Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / *Online Support* - ISSN 1980-0827 Suporte CD-ROM / *CD-ROM Support*

Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 2, 2025

Germination and transplant resistance of four *cerrado* species from São Paulo state with landscape potential

Pedro Lemos Gomes
Master's student, UNESP, Brasil
pedro.lemos@unesp.br
ORCID iD 0000-0002-5312-4416

Victor Augusto Bincoleto
Master's student, UNESP, Brasil
victor.bincoleto@unesp.br
ORCID iD 0009-0001-7656-8335

Veridiana de Lara Weiser
Professor, PhD, UNESP, Brasil
veridiana.weiser@unesp.br
ORCID iD 0000-0003-1836-7540

Marta Enokibara
Professor, PhD, UNESP, Brasil
marta.enokibara@unesp.br
ORCID iD 0000-0002-4790-7756

Submissão: 17/05/2025
Aceite: 10/08/2025
GOMES, Pedro Lemos; BINCOLETO, Victor Augusto; WEISER, Veridiana de Lara; ENOKIBARA, Marta. Germinação e resistência ao transplante de quatro espécies do cerrado paulista com potencial paisagístico. **Periódico Eletrônico Fórum Ambiental da Alta Paulista**, *[S. l.]*, v. 21, n. 2, 2025.
DOI: 10.17271/1980082721220225888. Disponível em: https://publicacoes.amigosdanatureza.org.br/index.php/forum_ambiental/article/view/5888.

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / *Online Support* - ISSN 1980-0827 Suporte CD-ROM / *CD-ROM Support*

Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 2, 2025

Germinação e resistência ao transplante de quatro espécies do cerrado paulista com potencial paisagístico

RESUMO

Objetivo – O presente estudo avaliou a germinação, o crescimento e a resistência ao transplante e plantio de quatro espécies nativas do cerrado paulista com potencial paisagístico: *Andropogon bicornis*, *Mimosa dolens*, *Paspalum stellatum* e *Schizachyrium sanguineum*.

Metodologia – A pesquisa adotou a semeadura indireta das espécies em vasos, com monitoramento semanal por seis meses, analisando: taxas de germinação, velocidade de crescimento e resistência ao transplante e plantio. Após o transplante, os indivíduos sobreviventes foram plantados em canteiro.

Originalidade/relevância – A seleção das espécies foi baseada nos critérios adotados pelo paisagista holandês Piet Oudolf, que definiu três categorias para a composição paisagística de jardins naturalistas: espécies protagonistas, coadjuvantes e matrizes. Ao definir as espécies baseadas nessa seleção e a sistematização de informações sobre germinação, crescimento e resistência ao transplante das espécies testadas, a pesquisa amplia o conhecimento para a sua inserção em projetos paisagísticos.

Resultados – Os resultados indicaram que a espécie *Mimosa dolens* apresentou a maior taxa de germinação, enquanto o *Andropogon bicornis* destacou-se pela resistência ao transplante e melhor vigor após o plantio. Já as espécies *Paspalum stellatum* e *Schizachyrium sanguineum* apresentaram desenvolvimento significativo inicialmente, mas não resistiram ao plantio definitivo.

Contribuições teóricas/metodológicas – O estudo fornece informações para a utilização de espécies nativas do cerrado em projetos paisagísticos com enfoque naturalista, fornecendo dados como subsídio para a inserção dessas espécies herbáceas e arbustivas em viveiros, possibilitando sua introdução no paisagismo.

Contribuições sociais e ambientais – Os resultados da pesquisa contribuem para uma maior visibilidade do Cerrado, o segundo bioma mais devastado do país, colaborando para mitigar os problemas referentes às mudanças climáticas.

PALAVRAS-CHAVE: Espécies nativas. Germinação de sementes. Crescimento de plântulas.

Germination and transplant resistance of four *cerrado* species from São Paulo state with landscape potential

ABSTRACT

Objective – The present study evaluated the germination, growth, and resistance to transplanting and planting of four *cerrado* native species from São Paulo state with landscape potential: *Andropogon bicornis*, *Mimosa dolens*, *Paspalum stellatum*, and *Schizachyrium sanguineum*.

Methodology – The research adopted indirect sowing of the species in pots, with weekly monitoring for six months, analyzing germination rates, growth rate, and resistance to transplanting and planting. After transplanting, the surviving seedlings were planted in garden beds.

Originality/relevance – The selection of the species was based on the criteria adopted by the Dutch landscape designer Piet Oudolf, who defined three categories for the landscape composition of naturalistic gardens: primary species, scatter species, and matrix species. By defining the species based on this selection and systematizing information on germination, growth, and resistance to transplanting of the tested species, the research expands knowledge for their incorporation into landscape design projects.

Results – The results indicated that *Mimosa dolens* exhibited the highest germination rate, while *Andropogon bicornis* stood out for its resistance to transplanting and better vigor after planting. The species *Paspalum stellatum* and *Schizachyrium sanguineum* showed significant initial development but did not withstand final planting.

Theoretical/methodological contributions – The study provides information for the use of native *cerrado* species from São Paulo state in landscape projects with a naturalistic focus, offering data to support the inclusion of these herbaceous and shrub species in nurseries, enabling their introduction into landscaping.

Social and environmental contributions – The research results contribute to greater visibility of the *Cerrado*, the second most devastated biome in the country, helping to mitigate issues related to climate change.

KEYWORDS: Native species. Seed germination. Seedling growth.

Germinación y resistencia al trasplante de cuatro especies del cerrado paulista con potencial paisajístico

RESUMEN

Objetivo – El presente estudio evalúo la germinación, el crecimiento y la resistencia al trasplante y plantación de cuatro especies nativas del cerrado *paulista* con potencial paisajístico: *Andropogon bicornis*, *Mimosa dolens*, *Paspalum stellatum* y *Schizachyrium sanguineum*.

Metodología – La investigación adoptó la siembra indirecta de las especies en macetas, con monitoreo semanal durante seis meses, analizando: tasas de germinación, velocidad de crecimiento y resistencia al trasplante y plantación. Después del trasplante, los individuos sobrevivientes fueron plantados en canteros.

Originalidad/relevancia – La selección de las especies se basó en los criterios adoptados por el paisajista neerlandés Piet Oudolf, quien definió tres categorías para la composición paisajística de jardines naturalistas: especies protagonistas, secundarias y de matriz. Al definir las especies con base en esta selección y sistematizar la información sobre germinación, crecimiento y resistencia al trasplante de las especies evaluadas, la investigación amplía el conocimiento para su incorporación en proyectos de paisajismo.

