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Articles

Establishment of native seedlings species as an indicator of ecological restoration of riparian forest, Cerrado, DF, Brazil

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Abstract - This study evaluated the survival of seedlings of native species of Cerrado - Brazil and its potential as an indicator of ecological restoration of riparian forests. The factors affecting survival were also analyzed. The experiment consisted of three planting models with three replications (T1 = nucleation: Anderson model; T2 = nucleation: Anderson model + artificial perches; T3 = filling line and diversity line). The influence of factors such as leaf herbivory, stem herbivory, absence of leaves (predation, dehydration or malnutrition) and sprouting/regrowth survival were assessed by cluster analysis. The survival rates ranged from 58.6 to 100% (average 73.6%). Out of eighteen species, fifteen showed survival rate above 60%, and could be potentially used in the restoration of degraded areas. The hierarchical clustering using survival efficiency and biotic factors resulted in the distinction of two groups of species with high frequency of leaves and stem herbivory, differing statistically (test "t", $p < 0.05$) in the sprouting and regrowth. The survival efficiency shows potential of being used as a restoration indicator.

Estabelecimento de mudas de espécies nativas como indicador de restauração ecológica de mata ripária, Cerrado, DF

Resumo - Este trabalho avaliou a sobrevivência das mudas de espécies nativas do Cerrado – Brasil e seu potencial como indicador de restauração ecológica de matas ripárias. Os fatores que afetam a sobrevivência também foram analisados. O experimento consistiu em três tratamentos com três repetições (T1= nucleação: modelo de Anderson; T2 = nucleação: modelo de Anderson + poleiros artificiais; T3 = linha de recobrimento e linha de diversidade). A influência dos fatores: herbivoria foliar, herbivoria caulinar, ausência de folhas (predação, desidratação ou desnutrição) e brotação/rebrota na sobrevivência foi avaliada através da análise de agrupamento. A taxa de sobrevivência variou de 58,6% a 100% (média 73,6%). Das dezoito espécies, quinze apresentaram sobrevivência acima de 60%, com potencial para recuperação de áreas degradadas. O agrupamento da sobrevivência com os fatores bióticos resultou na formação de dois grupos de espécies, com altas frequências de herbivorias foliares e caulinares, diferindo-se estatisticamente (teste "t", $p < 0,05$) para brotação e rebrota. A eficiência da sobrevivência como potencial indicador de restauração foi satisfatória.

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Introduction

The Cerrado biome occupies 25% of the Brazilian territory (Silveira et al., 2019) and occurs in 11 states, from Paraná to Maranhão (Brandão Junior et al., 2020). The biome consists of flora and fauna grouped by vegetation types, with similar geological conditions, climate and landscape formation (Passaretti et al., 2020). Due to its location in the central part of the country, the Cerrado includes the main sources for the basins of the São Francisco, Paraná, Araguaia, Tocantins and Parnaíba rivers (Brandão Junior et al., 2020).

The Cerrado vegetation contains several physiognomies, including dry forests and riparian forests (Del-Claro & Torezan-Silingardi, 2019). It is the most affected Brazilian biome by the agricultural expansion in its diverse phyto-physiognomies.

Riparian forests margin water bodies and, therefore, have certain floristic peculiarities due to regular water flow, sediments and nutrients. The process of deforestation and fragmentation of the natural vegetation leads to the physical degradation of the soil, resulting in erosion and consequently to the silting of rivers, leading to the decline of springs (Albuquerque et al., 2013; Chen et al., 2019; Nóbrega et al., 2020). Therefore, the ecological restoration of riparian environments aims to initiate or to accelerate the recovery of these ecosystems relative to their health, integrity and sustainability (Chen et al., 2019).

According to Lima et al. (2015), the process of ecological restoration of degraded ecosystems requires the use of information and concepts that are associated with low cost and high social and environmental returns. However, the restoration of riparian forests is hampered by several abiotic and biotic factors and the impact of these factors on the restoration process varies with the forest types and sites (Passaretti et al., 2020).

As the restoration processes are implemented, some parameters need to be monitored periodically and could be used as ecological indicators (Rodrigues et al., 2009; Prach et al., 2019). The selection and use of indicators in the restoration process makes it possible to evaluate if the used methods are on par with the technical recommendations, as well as if the objectives are met with as the restoration of degraded environment evolve (Lima et al., 2015). Some of the recommended restoration indicators in the implantation phase are: the presence of invasive tree species and the quantification of individuals from natural regeneration, the height and diameter of planted seedlings as well as their survival rate (Rodrigues et al., 2009).

The survival rate of the seedlings should be evaluated as part of the initial monitoring of the ecosystem's structural restoration. The analysis of the native species survival in the Cerrado has been carried out by several authors (Oliveira et al., 2015; Lima et al., 2018; Artioli & Corrêa, 2019), who have found satisfactory results for the species analyzed in each study.

