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FORESTRY SCIENCE

# Biodegradable capsules may increase the seed germination of forest species from the Cerrado

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**ABSTRACT**: A good grasp of the different facets of seed germination of the plant species native to the Cerrado will facilitate the selection of species that can be used to restore degraded ecosystems. Hence, the objective of the current study was to confirm the ways biodegradable capsules affect the germination of the seeds of three tree species typical of the physiognomies of the Cerrado forest (*Enterolobium contortisiliquum*, *Anadenanthera colubrina* and *Dipteryx alata*). The experiments, conducted in a greenhouse, included two treatments: seeding performed inside biodegradable capsules and direct seeding on the substrate surface. Two seeds from each of the species were sown in plastic bags containing the Quartzarenic Neosol class of substrates. Using five replicates for each treatment resulted in 20 plastic bags for each. The greenhouse conditions included controlled temperature and relative humidity. Inside the capsules, the findings revealed that the baru, angico-branco and tamboril seeds germinated at the rates of 97%, 42%, and 12%, respectively. However, during direct seeding, germination rates for baru, angico-branco and tamboril were 15%, 21% and 8%. From the findings, it is evident that when biodegradable capsules are used, the germination of all three Cerrado species investigated is favoured. Thus, both capsules and the cited species can be recommended for projects of ecological restoration.
**Key words**: cerrado, artificial cover, aerial seeding, tree species, encapsulation.

## Cápsulas biodegradáveis podem ampliar a germinação de sementes de espécies florestais do Cerrado

**RESUMO**: Entender aspectos da germinação de sementes de espécies nativas do Cerrado pode auxiliar na escolha de espécies a serem utilizadas na restauração de ecossistemas degradados. Portanto, o estudo teve como objetivo verificar o efeito de cápsulas biodegradáveis na germinação de sementes de três espécies arbóreas típicas de fisionomias florestais do Cerrado (*Enterolobium contortisiliquum*, *Anadenanthera colubrina* e *Dipteryx alata*). O experimento foi conduzido em casa de vegetação, com dois tratamentos: semeadura no interior de cápsulas biodegradáveis e semeadura direta na superfície do substrato. Duas sementes de cada espécie foram utilizadas por tratamento, as quais foram acomodadas em sacos plásticos com substrato arenoso oriundo da classe Neossolo Quartzarênico. Para cada tratamento, foram utilizados cinco blocos (repetições), com 20 sacos plásticos cada. A casa de vegetação teve condições controladas de temperatura e umidade relativa. Dentro das cápsulas, os resultados mostraram que as sementes de baru, angico-branco e tamboril apresentaram germinação de 97%, 42% e 12%, respectivamente. Por outro lado, na semeadura direta, a germinação foi de 15% para baru, 21% para angico-branco e 8% para tamboril. Os resultados indicam que o uso de cápsulas biodegradáveis favorece a germinação das espécies do Cerrado estudadas. Assim, tanto a utilização das cápsulas quanto as espécies elencadas são recomendadas em projetos de restauração ecológica.
**Palavras-chave**: cerrado, cobertura artificial, semeadura aérea, espécies arbóreas, encapsulamento.

## INTRODUCTION

Brazil is recognized globally for the biodiversity loss it has suffered over a long time, caused by the implementation of agricultural advancements, particularly in the typical forest biomes of the Amazon and Atlantic, as well as of the Cerrado (FEARNSIDE, 2005). In the Cerrado, 50% or more of its natural vegetative cover has seen much change, and the state of Goiás was ranked second on the deforestation scale, from 2001 to 2019, after Mato Grosso. This was attributed to the intensification of the agricultural advancements in Mato Grosso (ROSS et al., 2022), which accelerated the fragmentation of the natural ecosystems. Therefore, related to its high diversity and endemism, this biome is acknowledged as a global hotspot requiring the protection of its biodiversity (RAUPP et al., 2020). Accepted as the second biggest biome in Brazil, the Cerrado is an extensive territorial stretch. Furthermore, it has exceptional species richness, leading to its position as the savannah, possessing the highest biological diversity, worldwide. This union of the vast expanse and wide biodiversity makes the Cerrado a very significant biome (PASSARETTI et al., 2020). Its fundamental role in water supply cannot be minimized,

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because the springs of the main Brazilian river basins are concentrated here. It supplies 14% of the surface water production in Brazil (BRANCALION et al., 2015). It is the main representative of the tropical biomes, with a grassland and savanna physiognomy in Brazilian territory, crucial for the balance of the environment due to its high biodiversity.