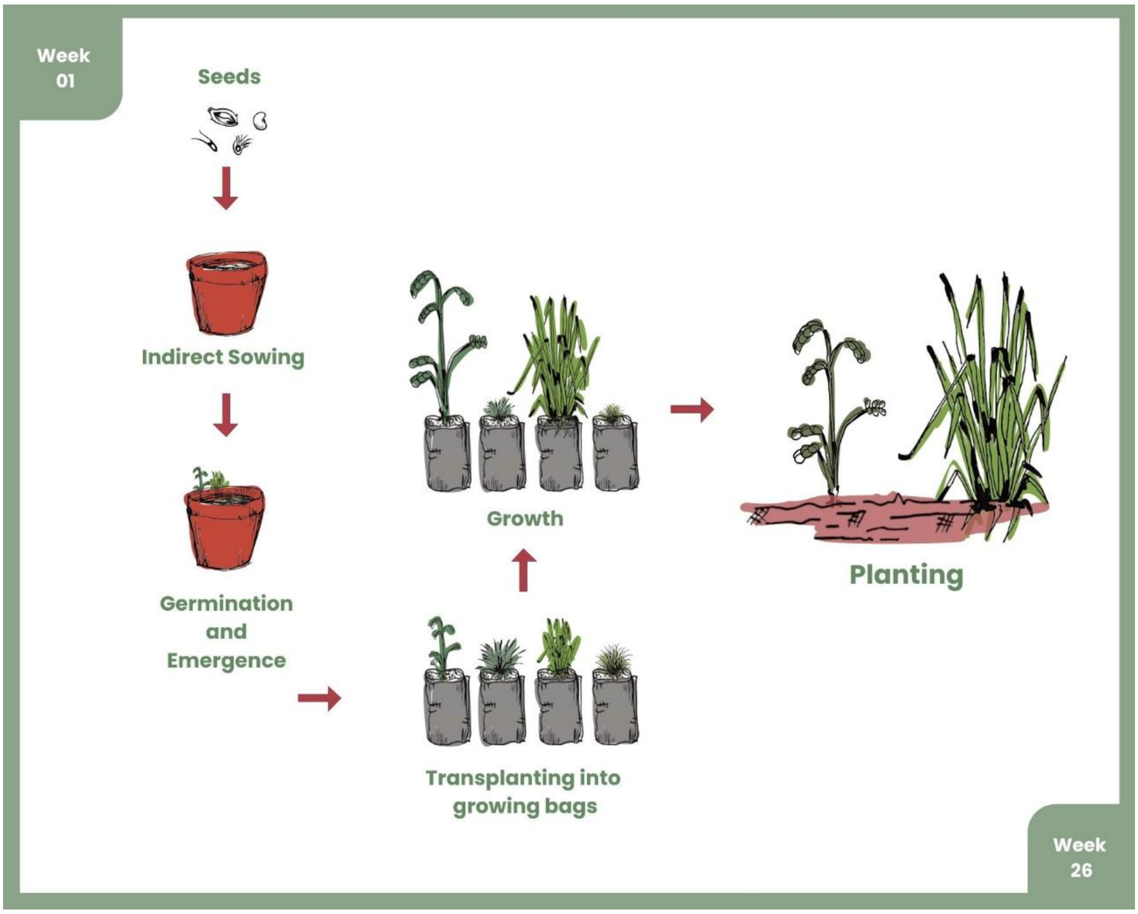
Resultados – Los resultados indicaron que *Mimosa dolens* presentó la mayor tasa de germinación, mientras que *Andropogon bicornis* se destacó por su resistencia al trasplante y mayor vigor después de la plantación. Las especies *Paspalum stellatum* y *Schizachyrium sanguineum* mostraron un desarrollo significativo inicialmente, pero no resistieron a la plantación definitiva.

Contribuciones Teóricas/Metodológicas – El estudio proporciona información para la utilización de especies nativas del cerrado en proyectos paisajísticos, brindando datos como subsidio para la inclusión de estas especies herbáceas y arbustivas en viveros, posibilitando su introducción en el paisajismo.

Contribuciones Sociales y Ambientales – Los resultados de la investigación contribuyen a una mayor visibilidad del Cerrado, el segundo bioma más devastado del país, colaborando para mitigar los problemas relacionados con el cambio climático.

PALABRAS CLAVE: Especies nativas. Germinación de semillas. Crecimiento de plántulas.

GRAPHICAL ABSTRACT



1 INTRODUCTION

Brazil, widely recognized as the most biodiverse country on the planet, is home to six major biomes that span its territory: the Amazon, *Caatinga*, *Cerrado*, Atlantic Forest, *Pampas*, and *Pantanal* (IBGE, 2023). Among these biomes, the Atlantic Forest and the *Cerrado* stand out for their high levels of degradation. The Atlantic Forest, the most devastated biome (Barretto; Catharino, 2022), was severely impacted by the occupation of Brazilian territory, which expanded from the coast to the interior, with the exploitation of natural resources, livestock farming, and urbanization as the main causes of destruction (Colombo; Joly, 2010; Dean, 1996). The *Cerrado*, in turn, although considered a global hotspot for biodiversity conservation (Myers *et al.*, 2000; Parente *et al.*, 2021), ranks second in vegetation cover loss due to the expansion of agriculture and livestock farming, as well as anthropogenic development actions, combined with limited legal protection instruments, which together have drastically transformed its natural landscape, increasingly exploited due to its favorable location and terrain (Nunes; Castro, 2021; Strassburg *et al.*, 2017).

In a scenario of climate change and intensifying environmental catastrophes, it becomes increasingly evident that global-scale environmental issues require significant modifications in the economic, technological, and cultural aspects of society (Moreira; Ramos; Gallego, 2025). The challenges arising from climate change also demand a range of initiatives, from international agreements to actions implemented at national and local levels (Bottoni *et al.*, 2025), among which the United Nations Agenda 2030 and the establishment of the Decade on Ecosystem Restoration (2021–2030) stand out, highlighting the urgency of actions aimed at environmental preservation and restoration (United Nations, 2021; WWF, 2022). The United Nations Sustainable Development Goal 15 (SDG 15), titled “Life on Land,” reinforces the need to protect, restore, and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and biodiversity loss (United Nations, 2023). These actions require national engagement and commitment to address the emerging climate crises (Machado *et al.*, 2024), with an integrated vision at different scales, from ecological restoration to residential gardens.

In this context, contemporary naturalistic gardens play an important role as, by incorporating regional vegetation, they contribute to harmonizing aesthetics with ecology, promoting biodiversity and sustainability. These gardens use native or adapted exotic species and management techniques that minimize human intervention, creating functional ecosystems that not only beautify but also contribute to environmental conservation (Dunnett; Hitchmough, 2004; Hitchmough, 2017; Oudolf; Kingsbury, 2013). By using plant species adapted to local conditions, the use of pesticides, fertilizers, and artificial irrigation is substantially reduced or even eliminated, a practice that not only lowers the environmental impact but also attracts pollinators and benefits the ecosystems in which they are established (Erickson; Patch; Grozinger, 2021; Russo, 2024). Among notable projects in the contemporary naturalistic style are the High Line Park in New York and the Lurie Garden in Chicago (Forsyth, 2021; Loughran, 2024) by the Dutch landscape designer Piet Oudolf, one of the most prominent professionals in the field.