The success of planting in the early stages (survival) depends primarily on the quality of the seedlings (Lima Filho et al., 2019). Good seedlings quality is necessary for a higher survival rate after transplantation, which is critical to the success of any restoration program. Furthermore, the transplanted plant species should compete successfully with exotic plants (Prach et al., 2019) as well as with herbivores (Kimball et al., 2019). For this reason, there should be silvicultural management actions before and after planting and seedlings ought to be planted in the rainy season. The survival rate can be negatively influenced by the intensity of the physical degradation of the soil in the area (Macera et al., 2017), by the pervasiveness of exotic species and by the absence of native species of flora and fauna in the restoration area (Rodrigues et al., 2009; Albuquerque et al., 2013).

In this context, the objective of this work was to evaluate the survival of native species seedlings and the factors affecting it in the transplantation phase of the restoration experiment, as well as its potential as an indicator of ecological restoration of riparian forests.

Material and methods

Study area

This work was part of the Aquaripária/CNPq project (whose general objective was to test techniques to accelerate the process of ecological restoration of riparian forests in the Cerrado), developed at the Center for Technology Transfer for Dairy Zebu Breeds (CTZL, in its Portuguese acronym) - Embrapa Cerrados, Núcleo Rural Ponte Alta, Gama, DF, Brazil (15°56'57.27" S and 48°07'28.24" W). The experimental area (2.56 ha), a disturbed, non-flooded riparian forest, limited by pasture and forest fragments, is located on the right bank of the Ponte Alta stream (second order, well fitted) (Figure 1).

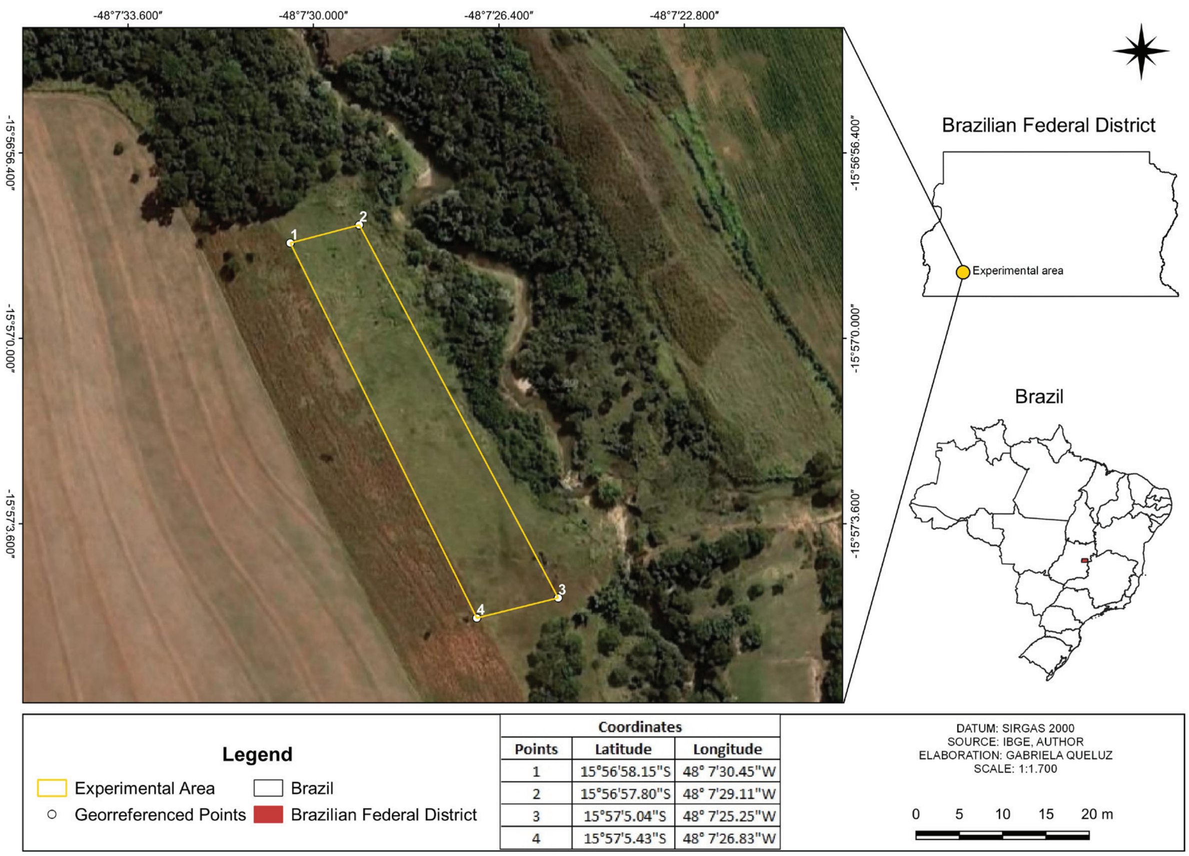

Figure 1. Location of the ecological restoration experiment of riparian forests, Gama, DF, Brazil.