The great loss of territory and the many processes leading to the decline, makes ecological restoration (RE) pivotal in fulfilling the objectives of global conservation and is a dynamic instrument in controlling biodiversity loss (MARTINS et al., 2020). Therefore, RE is a high priority, in the Cerrado, as well as across Brazil (RAUPP et al., 2020).

From the various RE methods available, direct seeding offers better results concerning plant recovery in the regions where degradation and alteration are evident (GORNISH et al., 2019; ARAGÃO et al., 2023). This is because this is a potentially cost-effective technique as it bypasses the phase of seedling production in a nursery. After much development and fine-tuning this technique was found useful in the recovery of the denuded regions of the Cerrado areas and the execution of reforestation for economic benefit (VIEIRA et al., 2017).

Research done on direct seed tried to relate the seeds germination of the native species to the restoration of vegetation, in very dissimilar ecosystems (OVERBECK et al., 2013; AIRES et al., 2014; PELLIZZARO et al., 2017). These studies along with the research associated with other factors of revegetation, such as fruiting phenology and seed production have enriched the present fund of knowledge (ESCOBAR et al., 2018; KHURANA & SINGH, 2001; RAMOS et al., 2017). The findings from these studies revealed that the germination lag in the native Cerrado seeds, among others, is linked to seed and seedling mortality, where desiccation occurs at the higher temperatures present in open areas, and even seed predation (PELLIZZARO et al., 2017). Hence, direct seeding can be successful only when different factors, like the use of technologies and sound field practices, enhance the seed germination of the species native to the Cerrado.

The objective of the present research is to examine how biodegradable capsules affect the seed germination of three tree species, all native to the Cerrado forest, by determining the potential that these capsules possess for implementation in projects of ecological restoration. The research hypothesis focuses on using capsules as the more efficient method of seed preservation, through the retention of humidity and offering protection from attacks by biological agents, and therefore to the germination potential itself.

## METHODS

The experiments were conducted at the Prof. Dr. Luiz Eduardo de Oliveira Sales (FELEOS) Experimental Farm, situated on Campus II of the Centro Universitário de Mineiros (UNIFIMES), in the rural region of the municipality of Mineiros, GO (17º27'4.05" S 52º36'8.035" W).

The outcomes of using biodegradable capsules on the seed germination of the three tree species were recorded. First, an experiment was set up, which included two treatments as cited: i) biodegradable capsules composed using cardboard boxes (Figure 1) and ii) direct seeding.

The biodegradable capsules were developed with cardboard that had been used earlier as packaging material for the transport and storage of eggs, and which would ultimately be categorized as disposable solid waste. These rounded capsules have dimensions of 40 × 40 × 20 mm (Figure 1). The capsule mold was manufactured using the 3D printing technique with PLA plastic filament, with dimensions of 50 × 60 × 25 mm.

The four-month experiment was set up in a greenhouse. In each treatment, 450 mL capacity black plastic bags, 8 cm x 15 cm were taken and the seeds were sown in a sandy substrate, originally of the Quartzarenic Neossolo soil class, supplied by FELEOS. The capsules carrying the seeds (Treatment 1) and direct seeding (Treatment 2) were embedded on the surface of the substrate. Each treatment included five blocks (replications), that is 20 plastic bags, making a total of 100 sample units. In each sampling unit, two seeds from the three tree species native to the Cerrado forest physiognomies were planted, so that each capsule contained six seeds. The seeds used belonged to the species cited here: tamboril [*Enterolobium contortisiliquum* (Vell.) Morong]; angico-branco [*Anadenanthera colubrina* (Benth.) Brenan]; and baru [*Dipteryx alata* (Vogel)]. Recently harvested seeds acquired by the Xingu Seed Network, Rede de Sementes do Xingu, were used. Initially, to characterize the seed germination, a germination test was performed in the laboratory using filter paper discs (LOPES et al., 2010). The percentage of seed germination of the species investigated was 86%, 93%, and 43% for the angico, baru, and monkfish, respectively. Constant irrigation was provided in the greenhouse, to ensure that the relative air humidity was maintained from 60 to 90%, and the temperature hovered from 26 to 35 °C.