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / Online Support - ISSN 1980-0827 Suporte CD-ROM / CD-ROM Support
Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 2, 2025

Oudolf uses aesthetic criteria that emphasize plant structure and visual texture, with a focus on grasses and other ornamental herbaceous species, organized into three categories: primary plants, scatter plants, and matrix plants (Fernandes, 2020). Landscape architect Mariana Siqueira explains that the primary plant is one that draws attention year-round, while the scatter plant has temporary attractiveness, and the matrix plant is less noticeable but effective in covering the soil (Mello, 2020).

Although the market offers options of exotic species and natives from forest biomes such as the Atlantic Forest, this supply is limited regarding the *Cerrado*, especially regarding its shrub and herbaceous plants. The flora of this biome remains little visible in Brazilian landscaping, with an incipient supply of plants, except for tree species (Mello, 2020). The lack of visibility of this flora is one of the main obstacles to the implementation of *cerrado* gardens in the country (Siqueira, 2016).

To address this issue, it is essential to develop strategies, techniques, and logistics that enable the use of these plants in landscaping (Brandão, 2015; Granzotto, 2018). Pioneering experiences have been carried out in Brasília by landscape designer and agronomist Júlio Pastore (Pastore; Honorato, 2023) and by landscape architect Mariana Siqueira, who draws inspiration from Oudolf's gardens to design with *cerrado* flora (Mello, 2020; Siqueira, 2016). In the state of São Paulo, the "*Campina Experimental do Cerrado*" project, initiated in November 2022, established an experimental garden with native *cerrado* species from São Paulo state and has been conducting experiments since then (Enokibara *et al.*, 2024). Among these experiments, the trial presented in this study stands out, aiming to analyze the germination rate, growth rate, and resistance to transplanting and planting of four *cerrado* species from São Paulo state, with the goal of understanding their behavior for future incorporation into landscape design projects.

2 MATERIALS E METHODS

2.1 Characterization of the Study Area

The experiment was conducted in the courtyard of the Central Laboratories at the School of Architecture, Arts, Communication, and Design (FAAC) of the São Paulo State University (Unesp), Bauru Campus, located at coordinates 22°20'47" S e 49°01'44" W, in an area of 222.40 m² (Enokibara *et al.*, 2024). The campus, in addition to its built area, included 265.4235 ha of legal reserve within its territorial extension (Joanitti *et al.*, 2017). However, in 2024, due to an environmental compensation measure, the legal reserve area increased to 266.7865 ha.

According to Coutinho (2002), the predominant *Cerrado* climate (Köppen's Cwa) is tropical seasonal with dry winters, with an average annual temperature of approximately 22–23°C. Typically, the average annual precipitation in the *Cerrado* ranges between 1,200 and 1,800 mm. The average monthly precipitation is concentrated between October and March (spring and summer), which is the rainy season. Between May and September (autumn and winter), monthly rainfall indices drop significantly, resulting in the dry season, which lasts between three and five months (Coutinho, 2002). Therefore, the climate of the municipality of Bauru is characterized by seasonality, with a hot, humid summer and a cold, dry winter (Weiser, 2007).

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / *Online Support* - ISSN 1980-0827 Suporte CD-ROM / *CD-ROM Support*

Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 2, 2025

2.2 Selection of Species

The species *Andropogon bicornis* (capim rabo-de-burro), *Mimosa dolens* (mimosa), *Paspalum stellatum* (capim orelha-de-coelho), and *Schizachyrium sanguineum* (capim roxo) were selected for their potential to fit into the categories defined by Piet Oudolf (Fernandes, 2020), adapted to the *cerrado* flora (Table 1, Figure 1).

Table 1 – Scientific and common names of the species and classification of their potential for use in contemporary naturalistic gardens.

ID	Scientific Name	Common Name	Potential Classification for Use in Contemporary Naturalistic Gardens
1	*Andropogon bicornis* L.	capim rabo-de-burro	primary plants
2	*Mimosa dolens* Vell.	mimosa	scatter plants
3	*Paspalum stellatum* Humb. & Bonpl. ex Flüggé	capim orelha-de-coelho	matrix plants
4	*Schizachyrium sanguineum* (Retz.) Alston	capim roxo	scatter plants

Source: own authorship.

Figure 1 – Well-established individuals of the selected species. A - *Andropogon bicornis*. B - *Mimosa dolens*. C - *Paspalum stellatum*. D - *Schizachyrium sanguineum*.

Source: A and B - own authorship. C - Gabriel Hugo Rua (2020). License: CC BY 4.0. Available at: https://bit.ly/4aFmzmw. Access on: 18 Feb. 2025. D - Maurício Mercadante (2017). License: CC BY-NC-SA 2.0. Available at: https://bit.ly/42BBFaA. Access on: 18 Feb. 2025.

Commonly found in grassland physiognomies, *Andropogon bicornis* (capim rabo-de-burro) is an erect, tufted herbaceous plant that stands out for its height of up to 2 m and its inflorescences, which have high ornamental potential, with a plumy appearance and white, cream, or reddish coloration (Durigan *et al.*, 2018; Moreira; Bragança, 2010).

The species *Mimosa dolens* (mimosa), also common in grassland physiognomies and occurring in the region, is a sparsely branched subshrub with an average height of 1.5 m, exhibiting a vertical volumetry. Its purple inflorescences, as well as its fruits, form globose structures that stand out in the landscape (Durigan et al., 2018), giving the species a remarkable visual appeal.

Regarding the other species tested, also found in grassland physiognomies, *Paspalum stellatum* (capim orelha-de-coelho) exhibited the shortest height, ranging from 0.40 to 0.80 m. It was selected for its caespitose growth habit, that is, its high capacity for ground cover and the formation of dense vegetative matrices (Paredes, 2016).

Found in grassland physiognomies, the species *Schizachyrium sanguineum* (capim roxo) exhibits a vibrant reddish coloration on its stems, with a height ranging from 0.40 to 1.20 m, forming a dense tufted clump (Durigan *et al.*, 2018).

The selected species, except *Mimosa dolens* (collected at the Unesp-Bauru Campus), were obtained through the company Verde Novo (https://verdenovosementes.com.br), based in Brasília. In addition to marketing native *cerrado* seeds, the company promotes sustainable income generation for seed collectors living in socially vulnerable situations (Enokibara *et al.*, 2024).