The experiment area was dominated by *Urochloa decumbens* (Stapf) R.D. Webster (brachiaria) and some plants native of the Brazilian Cerrado. Before starting the experiment, the area was under a two-year crop rotation cycle between corn and brachiaria (pasture for cattle), adding NPK fertilizer 4-14-8 for both crops.

The average annual temperature in the Brazilian Federal District is approximately 21 °C, presenting the higher averages in September (23.1 °C) and October (22.9 °C) and the lower averages in May (19.0 °C) and July (19.0 °C). The average annual rainfall is of 1,600 mm. The region climate follows the characteristics of the Cerrado biome, with wet and rainy summers (from October to April) and dry and relatively cold winters (from May to September). The rainiest months were from January to March of 2012, November of 2012 and January of 2013; the driest weeks were between June and August of 2012. The altitude is of approximately 960 m, and its climate type is Aw, according to Köppen.

The physical-chemical characterization of the soil in the area was performed in four depths: 10, 20, 40 and 60 cm. Four soil composite samples were collected in the experiment area. For each composite sample, 20 single samples were randomly collected from each planting model. After collection, the soil was homogenized and approximately 300 g were removed to determine the physio-chemical properties in the laboratory. The soil presents medium acidity, with high contents of Al^{3+}, H+Al and saturation of aluminum. Other elements considered essential for plant survival, such as Ca^{2+}, Mg^{2+}, Na^{+} and P, confer moderate fertility to the soil. Average organic matter levels were also found at all depths. Its texture is clayey (above 400 g kg^{-1} clay) in all layers (Table 1).

Table 1. Soil physical-chemical characteristics in the experiment of ecological restoration of riparian forest, Gama, DF, Brazil.

Characteristics	depth (cm)			
	0-10	10-20	20-40	40-60
Granulometric composition (g kg^{-1})				
Clay	468	525	503	513
Sand	313	312.5	303	293
Silt	218	162.5	193	183
Sorptive complex				
pH (H_2O)	5.78	5.75	5.66	5.76
P available (mg dm^{-3})*	1.16	0.90	0.66	0.68
K (mg dm^{-3})	67.34	56.80	18.20	8.85
Ca^{2+} (cmol$_c$ dm^{-3})	1.18	1.05	0.84	0.66
Mg^{2+} (cmol$_c$ dm^{-3})	0.46	0.45	0.36	0.32
Na^{+} (cmol$_c$ dm^{-3})	0.05	0.05	0.05	0.04
Al^{3+} (cmol$_c$ dm^{-3})	0.08	0.20	0.24	0.34
Acidity (H+Al) (cmol$_c$ dm^{-3})	3.10	3.70	3.40	3.70
Exchangeable bases (cmol$_c$ dm^{-3})	1.95	1.80	1.51	1.30
Cation exchange capacity (cmol$_c$ dm^{-3})	5.05	5.50	4.91	5.00
Base saturation - V (%)	38.80	33.00	31.60	26.40
Aluminum saturation - m (%)	4.06	10.65	13.92	22.18
Sodium saturation - ISNa (%)	2.56	3.30	3.12	3.22
Organic matter (dag kg^{-1})	2.10	2.80	2.18	2.36

*P: determination by the method of Mehlich-1.

Ecological restoration experiment

Survival monitoring was carried out in the Aquaripária project, which was initiated in December of 2011 with different restoration techniques: planting in lines (method of filling lines and diversity lines), adapted from the model proposed by Rodrigues et al. (2009), and nucleation (Anderson model and artificial perch) adapted from the method proposed by Anderson (1953) and Reis et al. (2007).

The preparation of the area for the experiment consisted of demarcating the plots and opening the pits (30 cm × 40 cm) according to the standard arrangement in each method (cores, lines and/or perches). To fix the perches, the pits measured 40 cm × 80 cm. The manual crowning of the seedlings was performed semiannually to decrease the competition with the brachiaria, as well to control the ants.

The experimental design consisted of three planting models, with three randomized replicates in nine independent plots, 3 m apart from each other. The monitored treatments (T) were:

T1 = Nucleation - Anderson model: five densified seedlings (1 m spaces between seedlings) were distributed in a cross forming a nucleus. The lateral seedlings were shrubs and the distance between cores was of 5 m, in a plot of 30 m × 30 m. A rapidly growing shrub (zoochoric) species were used to attract fauna to the treatment and to shade the central seedlings, and consequently, to aid the development of tree seedlings. Twenty five nuclei were allocated with 125 seedlings (Figure 2A).