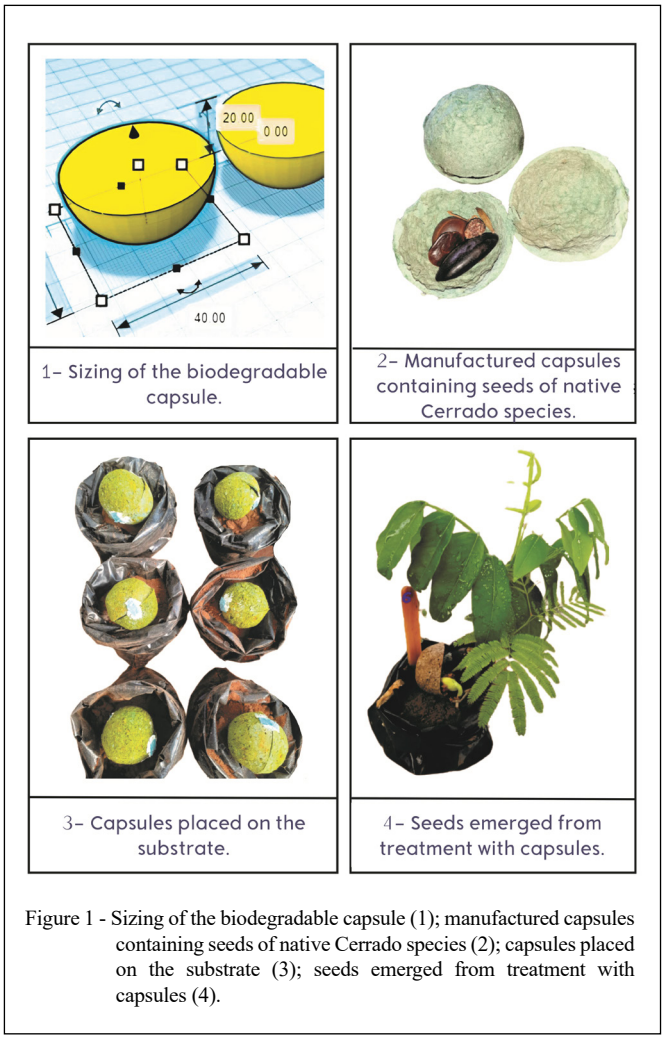


Figure 1 - Sizing of the biodegradable capsule (1); manufactured capsules containing seeds of native Cerrado species (2); capsules placed on the substrate (3); seeds emerged from treatment with capsules (4).

Table 1 lists the chemical constituents of the soil, revealing the acidic nature of the substrate used, with an overall low presence of macro and micronutrients, characteristic of the Cerrado soils.

The Mann-Whitney test (Wilcoxon rank-sum test) was done to determine the effect of the treatments on the percentage of germination, for unpaired data, because the data was not normally distributed.

## RESULTS AND DISCUSSION

From the findings, it was clear that when compared to the treatment of direct seeding on the substrate, the biodegradable capsule enhanced the germination process in all three tree species investigated (Figure 1). In the treatment using the capsules, the baru seeds showed excellent results with 97% germination, while the angico-branco and tamboril seeds showed an increase of 42% and 12%, respectively (Figure 2). For the direct seeding treatment, the germination process respectively for baru, angico-branco, and tamboril, showed 15%, 21% and 8% (Figure 2).

The correlation between germination and the seeding type may have been affected by the thermal comfort that the biodegradable capsule offered, as the seeds were encased in the capsule material which, on watering and direct exposure to sunlight, provided conditions conducive for germination. Further, the capsule offers protection for the seeds against herbivore- and predator-attack, very different from directly seeding the seed in the soil substrate. FERREIRA et al. (2022) reported that in the case of direct broadcast seeding, some seeds died from desiccation, or that the newly emerged seedlings showed low survival rates, probably due to exposure. Other studies, that employed seed protection (such as seed balls) reported better seed

Table 1 - Chemical attributes of the soil, indicating that the substrate used is acidic and, in general, with a low level of macro and micronutrients, typical of Cerrado soils.

| Acronym | ----------Description---------- | ----------Unit---------- | ----------Soil---------- |
|---|---|---|---|
| M.O | Organic Matter | $g.dm^{-3}$ | 12 |
| pH | $CaCl_2$ | | 4.0 |
| P | Phosphor Mehlich | $mg.dm^{-3}$ | 1 |
| K | Potassium | $mmol_c.\ dm^{-3}$ | 0.2 |
| Ca | Calcium | $mmol_c.\ dm^{-3}$ | 2 |
| Mg | Magnesium | $mmol_c.\ dm^{-3}$ | 1 |
| Al | Aluminium | $mmol_c.\ dm^{-3}$ | 7 |
| H+AI | Ac. Potential | $mmol_c.\ dm^{-3}$ | 25 |
| S.B. | Sum of bases | $mmol_c.\ dm^{-3}$ | 3.2 |
| CTC | cation exchange capacity | $mmol_c.\ dm^{-3}$ | 28.2 |
| V | Base Saturation | % | 11,45 |
| S | Sulfur | $mg.dm^{-3}$ | 3 |
| C | Carbon | $mg.dm^{-3}$ | 7 |