The dates of seed collection (by Verde Novo), purchase (by the authors), and the initiation of sowing in pots occurred during different time periods (Table 2).

Table 2 – Scientific and common names of the collected and purchased species, collection and sowing dates. Legend: — denotes absence of data.

ID.	Scientific name	Common name	Purchase / collection	Seed collection date	Purchase date	Sowing date in pots
1	*Andropogon bicornis* L.	capim rabo-de-burro	purchase	Feb/2022	Jul/2023	Dec/2023
2	*Mimosa dolens* Vell.	mimosa	collection	Apr/2022	—	Dec/2023
3	*Paspalum stellatum* Humb. & Bonpl. ex Flüggé	capim orelha-de-coelho	purchase	Feb/2022	Aug/2022	Dec/2023
4	*Schizachyrium sanguineum* (Retz.) Alston	capim roxo	purchase	May/2023	Jul/2023	Dec/2023

Source: own authorship.

2.3 The experiment

Four species native to the *cerrado* of São Paulo state were sown: *Andropogon bicornis* (capim rabo-de-burro), *Mimosa dolens* (mimosa), *Paspalum stellatum* (capim orelha-de-coelho), and *Schizachyrium sanguineum* (capim roxo). The study assessed these species through a practical experiment that evaluated three parameters: germination rate, growth rate, and resistance to transplanting and planting. To determine the number of seeds used for sowing, 180 mL plastic cups were used as a volume reference (Figure 2).

Figure 2 – Seed portioning of *Paspalum stellatum*. A and B - Quantity of seeds in a 180 mL cup (before screening). C - Close-up of the seeds on a 1×1 cm grid mesh.

Source: own authorship.

After seed portioning, processing was carried out, including manual sorting to remove debris that the seeds might contain, such as husks, straw, and impurities (Figure 3), in order to enable accurate quantification.

Figure 3 – Screening of the *Mimosa dolens* on a 1×1 cm grid mesh. A and B - Involucres, husks, and debris. C - *Mimosa dolens* seeds after screening, ready for quantification.

Source: own authorship.

Among the planting methods commonly used are direct sowing, which refers to sowing seeds directly in the field for in situ germination, and indirect sowing, which consists of transferring seedlings from containers (trays, pots, tubes) to the site where they will be grown (Brown; Perez; Miles, 2015; Souza Junior; Brancalion, 2016).

Planting was carried out in December 2023 using the indirect sowing technique. Each species was sown in 60-L pots, filled with different layers: two-thirds of the volume was occupied by a draining material (basaltic gravel), over which a layer of geotextile fabric (bidim) was placed. The remaining one-third was filled with soil collected from a native *cerrado* vegetation area located approximately 70 m from the experimental site.

Soil was collected from a depth of approximately 1 m to avoid the presence of seeds from the superficial layer (seed bank). To ensure seed stabilization and protection against predation by birds and insects, a thin layer of topsoil was applied (Figure 4).

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / *Online Support* - ISSN 1980-0827 Suporte CD-ROM / *CD-ROM Support*
Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 2, 2025

Figure 4 – Experiment setup. A - Placement of the basalt gravel layer. B - Addition of *cerrado* soil over the geotextile fabric (bidim). C - Sowing of the species. D - Application of a thin layer of topsoil.

Source: own authorship.

2.3.1 Analysis Procedures

The monitoring of seedlings of each species was conducted weekly from January to June 2024. The germination rate was calculated as the ratio of the number of seeds that germinated to the total number of seeds sown (Figure 5).

Figure 5 – Equation used to determine the germination rate of the species.

$$\text{Germination rate (\%)} = \left(\frac{\text{number of germinated seeds}}{\text{total number of sown seeds}}\right) \times 100$$

Source: own authorship.

Data on the height and stem diameter of the seedlings (stem and leaves), as well as the photographic records of each pot, were collected. The mean growth values were obtained by monitoring five seedlings of each species, randomly selected from among those that emerged. The means were calculated weekly and independently for each variable (height and diameter), based on the ratio between the sum of the recorded values for the seedlings (n) and the total number of seedlings (Figure 6).

Figure 6 – Equation used to determine the species' mean growth.

$$\text{Mean growth} = \frac{n1 + n2 + n3 + n4 + n5}{5}$$

Source: own authorship.

The mean growth rate was calculated based on the ratio between the sum of the differences in the seedlings' weekly mean growths (s) and the number of weekly intervals over the period during which the experiment was analyzed (Figure 7).

Figure 7 – Equation used to determine the species' mean growth rate.

$$\text{Mean growth rate} = \frac{(s26 - s25) + (s25 - s24) + \ldots + (s2 - s1)}{25}$$

Source: own authorship.

In the 21st week of monitoring, the seedlings were transplanted into 18 × 24 cm plastic growing bags filled with topsoil. Measurements under these conditions were taken until the 26th week, aiming to analyze the impacts of transplanting through visual indicators such as growth stagnation, the development of senescent leaves, and, finally, mortality (Inácio; Leite, 2007).

3. RESULTS

The evaluation of the development of the selected species enabled the analysis of their performance under the experimental conditions. The data obtained reflected the species' responses to these conditions in terms of germination rate, seedling growth, and seedling resistance, considering the adaptation after transplanting and planting.

3.1 Germination rate

From the data obtained in the experiment, it was observed that the germination rate of the species used was low, with values below 5% (Table 3).

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / Online Support - ISSN 1980-0827 Suporte CD-ROM / CD-ROM Support
Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 2, 2025

Table 3 – Approximate number of seeds used per species and germination rate.