T2 = Nucleation - Anderson model + artificial perches: use of adapted Anderson model associated with artificial perches. A space of 5 m was set between nuclei and perches, alternately distributed, making up 13 cores with 65 seedlings, interspersed with 12 perches, in plots of 29 m × 29 m (Figure 2B).

T3 = Filling line and diversity line: planting in lines, four filling (starting at the edges), alternated with three lines of diversity, spaced 3 m × 3 m between the seedlings, in plots of 21 m × 21 m (Figure 2C).

The selection of tree and shrub species from riparian zones (Table 2) was performed based on the ecological principles and criteria required in each method that was used in the experiment, also considering the adaptability of each species, the environmental conditions of the riparian forest, its habitat and sucessional category. The seedlings used were produced in the nursery of Embrapa Cerrados, DF, which had, at the date of planting, between 20 and 40 cm in height.

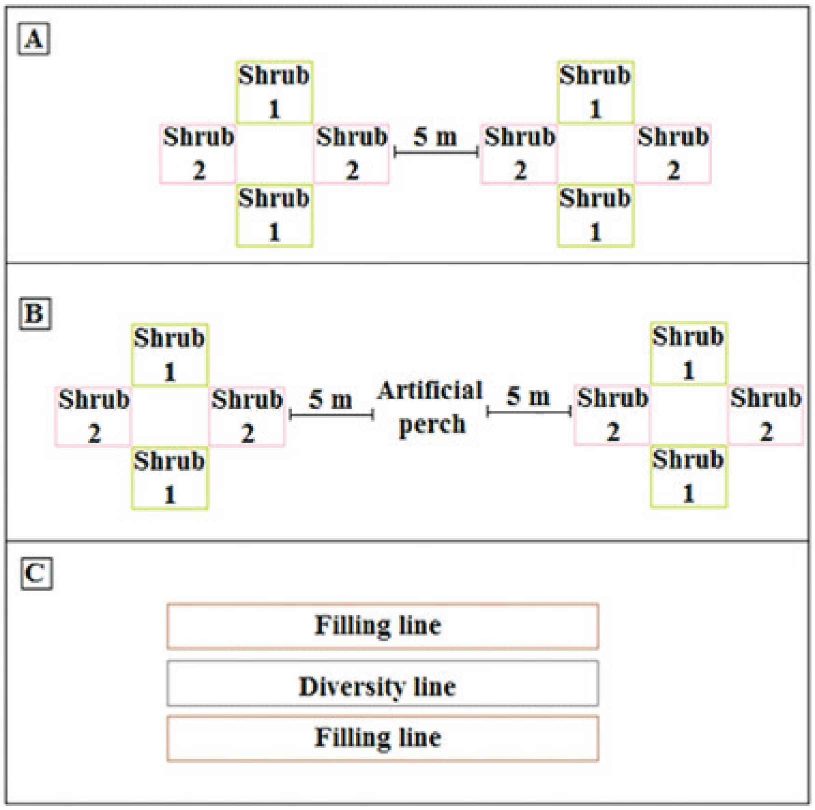

Figure 2. Treatments applied in the ecological restoration experiment, Gama, DF, Brazil.

Data collection and analysis

Survival monitoring was carried out five times between January 2012 and January 2013, two, three, four, six and 12 months after planting. The survival rate of the seedlings was calculated by comparing the final and the initial rates (Equation 1).

$$T\ (\%) = \frac{TF}{TI} x\ 100 \quad (1)$$

Where T = survival rate; TF = total number of surviving seedlings at the end of the evaluation period; TI = total seedlings at the beginning of the evaluation period.

Also, during that same period, some factors that may have influenced the quality of the seedlings and their survival were monitored and analyzed: (i) leaves herbivory, (ii) stem herbivory, (iii) absence of leaves, (iv) sprouting and (v) regrowth. The occurrence of these factors on seedlings was estimated by field observations of their health. In January 2012, the first evaluations of the seedling status, considered the initial zero mark, were carried out. The visible parameter considered was sprouting in the initial stages of plant development, above the collar of the plant. Regrowth was considered as the initial sprouting of stem development below and/or in the root collar of the plant.

The incidence percentage of factors was obtained. Thus, the cluster analysis was performed according to the Ward method (Ward, 1963) for survival. The square Euclidean distances and the groups were extracted using the graphs of the bond distances in the successive steps of the cluster analysis as a definition criterion. After the set of groups for survival were identified, the results of the factors were subjected to the t-test for comparison of means ($p < 0.05$). Statistical analysis was performed in SPSS software version 19.0 (IBM, 2010).