protection and higher moisture retention, causing an increase in the germination and seedling emergence speed (JAWAHAR & UMARANI, 2020). Therefore, our results indicated that the differences between the treatments in terms of germination percentages may be correlated to the biodegradable capsules, which protect the seeds and heighten moisture retention and thus enhance seed germination and hence seedling emergence. Therefore, the capsule is seen to provide a conducive environment for the seeds, averting rapid desiccation and viability losses, because humidity is a vital factor in the activation of the enzymes that govern the germination process (ROSS et al., 2020).

From this angle, the capsules act as an initial protective agent, facilitating seed germination during unfavorable conditions, apart from guaranteeing a more supportive environment for germination. The results reported here; therefore, encourage the use of biodegradable capsules rather than direct seeding, as they offer the potential for enhanced seed germination and seedling growth. This opens up an extensive range of possibilities for the implementation of this seed protective method that can improve germination and raise the level of ecological restoration, more than with the direct seeding of seeds.

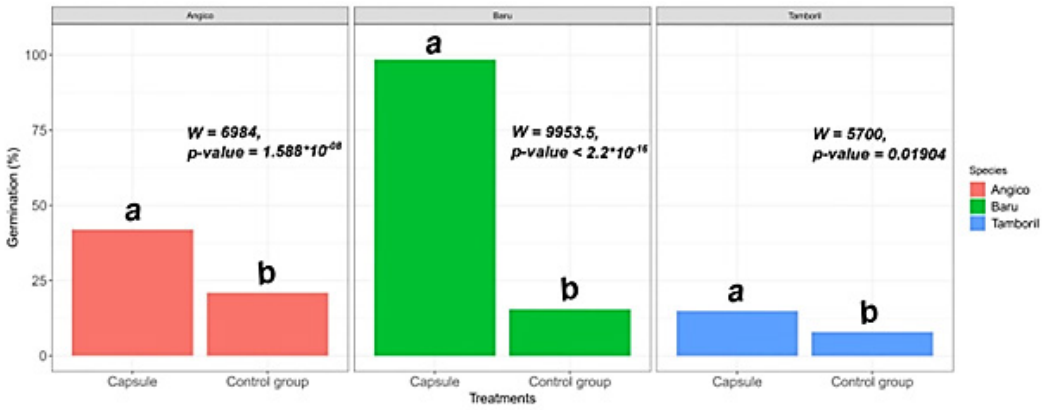


Figure 2 - Seed germination percentage (%) of Cerrado tree species subjected to two treatments: biodegradable capsules and control group (direct seeding).

## CONCLUSION

The results achieved displayed the success of using biodegradable capsules on the rates of seed germination for all three tree native species to the Cerrado forest. More studies are required in the future, from the perspective of continued assessment in the field focussing on the speedy growth and survival of newly germinated seedlings. Besides this, an evaluation of the expenditure involved is also significant, because no investment is required for seed preparation, thus negating labor costs. Finally, it is crucial to understand the findings of the current study as a step forward in enhancing the future of ecological restoration efforts, particularly when the aim is to decrease the time, boost the rates of seed germination and thus enhance the plant density.

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## DECLARATION OF CONFLICT OF INTEREST

The authors declare that they have no conflict of interest in this work. The financial sponsors had no role in the study design, data collection, analysis, or interpretation, writing of the manuscript, and decision to publish the results.

## AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and writing of the manuscript, and critically reviewed the manuscript and approved the final version.

## REFERENCES

AIRES, S. S. et al. Seed characterization and direct seeding of native grass species as a management tool. **Grass and Forage Science**, v.69, n.3, p.470–478, 2014. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1111/gfs.12077>. Accessed: Mar. 12, 2022. doi: 10.1111/gfs.12077.

ARAGÃO, J. S. et al. Forest recovery by direct seeding on the southern edge of the Brazilian Amazon. **Restoration Ecology**, 2023. Available from: <https://onlinelibrary.wiley.com/doi/10.1111/rec.14036?af=R>. Accessed: Oct. 30, 2023. doi: 10.1111/rec.14036.

BRANCALION, P. H. S. et al. **Restauração florestal**. São Paulo: Oficina de Textos, 2015.