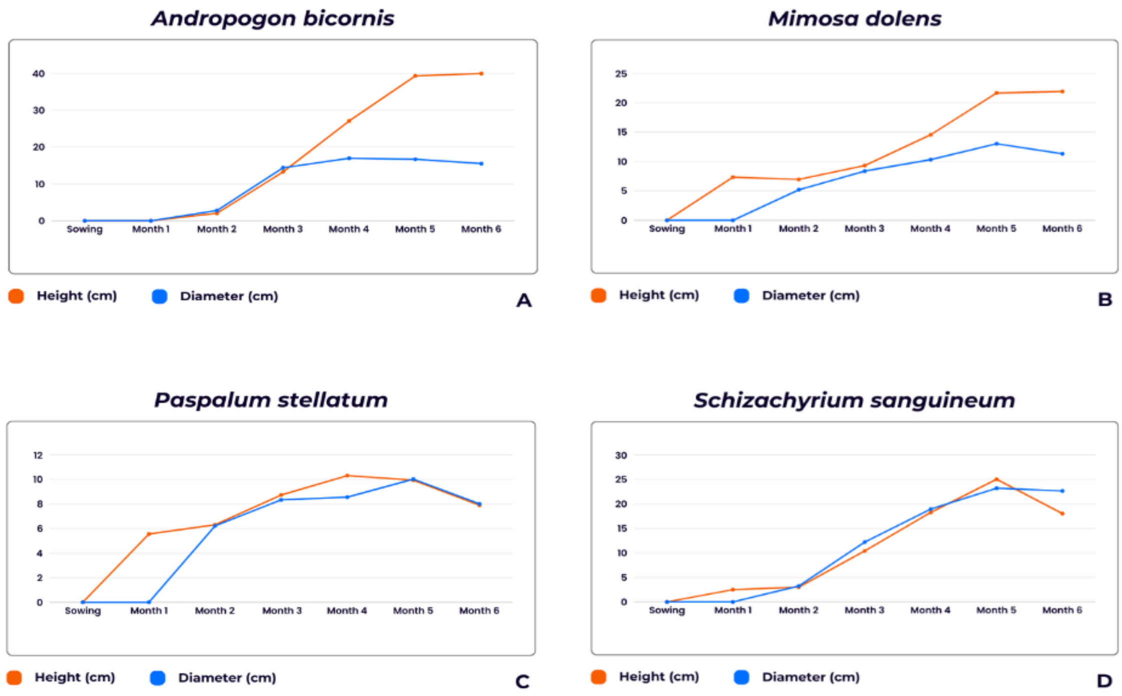
ID.	Species	Approximate number of seeds used per sowing in a 180 ml cup	Number of germinated seeds	Germination rate
1	*Andropogon bicornis*	6.076	22	0.37%
2	*Mimosa dolens*	418	20	4.79%
3	*Paspalum stellatum*	4.716	89	1.88%
4	*Schizachyrium sanguineum*	3.038	59	1.94%
TOTAL		**14.248**	**190**	**8.98%**

Source: own authorship.

3.2 Seedling growth

All species exhibited continuous growth until the fifth month, when transplanting was performed (Figure 8). During this period, particularly between the fifth and sixth months, some signs of impact were observed (Figure 8).

Figure 8 – The mean height and mean diameter of the seedlings of the tested species. A - *Andropogon bicornis*. B - *Mimosa dolens*. C -*Paspalum stellatum*. D - *Schizachyrium sanguineum*.



Source: own authorship.

The seeds of *Andropogon bicornis* (capim rabo-de-burro) germinated, with seedlings emerging in the last week of the first month (Figure 8). The species exhibited a germination rate

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / Online Support - ISSN 1980-0827 Suporte CD-ROM / CD-ROM Support
Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 2, 2025

of 0.37%. In the following months, the seedlings showed progressive growth, with increases in the mean height and mean diameter (Table 4). Between the second and fourth months, growth accelerated, with the mean height rising from 2.03 cm to 27.07 cm and the mean diameter from 2.78 cm to 16.94 cm (Table 4). In the fourth month, one seedling died. By the fifth month, before transplanting, the seedlings reached a mean height of 39.26 cm, while maintaining a diameter similar to that of the previous month (Table 4). After transplanting, a slight reduction in the mean diameter was observed (15.50 cm in the sixth month), whereas the mean height remained stable at 39.94 cm (Table 4). The species' mean growth rate was 1.57 cm per week.

The seeds of *Mimosa dolens* (mimosa) germinated, with seedlings emerging in the first month (Figure 8). The species exhibited a germination rate of 4.79%, with an initial mean height of 7.33 cm and an undeveloped diameter (Table 4). In the following months, growth occurred gradually. Between the second and fourth months, increases in the mean height and mean diameter were observed, reaching 14.56 cm and 10.33 cm, respectively (Table 4). By the fifth month, before transplanting, the seedlings reached their highest growth, with a mean height of 21.66 cm and a mean diameter of 13.03 cm (Table 4). After transplanting, a slight reduction in the mean diameter was observed (11.32 cm in the sixth month), while the mean height remained practically stable at 21.93 cm (Table 4). The species' mean growth rate was 0.67 cm per week.

Table 4 – Scientific names of the species and the mean height and the mean diameter measured throughout the experiment.

Mês	*Andropogon bicornis*		*Mimosa dolens*		*Paspalum stellatum*		*Schizachyrium sanguineum*	
	Height	Diameter	Height	Diameter	Height	Diameter	Height	Diameter
1	0.00	0.00	7.33	0.00	5.56	0.00	2.50	0.00
2	2.03	2.78	6.96	5.20	6.31	6.22	3.01	3.24
3	13.26	14.37	9.32	8.38	8.73	8.34	10.42	12.22
4	27.07	16.94	14.56	10.33	10.31	8.56	18.26	18.95
5	39.26	16.68	21.66	13.03	9.94	10.02	25.04	23.22
6	39.94	15.50	21.92	11.32	7.90	8.01	18.04	22.67

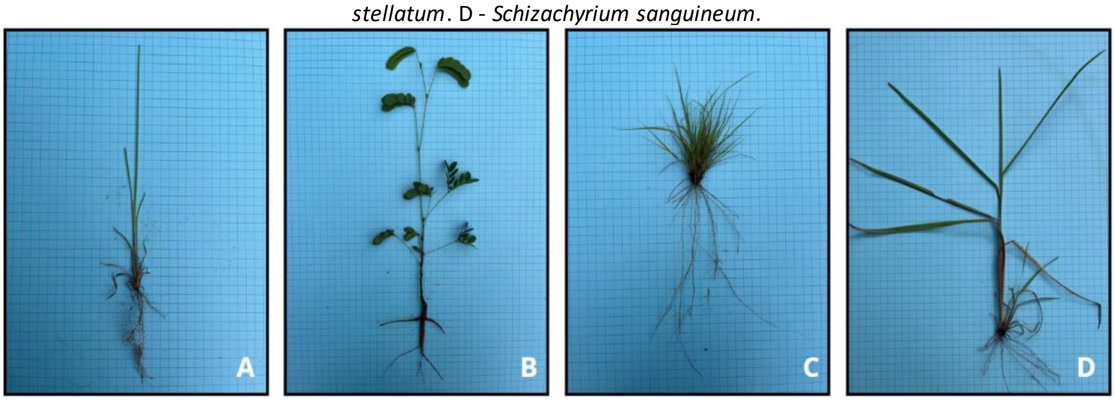
Source: own authorship.

The seeds of *Paspalum stellatum* (capim orelha-de-coelho) germinated, with seedlings emerging in the first month (Figure 8). The species exhibited a germination rate of 1.88%, with an initial mean height of 5.56 cm and an undeveloped diameter (Table 4). In the following months, growth was modest, with gradual increases in the mean height and the mean diameter until the fourth month, when the mean height reached 10.31 cm and the mean diameter 8.56 cm (Table 4). In the fifth month, a slight reduction in the mean height was observed (9.94 cm), while the mean diameter continued to increase, reaching 10.02 cm (Table 4). By the sixth month, both the mean height and the mean diameter decreased to 7.90 cm and 8.01 cm, respectively (Table 4). The species' mean growth rate was 0.13 cm per week.