The sequence of the clusters was represented graphically by a dendrogram. The potential of survival as an indicator of restoration was assessed using the characteristics of an ecological indicator, proposed by State Environmental Goals and Indicators Project (SEGIP) (1995) and

Metzger & Casatti (2006). To evaluate the aspects and descriptors proposed in this method (sensitivity, performance, cost, comprehension and interpretation, predictability or trend and scale), the five-level Likert scale was used from the least efficient (0) to the most efficient (5) scale. The marks attributed to each aspect were based on its descriptor: whether the indicator is able to detect changes in the environment and differences between them (sensitivity), produces measurable results, has low application costs, is capable of being understood and interpreted without difficulty (understanding and interpretation), clearly indicates trends in response to changes in the environment over time, allows evaluation and monitoring (predictability or trend), presenting clear values and parameters that can be applied as a reference to evaluate the state of each area and their changes (scale) and allows the formulation of criteria bringing together various attributes of the ecosystem or area, allowing or enabling a unique analysis of several characteristics or states of the focus areas. By assigning efficiency levels to these aspects, it will be possible to assess their potential as an ecological indicator of restoration.

Table 2. Number of seedlings of Cerrado native species per treatment in the experiment of ecological restoration of riparian forests, Gama. DF, Brazil.

Scientific name	Family	Occurrence: phytophysiognomy*	Sucessional category**	Habitat***	Number of seedlings			
					T1	T2	T3	Total
Alibertia macrophylla (Schum)	Rubiaceae	GF, DF, CÃO, CER[2]	LS[1]	NF[1]	6		6	12
Aspidosperma parvifolium A. DC.	Apocynaceae	CF, GF, DF[2]	ST[3]	NF[2]			6	6
Buchenavia tomentosa Eichler	Combretaceae	CF, GF, DF, CÃO, CER[2]	CL[4]	NF[2]	6	6	15	27
Cariniana estrellensis (Raddi) Kuntze	Lecythidaceae	CF, GF, DFs[2]	LS[1]	NF[1]	9	9	9	27
Calophyllum brasiliense Cambess	Calophyllaceae	CF, GF[2]	LS[1]	F[2]	9	6	6	21
Copaifera langsdorffii Desff.	Fabaceae	CF, GF, CÃO, CER[2]	P[1]	NF[1]			3	3
Croton urucurana Baill	Euphorbiaceae	CF, GF[2]	P[3]	F[2]	6		18	24
Cybistax antisyphilitica (Mart.) Mart.	Bignoniaceae	CÃO, CER, DG, Am-CER[2]	P[4]	NF[2]	9		6	15
Genipa americana L.	Rubiaceae	CF, GF, CÃO[2]	LS[1]	NF[1]		6		6
Handroanthus impetiginosus (Mart. ex DC.) Mattos	Bignoniaceae	CF, DF[2]	P[1]	In[1]	9		6	15
Handroanthus serratifolius (Vahl) S. O. Grose	Bignoniaceae	GF, DF, CER, Am-CER[2]	LS[1]	F[1]	9	6	6	21
Inga laurina (Sw.) Willd.	Fabaceae	GF[2]	LS[3]	NF[2]			18	18
Maclura tinctoria (L.) Don ex Steud.	Moraceae	GF; CF[9]	P[5]	F[8]		6		6
Miconia ibaguensis (Bonpl.) Triana	Melastomataceae	GF, CER, CÃO, RF[2]	P[4]	F[2]	150	78	9	237
Myrsine guianensis (Aubl.) Kuntze	Primulaceae	CF, GF, DF, CER, SF, MF, RF[2]	P[1]	In[1]		78	6	84
Salacia elliptica (Mart.) G. Don	Celastraceae	DFd, DG[2]	P[6]	In[2]	6			6
Tapirira guianensis Aubl.	Anacardiaceae	CF, GF, DFs, CÃO, CER, SF, Am-CER[2]	IS[3]	In[2]	6		18	24
Tibouchina stenocarpa (DC.) Cogn	Melastomataceae	GF, CÃO, CER, RF[2]	P[7]	F[2]	15		15	165
Total Seedlings						**717**		

[1]Felfili et al. (2000); [2]Adapted from Sano et al. (2008); [3]Vale et al. (2008); [4]Franczak et al. (2009); [5]Hardt et al. (2006); [6]Costa et al. (2011); [7]Dias-Neto et al. (2009); [8]Backes & Irgang, (2004); [9]Battilani et al. (2006). *Occurrence in the phytophysiognomies: Cerradão = CÃO; Cerrado = CER; Amazonian Cerrado = Am-CER; gallery forest = GF; ciliary forest = CF; dry forest = DF (deciduous = d, semideciduous = s); dirty grassland (campo sujo) = DG; highland rocky fields (campo rupestre) = RF; murundu field = MF (campo com murunduns); palm swamp forests (vereda) = SF]; **Successional category: late secondary = LS; climax = CL; pioneer = P; initial secondary = IS; ***Habitat: non-floodable = NF; floodable = F; indifferent = In.

