2009) obtained high mortality and low growth of this species after sowing in a controlled environment when testing different substrates compared to the other species studied. Studies on direct seeding in the field involving this species are scarce in the literature. However, Lorenzi (2002) reported *Cassia ferruginea* as a rapidly growing and rustic species, suggesting that it could be used for the mixed reforestation of degraded areas.

The descriptive analysis of the data, in general, revealed higher averages for the treatments in which sawdust was used as an aggregating material for the release of the seeds. In the mixture, the seed mixture must be homogenized with some aggregating material to avoid stratification by size and uneven distribution of the seeds. Sawdust may have contributed to a better spreading of the seeds in the area because of its lower density, thus reducing the initial competition and increasing the emergence, survival, and growth of the seedlings in comparison with the treatments in which clay was used.

According to the analysis of the species, *Tamarindus indica* was the one that had the greatest emergency. However, it is an exotic species used by the Instituto Socioambiental (ISA) to minimize attacks by leaf-cutting ants on newly germinated seedlings in the field.

Among the native tree species, *Piptadenia gonoacantha* had the highest emergence values, followed by *Mabea fistulifera* and *Senegalia polyphylla*. These species had the highest number of plants established per square meter. The species with the highest survival rates were *Anadenanthera colubrina*, *Dalbergia nigra*, and *Piptadenia gonoacantha*, with an average survival of > 60%.

The tested treatments did not show different means in relation to the number of established plants (0.43 plants m⁻²) and survival (54%) according to the ANOVA performed. This survival rate was much higher than the density of plants obtained in the 3 × 2 m spacing, which is generally used for planting seedlings in ecological restoration. A spacing of 3 x 2 m results in 1,666 individuals per hectare, in contrast to direct sowing, these values can reach 45,000 seedlings per hectare of woody individuals (PELLIZZARO, 2016). In the present study, the value of 0.43 seedlings m⁻² corresponds to 4,300 seedlings per hectare, similar to Souza (2013) who obtained density of 0.6 individuals per m⁻². Therefore, this result compared to other techniques such as planting seedlings can be considered superior. A study by Cava *et al.* (2016), comparing different techniques for restoring vegetation in abandoned pasture areas, found that direct seeding promotes a density of species higher than the treatments of assisted natural regeneration, passive restoration and planting of seedlings.

The average growth of species in height was 11.5 cm and 1.45 mm in diameter. Similar results were obtained by Souza (2013), evaluating the direct seeding of native forest species, such as alternative ecological restoration. Resende and Pinto (2013) evaluating seed mixture in a degraded area in southern Minas Gerais obtained similar averages in some of the species used, as well as Soares (2007) evaluating the effect of rhizobia inoculation in native species by direct seeding. These values are considered satisfactory for cerrado areas (SILVA *et al.*, 2015), however, the area in question is an area of Atlantic forest.

The species *Mabea fistulifera* showed the highest growth values, reaching 22 cm in height and 2 mm in diameter. Gomes Júnior (2011) studying the growth of

the species on different substrates and levels of shading concluded that the initial growth of *Mabea fistulifera* seedlings is favored by the level of shading. What may have given prominence to this species in this study, since the plots showed a considerable percentage of coverage of the invasive grass *Urochloa brizantha* throughout the growth evaluation. The strong presence of this grass may have interfered with the growth of the other species, keeping low values of height and mainly diameter. This is due to the competitive superiority of grasses over native ones, explained by their greater ability to retain resources (TECCO *et al.*, 2010), and in the efficiency of the use of nutrients even in areas with low availability of these resources (FUNK, 2013).

5 CONCLUSIONS

The treatments to overcome dormancy, the association of tree and herbaceous species, and substrate of mixture did not affect emergence, survival, and initial growth of seedlings.

The species with the greatest establishment in the study area were *Piptadenia gonoacantha*, *Mabea fistulifera*, *Dalbergia nigra*, and *Senegalia polyphylla*. These species are recommended for use in ecological restoration projects through the use of seed mixture.

The seed mixture proved to be a viable technique for the recovery of the study area, presenting several surviving individuals in the evaluated period.

The growth of the species was slow because they suffered interference from competitiveness with the exotic grass *Urochloa brizantha*, which remained in the area until the end of the evaluation, and its control was not effective. Therefore, it is necessary to carry out further studies by applying a higher density of seeds of the cover species used in the area.