The seeds of *Schizachyrium sanguineum* (capim roxo) germinated, with seedlings emerging in the first month (Figure 8). The species exhibited a germination rate of 1.94%, with an initial mean height of 2.50 cm and an undeveloped diameter (Table 4). In the following months, growth was progressive, with a notable increase in the mean height and the mean diameter until the fifth month, when the mean height reached 25.04 cm and the mean diameter 23.22 cm (Table 4). By the sixth month, the mean height decreased to 18.04 cm, while the mean diameter remained stable at 22.67 cm (Table 4). The species' mean growth rate was 0.61 cm per week.

In the 21st week (fifth month), all seedlings were transplanted into growing bags (Figures 9 and 10).

Figure 9 – Seedling records at the time of transplanting. A - *Andropogon bicornis*. B - *Mimosa dolens*. C - *Paspalum stellatum*. D - *Schizachyrium sanguineum*.



Source: own authorship.

Figure 10 – Seedlings transplanted into growing bags. A - *Andropogon bicornis*. B - *Mimosa dolens*. C - *Paspalum stellatum*. D - *Schizachyrium sanguineum*.

Source: own authorship.

3.3 Seedling resistance to transplanting and planting

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / *Online Support* - ISSN 1980-0827 Suporte CD-ROM / *CD-ROM Support*
Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 2, 2025

The impacts of transplanting into the growing bags were monitored over a period of 5 weeks. Following transplanting into growing bags, two species exhibited mortality rates: *Paspalum stellatum* (60%) and *Schizachyrium sanguineum* (40%) (Table 5). In September 2024, the seedlings of the species that survived the transplanting n were introduced by planting into a bed at the "Campina Experimental do Cerrado" (Figure 11).

The impacts of planting were monitored over 15 weeks. Growth stagnation, the development of senescent leaves, and, eventually, seedling mortality were indicators of planting failure.

Table 5 - Species that did not survive transplanting into growing bags.

ID.	Species	Number of seedlings transplanted into growing bags	Number of surviving seedlings	Non-surviving seedlings
1	*Andropogon bicornis*	4	4	0
2	*Mimosa dolens*	5	5	0
3	*Paspalum stellatum*	5	2	3
4	*Schizachyrium sanguineum*	4	2	2

Source: own authorship.

Figure 11 – Planting of seedlings in the courtyard of the Central Laboratories of FAAC. A - Insertion of seedlings into the designated planting beds. B and C - Individuals of *Mimosa dolens* and *Schizachyrium sanguineum* after planting.

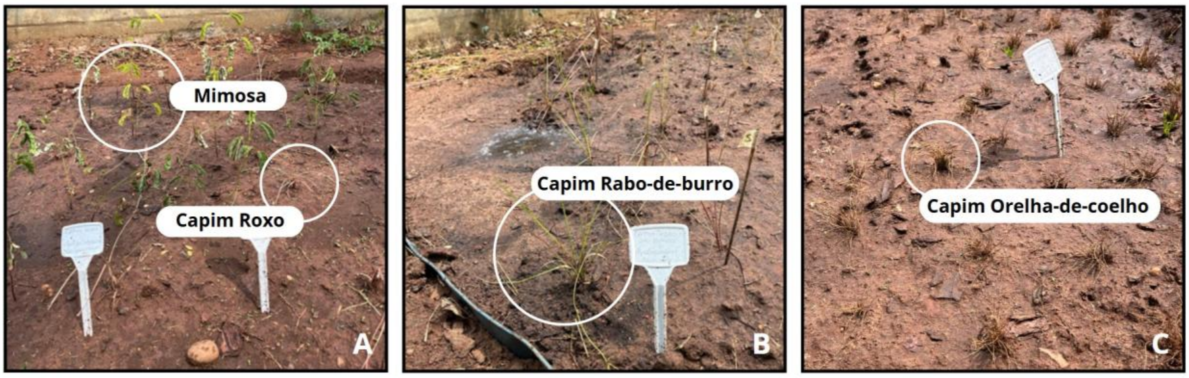
Source: own authorship.

One week after planting in the bed, the species *Paspalum stellatum* and *Schizachyrium sanguineum* exhibited a mortality rate of 100% (Figure 12).

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / *Online Support* - ISSN 1980-0827 Suporte CD-ROM / *CD-ROM Support*

Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 2, 2025

Figure 12 – Seedling condition in the planting bed 1 week after transplanting. A - *Mimosa dolens* and *Schizachyrium sanguineum*. B - *Andropogon bicornis*. C - *Paspalum stellatum*.



Source: own authorship.

The seedlings of *Andropogon bicornis* and *Mimosa dolens*, although showing signs of impact, development of senescent leaves, and symptoms of chlorosis, resisted planting. After 15 weeks, the remaining seedlings were counted and measured (Figure 13, Table 6).

Figure 13 – Beds after 15 weeks of planting. A - *Mimosa dolens*. B - *Andropogon bicornis*.

Source: own authorship.

Table 6 – Number of seedlings, mean height, and mean diameter of the remaining seedlings after 15 weeks of planting.

ID	Species	Number of seedlings that resisted planting	Mean height of seedlings (cm)	Mean diameter of seedlings (cm)
1	*Andropogon bicornis*	4	52.77	41.75
2	*Mimosa dolens*	5	34.50	13.72
3	*Paspalum stellatum*	0	0	0
4	*Schizachyrium sanguineum*	0	0	0

Source: own authorship.

4 DISCUSSION

The species *Andropogon bicornis* (capim rabo-de-burro) stood out for its resistance, showing the highest vigor after 15 weeks of planting, despite its low germination rate. Its ornamental characteristics (Durigan *et al.*, 2018; Moreira; Bragança, 2010; Stumpf *et al.*, 2009) and its ability to withstand transplanting and planting reinforce its potential for landscape use.

The species *Mimosa dolens* (mimosa) recorded the highest germination rate among the four species studied. However, its aerial development was slow throughout the 15 weeks of monitoring. Nevertheless, its aesthetic qualities (Durigan *et al.*, 2018), combined with the high germination rate and good resistance to transplanting, indicate that it may be a promising choice for landscape compositions.

The species with the highest number of seedlings that emerged from direct sowing was *Paspalum stellatum* (capim orelha-de-coelho). However, its growth was the slowest among the species studied, and its high sensitivity to transplanting resulted in the death of all seedlings by the end of the planting stage. This characteristic may restrict its use in landscaping through seedling planting, but indicates ornamental potential (Carmona, Martins & Fávero, 1999; Paredes, 2016) for application in gardens through direct sowing.