Results

The average survival rate of the 18 species after 90 days was 93.7%, reaching 73.6% at the end of the evaluation period. That is, of the total of 717 planted seedlings, 528 survived until the last evaluation. The survival percentage ranged from 100% (*Handroanthus serratifolius* and *Maclura tinctoria*) to 53.3% (*Cybistax antisyphilitica*). Some species showed high survival rates, such as *Aspidosperma parvifolium*; *H. impetiginosus*; *H. serratifolius*; *M. tinctoria*; *Croton urucurana*; *Genipa americana*; *Alibertia macrophylla*; *Buchenavia tomentosa*; *Cariniana estrellensis*; *Tibouchina stenocarpa*; *Tapirira guianensis*; *Inga laurina* and *Myrsine guianensis* (Table 3).

The comparative analysis of the survival rate with the biotic parameters (leaves herbivory, stem herbivory, leaves absence, sprouting and regrowth) obtained from the means of the seedlings health evaluation formed two groups (Table 4 and Figure 3), and presented meaningful differences in the survival, sprouting and regrowth variables. However, it was observed that both groups had high leaves herbivory values.

The species belonging to group 1 presented the highest percentage of survival, sprouting and regrowth. The species in group 2 had a lower survival rate and lower averages of regrowth and sprouting.

It was possible to evaluate the potential of these species as an indicator of ecological restoration. The results showed that the survival efficiency was satisfactory and presented the maximum score (5) in these aspects: yield, comprehension and interpretation, costs and predictability. Sensitivity scored lower (4 and 3) for the scale and synthesis aspects.

Table 3. Survival of the native species in the experiment of ecological restoration of riparian forests, Gama, DF, Brazil, between January 2012 and January 2013.

Species	Survival (%) per evaluation period (months)					
	n	2	3	4	6	12
Alibertia macrophylla	12	100	100	100	91.7	91.7
Aspidosperma parvifolium	6	100	100	100	100	100
Buchenavia tomentosa	27	96.3	96.3	96.3	92.6	88.9
Cariniana estrellensis	27	96.3	96.3	96.3	92.6	88.9
Calophyllum brasiliense	21	90.5	90.5	90.5	66.7	57.1
Copaifera langsdorffii	3	100	100	100	66.7	66.7
Croton urucurana	24	100	100	95.8	95.8	95.8
Cybistax antisyphilitica	15	100	100	100	53.3	53.3
Genipa Americana	6	100	100	100	83.3	83.3
Handroanthus impetiginosus	15	100	100	100	100	100
Handroanthus serratifolius	21	100	100	100	100	100
Inga laurina	18	88.9	88.9	83.3	83.3	72.2
Maclura tinctoria	6	100	100	100	100	100
Miconia ibaguensis	237	90.7	90.7	87.3	60.8	58.6
Myrsine guianensis	84	100	100	97.6	72.6	71.4
Salacia elliptica	6	100	100	100	66.7	66.7
Tapirira guianensis	24	100	100	95.8	83.3	79.2
Tibouchina stenocarpa	165	89.7	89.7	83	83	82.4
Total	**717**					
Average		**93.7**	**93.7**	**90.4**	**75.6**	**73.6**

n = initial number of seedlings.

Table 4. Mean and standard deviation of the factors and survival of the seedlings/species among the groups extracted from the cluster analysis, Gama, DF, Brazil, between January 2012 and January 2013.

Parameters (%)	Group 1 (n = 9)	Group 2 (n = 9)	p value
Leaves herbivory	18.97 ±11.97	19.11 ± 12.58	0.981
Stem herbivory	7.83 ± 3.91	7.03 ± 6.67	0.761
Absence of leaves	6.27 ± 4.23	3.91 ± 3.71	0.227
Sprouting	29.78 ± 22.43	12.71 ± 5.35	0.041*
Regrowth	10.88 ± 8.92	2.82 ± 3.79	0.024*
Survival	94.18 ± 6.50	67.61 ± 10.08	0.000

* Significant difference between the means of the groups by t-test ($p < 0.05$).