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REFERENCES

- ALVES, M. **Semeadura direta de ervas, arbustos e árvores para restauração do Cerrado**. 2016. 66 f. Dissertação (Mestrado em Ecologia). Universidade Federal de Brasília. Brasília, DF. 2016.
- AYOADE, J. O. 1996. **Introdução à climatologia para os trópicos**. Rio de Janeiro, Bertrand Brasil.
- BARBOSA, G.E.; PIVELLO, V.R.; BAUTISTA, S.Z.T.; RISSI, M.N.; FIDELIS, A. How can an invasive grass affect fire behavior in a tropical savanna? A community and individual plant level approach. **Biological Invasions** 17: 423–431. 2015.
- BELTRAME, T.P.; RODRIGUES, E. Comparação de diferentes densidades de feijão guandu (*Cajanus cajan* (L.) Millsp.) na restauração florestal de uma área de reserva legal no Pontal do Paranapanema, SP. **Scientia Forestalis**, v. 36, p. 317-327, 2008.
- BRAUN-BLANQUET, J. **Fitosociologia**: bases para el estudio de las comunidades vegetales. 3. ed. Madrid: Aum. Blume; 1979.
- CAMPOS-FILHO, E. M.; DA COSTA, J. N. M. N.; DE SOUSA, O. L.; JUNQUEIRA, R. G. P. Mechanized Direct-Seeding of Native Forests in Xingu, Central Brazil. **Journal of Sustainable Forestry**, Philadelphia, v. 32, n. 7, p. 702–727, 2013.
- CAVA, M. G. de B.; ISERNHAGEN, I.; MENDONÇA, A. H. de.; DURIGAN, G. Comparação de técnicas para restauração de vegetação lenhosa de Cerrado em pastagens abandonadas. **Hoehnea**, São Paulo, v. 43, n. 2, p. 301-315, 2016.
- CRUZ, Y. F.; MENDONÇA, A. P.; CARVALHO, M. B. F.; SALVATIERRA, Y. V. D.; CHAVES, N. M. C.; DORADO, A. J. Métodos de superação de dormência de canafístula (*Cassia fistula* L.). **Revista Brasileira de Ciências da Amazônia**, Rolim de Moura, RO, v. 8, n. 1, p. 007-011, 2019.
- DAMASCENO, G.; SOUZA, L.; PIVELLO, V.R.; BARBOSA, E.G.; GIROLDO, P.Z.; FIDELIS, A. Impact of invasive grasses on Cerrado under natural regeneration. **Biol Invasions**, v.20, p.3621–3629. 2018.
- EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA - **Pastagens**. Disponível em: <https://www.embrapa.br/agrobiologia/pesquisa-e-desenvolvimento/pastagens>. Acesso em: 25 abr. 2019.

FERREIRA, E.B.; CAVALCANTI, P.P.; NOGUEIRA, D.A. 2018. ExpDes.pt: Pacote Experimental Designs (Portuguese). R package version 1.2.0. <https://CRAN.R-project.org/package=ExpDes.pt>.

FERREIRA, E. de M.; ANDRAUS, M. de P.; TSAI, H. M.; CARDOSO, A. A.; LEANDRO, W. M. Área de preservação permanente em processo de revegetação com espécies arbóreas e adubos verdes. **Revista Engenharia Sanitária e Ambiental**, Rio de Janeiro, v. 23, n. 2, p. 243-252, 2018.

FUNK, J. L. The physiology of invasive plants in low-resource environments. **Conservation Physiology**, Oxford, v. 1, n. 1, 2013.

GOMES JÚNIOR, D. **Qualidade fisiológica de sementes e produção de mudas de *Mabea fistulifera* Mart.** 2011. 82 f. Dissertação (Mestrado em Ciências Florestais) Universidade Federal do Espírito Santo, Alegre-ES. 2011.

GORGONE-BARBOSA, E.; PIVELLO, V.R.; BAUTISTA, S.; ZUPO, T.; RISSI, M.N.; FIDELIS, A. How can an invasive grass affect fire behavior in a tropical savanna? A community and individual plant level approach. **Biological Invasions**, Tennessee, v. 17, n. 1, p. 423-431, 2015.

ISA - Instituto Socioambiental. Muvuca que vira floresta. 2018.

LORENZI, H. Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas do Brasil, v. 2. 2. Ed. Nova Odessa/SP: Instituto Plantarum, 2002.

MARCHANTE, H. **Invasion of portuguese dunes by *Acacia longifolia*: present status and perspectives for the future.** 2011. 212 f. Tese (Doutorado em Ecologia). Faculdade de Ciências e Tecnologia da Universidade de Coimbra. Coimbra. 2011.