Based on the results of this study, the species *Schizachyrium sanguineum* (capim roxo) exhibited a satisfactory germination rate. However, similar to *Paspalum stellatum*, transplanting and planting processes significantly impacted its growth, resulting in 100% mortality. These data indicate that the species has ornamental potential (Durigan *et al.*, 2018; Liao; Chen, 2019) and would perform better in landscape projects when established by direct sowing.

5 CONCLUSION

The resistance and vigor of *Andropogon bicornis*, even with a relatively low germination rate, indicate the promising potential of this species for landscaping. The high germination rate of *Mimosa dolens*, despite its slow aerial growth, makes this species a viable option due to its resistance to transplanting and ornamental qualities. This set of species appears to be suitable for contexts that require easy-to-establish and low-maintenance species. The germination rates of *Paspalum stellatum* and *Schizachyrium sanguineum*, combined with their sensitivity to transplanting, indicate that these species have greater potential for landscape projects using direct sowing, avoiding stages that compromise their growth.

The specific characteristics of each species should be considered in landscape planning, contributing to more appropriate choices and greater success in the implementation and maintenance of projects. A successful garden with these four species could likely be established through a mixed approach, combining seeds and seedlings. In Piet Oudolf's vision, *Andropogon bicornis* (capim rabo-de-burro) would act as the "protagonist," *Mimosa dolens* (mimosa) and *Schizachyrium sanguineum* (capim roxo) as "supporting plants," and *Paspalum stellatum* (capim orelha-de-coelho) as the "matrix."

REFERENCES

BARRETTO, E. H. P.; CATHARINO, E. L. M. Atlantic Forest hotspot: why we should consider mature forests a conservation priority in the São Paulo Metropolitan Region, Southeastern Brazil. **Journal of Environmental Protection**, v. 13, n. 1, p. 69-83, 2022. DOI: 10.4236/jep.2022.131004

BOTTONI, I. J. *et al*. Mudanças climáticas e plano de ação de mitigação das emissões de CO_2 no município de Campinas/SP. **Periódico Eletrônico Fórum Ambiental da Alta Paulista**, v. 21, n. 1, p. 71-89, 2025. DOI: 10.17271/1980082721120255597

BRANDÃO, D. C. **Fenologia e potencial paisagístico de *Mimosa setosissima* Taub., nativa da Serra dos Pirineus, Goiás.** 2015. Dissertação (Mestrado em Agronomia) – Escola de Agronomia, Universidade Federal de Goiás, Goiânia, 2015.

BROWN, M.; PEREZ, J.; MILES, A. **Teaching organic farming and gardening**: resources for instructors. 3rd. ed. Santa Cruz: The Center for Agroecology and Sustainable Food Systems, 2015.

CARMONA, R.; MARTINS, C. R.; FÁVERO, A. P. Características de sementes de gramíneas nativas do cerrado. **Pesquisa Agropecuária Brasileira**, v. 34, n. 6, p. 1067-1074, 1999. DOI: 10.1590/S0100-204X1999000600019

COLOMBO, A. F.; JOLY, C. A. Brazilian Atlantic Forest *lato sensu*: the most ancient Brazilian forest, and a biodiversity hotspot, is highly threatened by climate change. **Brazilian Journal of Biology**, v. 70, n. 3 suppl, p. 697-708, 2010. DOI: 10.1590/S1519-69842010000400002

COUTINHO, L. M. O bioma do cerrado. *In*: KLEIN, A. L. (org.). **Eugen Warming e o cerrado brasileiro:** um século depois. São Paulo: Editora UNESP, 2002. p. 79-82. Available at: https://jbb.ibict.br/bitstream/1/1326/1/Eugen%20Warming%20e%20o%20cerrado%20brasileiro%20um%20s%C3%A9culo%20depois.pdf Access on: 15 jan. 2025.

DEAN, W. **A ferro e fogo**: a história e a devastação da Mata Atlântica brasileira. São Paulo: Companhia das Letras, 1996. DOI: 10.1590/S0104-59701996000300014

DUNNETT, N.; HITCHMOUGH, J. **The dynamic landscape**: design, ecology and management of naturalistic urban planting. London: Taylor and Francis, 2004. DOI: 10.4324/9780203402870

DURIGAN, G. *et al.* **Plantas pequenas do cerrado**: biodiversidade negligenciada. São Paulo: SMA, 2018. Available at: https://arquivo.ambiente.sp.gov.br/publicacoes/2018/12/plantaspequenasdocerrado.pdf Access on: 13 mar. 2025.

ENOKIBARA, M. *et al.* Campina experimental do cerrado: uma pesquisa-ação na Unesp, Câmpus de Bauru. **Periódico Técnico e Científico Cidades Verdes**, v. 12, n. 37, p. 44-56, 2024. DOI: 10.17271/23178604123720245162

ERICKSON, E.; PATCH, H. M.; GROZINGER, C. M. Herbaceous perennial ornamental plants can support complex pollinator communities. **Scientific Reports**, v. 11, p. 17352, 2021. DOI: 10.1038/s41598-021-95892-w

FERNANDES, C. C. **Princípios e tendências de *Planting Design*.** Uma revisão sistemática da literatura. 2020. Dissertação (Mestrado em Arquitetura Paisagista) – Faculdade de Ciências, Universidade do Porto, Porto, 2020.

FORSYTH, K. J. **Where have all the flowers gone? Searching for answers in contemporary practice.** 2021. Dissertation (Master's in Landscape Architecture) – School of Graduate Studies Rutgers, The State University of New Jersey, New Brunswick, 2021.

GRANZOTTO, M. **Análise do crescimento inicial de espécies herbáceas e subarbustivas do cerrado para fins paisagísticos.** 2018. Trabalho de Conclusão de Curso (Bacharelado em Engenharia Florestal) – Faculdade de Tecnologia, Universidade de Brasília, Brasília, 2018.

HITCHMOUGH, J. **Sowing beauty**: designing flowering meadows from seed. Portland: Timber Press, 2017.

IBGE. Biomas Brasileiros. IBGE Educa, 2023. Available at: https://educa.ibge.gov.br/jovens/conheca-o-brasil/territorio/18307-biomas-brasileiros.html. Access on: 01 fev. 2025.

INÁCIO, C. D.; LEITE, S. L. C. Avaliação de transplante de árvores em Porto Alegre, Rio Grande do Sul. **Iheringia**, Sér. Bot., Porto Alegre, v. 62, n. 1/2, p. 19-30, 2007. Available at: https://isb.emnuvens.com.br/iheringia/article/view/169. Access on: 19 fev. 2025.