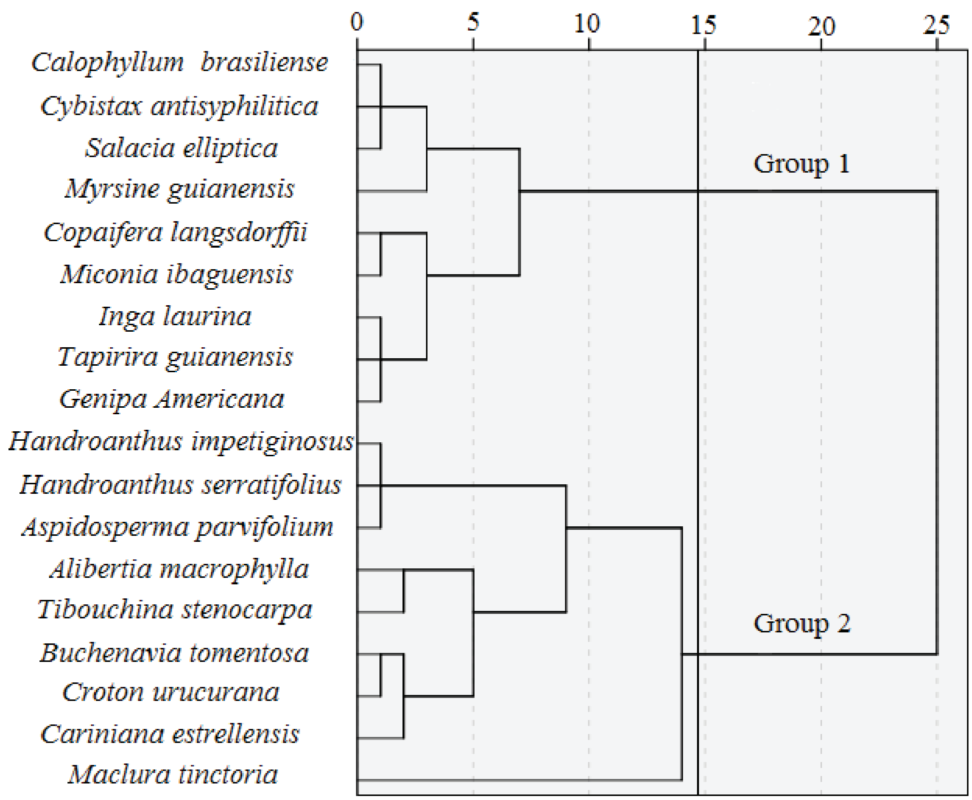

Figure 3. Cluster analysis of factors and survival of the seedlings/species in the experiment for the ecological restoration of riparian forests, Gama, DF, Brazil, between January 2012 and January 2013.

Discussion

Twelve months after planting, the average survival rate was high. A survival rate of native species in degraded areas of the Cerrado less than 60% is considered low (Oliveira et al., 2015; Lima et al., 2018). On the other hand, a survival above 80% in the same condition is an excellent result (Lima et al., 2018).

Some studies on the recovery of Cerrado degraded areas reported values similar to those found in this study. Oliveira et al. (2015), using native Cerrado species, reported survival values of 88.0%, 12 months after planting; Artioli & Corrêa (2019), evaluating the use of geotextile collars in the revegetation of a fragment of gallery forest in the Botanical Garden of Brasília, reported a survival rate of 68.1%, 6 months after planting. Pilon & Durigan (2013) observed 70% annual survival average of native Cerrado species planted in the Arboretum of the Assis State Forest, in the State of São Paulo.

The survival rate verified in this study can be considered high for the first 90 days after implantation and satisfactory at the end of 12 months, within the expected values for experiments in ecological restoration during the implantation phase. One of the factors that may have influenced the survival rate is the edaphic condition, as there are still no fertility standards for riparian forest species in the Cerrado.

The experiment area presented mineral constraints in the soil, acidity from pH, Al^{3+}, H+Al and aluminium saturation values. The texture is clayey in all depths, and the soil has low values of organic matter, Ca^{2+}, Mg^{2+} and generalized deficiency of P. According to Sorreano et al. (2012), P deficiency may influence the establishment and development of seedlings. Fagundes et al. (2019) stated that there is great variation in terms of fertility in riparian forests of the Cerrado. Therefore, soil conditions may have influenced the survival of some species.

The values obtained in the soil of the Center for Technology Transfer for Dairy Zebu Breeds (CTZL) experiment suggest that it has a medium acidity. Studies carried out by Lima et al. (2018) confirm that the survival of seedlings planted in degraded areas is proportional to the disturbance of edaphic conditions, that is, soils with high acidity and low fertility hinder the survival of the seedlings.

In addition to the edaphic conditions, Rodrigues et al. (2009) suggested that the establishment of native species in degraded areas can also be influenced by local microclimatic conditions. Although no correlation has been found between survival and edaphic factors, it was noticed that the highest mortality rate (14.8%) occurred between four to six months after planting, which coincided with the months of low precipitation. In January of 2013, six months after the last monitoring, the experiment presented a lower mortality rate, which may be associated with higher rainfall, favorable to plant survival.