NUNES, Y. R. F.; FAGUNDES, N. C. A.; VELOSO, M. D. M.; GONZAGA, A. P. D.; DOMINGUES, E. B. S.; ALMEIDA, H. S. Sobrevivência e crescimento de sete espécies arbóreas nativas em uma área degradada de floresta estacional decidual, norte de Minas Gerais. **Revista Árvore**, Viçosa. v.39, n.5, p. 801-810, 2015.

PAIXÃO, M. S.; LIMA, M. G. B. de; BOZETTI, M.; FARIA JÚNIOR, H. P. de; PAIXÃO, P. P. Superação de dormência das sementes e desenvolvimento de plântulas de acácia amarela (*Cassia ferruginea* (Schrad) Schrad ex DC). **Pesquisa Agropecuária Gaúcha**, Porto Alegre, v.23, n.1/2, p. 22-30, 2017.

PALMA, A.C., LAURANCE, S.G.W. A review of the use of direct seeding and seedling plantings in restoration: what do we know and where should we go? *Applied Vegetation Science*, v. 18, p. 561–568. 2015.

PELLIZZARO, K. F. **Restauração ecológica por meio de sementeira direta no cerrado: avaliando espécies de diferentes formas de vida e densidades de plantio.** Dissertação (Mestrado em Ecologia) Universidade de Brasília, Brasília, 75 f. 2016.

R CORE TEAM (2018) R: **Uma linguagem e ambiente para computação estatística.** R Foundation for Statistical Computing, Viena.

RAUPP, P. P.; FERREIRA, M. C.; ALVES, M.; CAMPOS-FILHO, E. M.; SARTORELLI, P. A. R.; CONSOLARO, H. N.; VIEIRA, D. L. M. **Direct seeding reduces the costs of tree planting for forest and savanna restoration.** *ECOLOGICAL ENGINEERING*, v. 148, p. 105788, 2020.

RESENDE, L. A.; PINTO, L. V. A. Emergência e desenvolvimento de espécies nativas em área degradada por disposição de resíduos sólidos urbanos. **Revista Agrogeoambiental**, Pouso Alegre, v. 5, n. 1, p. 37-47, 2013.

RODRIGUES, S. B.; FREITAS, M. G.; CAMPOS-FILHO, E. M.; DO CARMO, G. H. P.; DA VEIGA, J. M.; JUNQUEIRA, R. G. P.; VIEIRA, D. L. M. **Evaluating the success of direct seeding for tropical forest restoration over ten years.** *Forest Ecology and Management*, v. 438, p. 224-232, 2019.

SANTOS, J. A. dos; PINTO, L. V. A.; PEREIRA, A. J. Avaliação do desenvolvimento morfológico inicial de quatro espécies de leguminosas arbóreas sob diferentes substratos. **Revista Agrogeoambiental**, Pouso Alegre, MG, v. 1. n. 1, 2009.

SILVA, R. R. P.; OLIVEIRA, D. R.; DA ROCHA, G. P. E.; VIEIRA, D. L. M. Direct seeding of Brazilian savanna trees: effects of plant cover and fertilization on seedling establishment and growth. **Restoration Ecology**, v. 23, p. 393-401, 2015.

SOARES, P. G. **Efeito da inoculação com rizóbio no estabelecimento, crescimento inicial e abundância natural de 15N em leguminosas (Fabaceae) arbóreas nativas plantadas por semeadura direta.** Dissertação (Mestrado em Recursos Florestais) - Escola Superior de Agronomia "Luiz de Queiroz", Universidade de São Paulo. 69 f. 2007.

SOUZA, R. P. **Semeadura direta de espécies florestais nativas, como alternativa de restauração ecológica para a região de Dourados, Mato Grosso do Sul.** Dissertação (Mestrado em Ciência e Tecnologia Ambiental) - Faculdade de Ciências Exatas e Tecnológicas, Universidade Federal da Grande Dourados. Dourados-MS. 34 f. 2013.

TECCO, P. A.; DI, S.; CABIDO, M.; URCELAY, C. Functional traits of alien plants across contrasting climatic and land use regimes: do aliens join the locals or try harder than them? **Journal of Ecology**, London, v. 98, n. 1, p. 17-27, 2010.

VENABLES, W. N.; RIPLEY, B. D. **Modern Applied Statistics with S. Fourth Edition.** Springer, New York, 2002. <http://www.stats.ox.ac.uk/pub/MASS4>.

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