JOANITTI, S. A. *et al*. Vascular epiphytes in a woodland savanna forest in southeastern Brazil. **The Journal of the Torrey Botanical Society**, v. 144, n. 4, p. 439-449, 2017. DOI: 10.3159/TORREY-D-16-00029.110.3159/TORREY-D-16-00029.1

LIAO, H.-C.; CHEN, C.-H. Confirmation of a native grass, *Schizachyrium sanguineum* (Retz.) Alston (Poaceae), in Kinmen. **Taiwan Journal of Biodiversity**, v. 21, n. 3, p. 103-110, 2019. Available at: https://www.researchgate.net/publication/364224409. Access on: 25 fev. 2025.

LOUGHRAN, K. Environmental authenticity: constructing nature in postindustrial parks. **Qualitative Sociology**, v. 47, n. 3, p. 441-463, 2024. DOI: 10.1007/s11133-024-09570-0

MACHADO, F. F. *et al.* Beyond COP28: Brazil must act to tackle the global climate and biodiversity crisis. **NPJ Biodiversity**, v. 3, p. 19, 2024. DOI: https://doi.org/10.1038/s44185-024-00051-9

MELLO, S. S. **A flora ornamental do cerrado no paisagismo:** retrato da aplicação prática. 2020. Trabalho de Conclusão de Curso (Especialização em Paisagismo Sustentável) – Escola de Paisagismo de Brasília, Faculdade JK, Brasília, 2020.

MOREIRA, H. J. C.; BRAGANÇA, H. B. N. **Manual de identificação de plantas infestantes**: cultivos de verão. Campinas: FMC, 2010.

MOREIRA, P. R. S; RAMOS, H. R.; GALLEGO, J. L. Educação ambiental e sustentabilidade na instalação de ecopontos na cidade de Itaquaquecetuba/SP. **Periódico Eletrônico Fórum Ambiental da Alta Paulista**, v. 21, n. 1, p. 113-130, 2025. DOI: 10.17271/1980082721120255601.

MYERS, N. *et al.* Biodiversity hotspots for conservation priorities. **Nature**, v. 403, n. 6772, p. 853-858, 2000. DOI: 10.1038/35002501

NUNES, E. D.; CASTRO, S. S. Degradação de fitofisionomias do Cerrado e impactos erosivos hídricos lineares no sudoeste de Goiás – Brasil. **Sociedade e Natureza**, v. 33, e60606, 2021. DOI: http://dx.doi.org/10.14393/sn-v33-2021-60606

OUDOLF, P.; KINGSBURY, N. **Planting**: a new perspective. Londres: Timber Press, 2013.

PAREDES, M. V. F. **Germinação de gramíneas nativas e invasoras do Cerrado após exposição a pulsos de calor**. 2016. Dissertação (Mestrado em Ecologia) – Universidade de Brasília, Brasília, 2016.

PARENTE, L. *et al.* Quality assessment of the PRODES Cerrado deforestation data. Remote sensing applications: **Society and Environment**, v. 21, p. 100444, 2021. DOI: 10.1016/j.rsase.2020.100444

PASTORE, J. B.; HONORATO, P. H. Jardim de Sequeiro: a rainfed garden technique, innovative in aesthetics and environmental quality, inspired by the Cerrado. **Ornamental Horticulture**, v. 29, n. 3, p. 375-387, 2023. DOI: 10.1590/2447-536X.v29i3.2676

RUSSO, A. Savage gardens: balancing maintenance, aesthetics, and ecosystem services in the biodiversity crisis era. **Urban Science**, v. 8, n. 4, p. 170, 2024. DOI: 10.3390/urbansci8040170

SIQUEIRA, M. M. Jardins de Cerrado: potencial paisagístico da savana brasileira. **Revista CAU/UCB**, n. 4, p. 32-47, 2016. Available at: https://portalrevistas.ucb.br/index.php/CAU/article/view/7065/4384. Access on: 13 dez. 2024.

SOUZA JUNIOR, C. N.; BRANCALION, P. H. S. **Sementes e mudas**: guia para propagação de árvores brasileiras. São Paulo: Oficina de Textos, 2016.

STRASSBURG, B. B. N. *et al.* Moment of truth for the Cerrado hotspot. **Nature Ecology and Evolution**, v. 1, n. 4, p. 0099, 2017. DOI: https://doi.org/10.1038/s41559-017-0099

STUMPF, E. R. T. *et al.* Uso ornamental de *Andropogon bicornis* L. (Poaceae). **Revista Ceres**, v. 56, n. 2, p. 186-192, 2009. Available at: https://ojs.ceres.ufv.br/ceres/article/view/3426. Access on: 20 ago. 2025.

UNITED NATIONS. The Sustainable Development Goals Report 2023: Special Edition. New York: UN, 2023. Available at: https://unstats.un.org/sdgs/. Access on: 15 dez. 2024.

UNITED NATIONS. United Nations Decade on Ecosystem Restoration (2021-2030). Preventing, halting and reversing loss of nature. We are experiencing a dangerous decline in nature: but there are glimmers of hope. 2021. Available at: https://www.decadeonrestoration.org/. Access on: 12 jan. 2025.

WEISER, V. de L. **Árvores, arbustos e trepadeiras do cerradão do Jardim Botânico Municipal de Bauru, SP**. 2007. Tese (Doutorado em Ecologia) – Instituto de Biologia, Universidade Estadual de Campinas, Campinas, 2007. DOI: https://doi.org/10.47749/T/UNICAMP.2007.416444

WWF. **Living Planet Report 2022**: Building a nature-positive society. Almond, R. E. A. *et al.* (ed.). Gland: WWF, 2022.

STATEMENTS

AUTHOR CONTRIBUTIONS

Pedro Lemos Gomes: Data Curation, Formal Analysis, Investigation, Writing – Original Draft, Writing – Review & Editing.
Victor Augusto Bincoleto: Data Curation, Formal Analysis, Investigation, Writing – Original Draft, Writing – Review & Editing.
Veridiana de Lara Weiser: Conceptualization and Study Design, Data Curation, Formal Analysis, Methodology, Writing – Critical Review, Writing – Review & Editing, and Supervision.
Marta Enokibara: Conceptualization and Study Design, Data Curation, Funding Acquisition, Writing – Critical Review, Writing – Review & Editing, and Supervision.

DECLARATION OF COMPETING INTEREST

We, **Pedro Lemos Gomes, Victor Augusto Bincoleto, Veridiana de Lara Weiser e Marta Enokibara,** hereby declare that the manuscript entitled "**Germination and transplant resistance of four Cerrado species with landscape potential**":

1. **Financial Interests**: We have no financial relationships that could influence the results or the interpretation of this work.
2. **Professional Relationships**: We have no professional relationships that could affect the analysis, interpretation, or presentation of the results.
3. **Personal Conflicts**: We have no personal conflicts of interest related to the content of this manuscript.