The variation in the initial survival rate of native Cerrado species may be directly related to several exogenous and endogenous factors, as previously explained. In this study, from 18 species only three presented survival rates below 60%, which can be considered satisfactory for transplantation phase of the restoration. The survival of each riparian forest species in the Brazilian Federal District can be used as a reference in other riparian restoration projects.

Even if native species are expected to have good establishment and growth when introduced into degraded areas of similar environments, Kimball et al. (2019) stated that there are certain interactions with the environment, like herbivory, that may influence the establishment and growth of the introduced plants.

Some variations caused by herbivory, such as decreased leaf area and consequent decrease in photosynthetic rates and water use efficiency, may influence the survival rates of each species, depending on the extension of the damage. Pilon & Durigan (2013) presumed herbivory in 27% of the Cerrado species analyzed by them. In this study, we observed herbivory in species of both groups (Table 4). Among the grouped factors, group 1 had higher sprouting and regrowth rates, which had a positive influence on the survival of the seedlings.

Due to the attack of leaf-cutting ants, some plants may have developed response mechanisms (Crawley, 1997), stimulating sprouting and regrowth. Species with high sprouts percentage can be characterized as plants that invest energy in the root system in the initial growth phase (Duboc & Guerrini, 2007), favoring their establishment in disturbed areas.

The species in group 2 are mostly classified as pioneers, except for *Calophyllum brasiliense*, *Genipa americana* and *Inga laurina*, which are classified as secondary (Felfili et al., 2000; Vale et al., 2008), requiring shade for their establishment and development. This confirms the studies of Lima et al. (2018) suggesting that these factors can influence the survival of some species. It was also possible to evaluate that the species in group 2 presented significant lower averages for sprouting and regrowth.

Miconia ibaguensis and *C. brasiliense* are frequent species of flooded gallery soils (Sano et al., 2008), presenting one of the lowest survival rates. As this situation does not occur in the experiment area, this characteristic may have led to the lower survival rates of these species, consequently placing them in the group with the averages of listed biotic factors.

The values of the survival indicator were variable, perfectly identifiable and understood as to its action in the restoration, as well as the biotic and abiotic factors that had a predictable influence in the survival rates. It was also possible to detect changes in the environment in the early stages of the plants, such as increase in the mortality rate of some species. According to Lima et al. (2015) a potential indicator should reflect environmental changes in the first evaluation years. From these survival data, it will be possible to manage the process and make decisions in the next phases of restoration.

Survival rate as an indicator has been shown to be sensitive to abiotic (soil and climate) and biotic (herbivory and sprout) changes. The survival rate in the restoration action was easily measured and interpreted. The low cost of the survival indicator comes from the quick and easy monitoring of seedlings in the field.

In the scale, although they present values that can be applied as references in other areas, the data are initial and require more time to best evaluate this aspect, since survival can be reduced as time goes by, in addition to independent scale factors that change according to the experiment site. On the other hand, in the synthesis aspect that allows the formulation of criteria that combine several attributes of the ecosystem or area, allowing a unique analysis of several characteristics or states of the focus areas, the survival of the species does not reflect the other characteristics of the environment fragment that influence the area's resilience.

The potential of survival rate as an ecological indicator for the ecological restoration of riparian forests was superior to other studies that attributed degrees of efficiency in the Likert scale for aspects and descriptors of SEGIP (1995) and Metzger & Casatti (2006). Lima (2014), evaluating the growth rate in height of Cerrado native species in riparian forests, assigned low efficiency as a potential indicator, with lower degrees of efficiency for data comprehension, interpretation and predictability. However, Pachêco (2014), evaluating seed rain as a potential ecological indicator of restoration in a riparian forest, attributed a maximum score to all aspects as indicators. Lima et al. (2016), evaluating the coverage of regenerants as a potential indicator, also assigned a maximum score in the Likert scale, and recommended evaluating the trajectory of restoration experiments, even in the implantation phase.

Conclusions

The survival of seedlings of 18 native species from the Cerrado, 12 months after planting, proved to be viable and efficient as an indicator of ecological restoration in the riparian forest area. Biotic factors such as sprouting and regrowth affected the establishment of some species in the restoration project.

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Conflict of interest

The authors have no conflict of interest to declare.

Authors' contributions

Pedro Augusto Fonseca Lima: conceptualization, formal analysis, investigation, methodology, writing - original draft.

Lidiamar Barbosa de Albuquerque: conceptualization, formal analysis, investigation, methodology, supervision, writing - review & editing.

Alcides Gatto: Conceptualization, formal analysis, investigation, methodology, supervision and writing - review & editing.

Juaci Vitória Malaquias: formal analysis, investigation and methodology

Fabiana de Gois Aquino: conceptualization, formal analysis, investigation, methodology, supervision, writing - review & editing.

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