ESCOBAR, D. F. E. et al. Timing of seed dispersal and seed dormancy in Brazilian savanna: two solutions to face seasonality. **Annals of Botany**, v.121, n.6, p.1197–1209, 2018. Available from: <https://academic.oup.com/aob/article/121/6/1197/4841709?login=false>. Accessed: Aug. 15, 2022. doi: 10.1093/aob/mcy006.

FEARNSIDE, P. Deforestation in Brazilian Amazonia: history, rates, and consequences. **Conservation Biology**, v.19, n.3, p.680-688, 2005. Available from: <https://conbio.onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2005.00697.x>. Accessed: Aug. 10, 2022. doi: 10.1111/j.1523-1739.2005.00697.x.

FERREIRA, R. A. et al. Direct sowing with forest species in the implementation of riparian forest in Baixo São Francisco in Sergipe. **Scientia Forestalis**, v.37, n.81, p.37-46, 2022. Available from: <https://www.ipef.br/publicacoes/scientia/nr81/cap04.pdf>. Accessed: Aug. 15, 2022.

GORNISH, E. et al. Review of seed pelletizing strategies for arid land restoration. Restoration **Ecology**, v.27, n.6, p.1206-1211, 2019. Available from: <https://onlinelibrary.wiley.com/doi/full/10.1111/rec.13045>. Accessed: Aug. 20, 2022. doi: 10.1111/rec.13045.

JAWAHAR, R.; UMARANI, R. Development of seed cube technology for successful afforestation through direct seeding of *Thespesia populnea* trees. **Journal of Tropical Forest Science**, v.32, n.1, p.52-57, 2020. Available from: <https://jtfs.frim.gov.my/jtfs/article/view/123>. Accessed: Aug. 23, 2022. doi: 0.26525/jtfs32.1.52.

KHURANA, E.; SINGH, J. S. Ecology of seed and seedling growth for conservation and restoration of tropical dry forest: a review. **Environmental Conservation**, v.28, p.39-52, 2001.Availabe from <http://dx.doi.org/10.1017/S0376892901000042>. Accessed: Aug. 20, 2022. doi: 10.1017/S0376892901000042.

LOPES, R. et al. Biometria de frutos e sementes e germinação de *Plathymenia reticulata* Benth. e *Plathymenia foliolosa* Benth. (FABACEAE - MIMOSOIDEAE). **Revista Árvore**, v.34, p.797-805, 2010. Available from: <https://www.scielo.br/j/rarv/a/6MwC9cR5xYgwQ7XkFxYFJJS/?lang=pt>. Accessed: Aug. 25, 2022. doi: 10.1590/S0100-67622010000500005.

MARTINS, S. V. Monitoring the passive and active ecological restoration of areas impacted by the Fundão tailings dam disruption in Mariana, Minas Gerais, Brazil. In: VLIEGER, K. (Ed.) **Recent Advances in Ecological Restoration**. New York: Nova Science Publishers, 2020. p.51-95.

OVERBECK, E. et al. Testing broadcast seeding methods to restore urban forests in the presence of seed predators. **Restoration Ecology**, Washington, v.21, n.6, p.763–769, 2013. Available from: <https://onlinelibrary.wiley.com/doi/full/10.1111/j.1526-100X.2012.00933.x>. Accessed: Aug. 30, 2022. doi: 10.1111/j.1526-100X.2012.00933.x.

PASSARETTI, R. A. et al. Weed control, large seeds and deep roots: drivers of success in direct seeding for savanna restoration. **Applied Vegetation Science**, v.23, n.3, p.406-416, 2020. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1111/avsc.12495>. Accessed: Sept. 15,. 2022. doi: 10.1111/avsc.12495.

PELLIZZARO, K. F. et al. "Cerrado" restorarion by direct seeding: field establisment and initial growth of 75 trees, shrubs and grass species. **Brazilian Journal of Botany**, v.40, n.3,

p.681–693, 2017. Available from: <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/180967/1/Pellizzaro2017-Article-CerradoRestorationByDirectSeed.pdf>. Accessed: Sept. 10, 2022. doi: 10.1007/s40415-017-0371-6.

RAMOS, D. M. et al. Avoiding the dry season: dispersal time and syndrome mediate seed dormancy in grasses in Neotropical savanna and wet grasslands. **Journal of Vegetation Science**, v.28, n.4, p.798-807, 2017. Available from: <https://onlinelibrary.wiley.com/doi/abs/10.1111/jvs.12531>. Accessed: Aug. 13, 2022. 10.1111/jvs.12531.

RAUPP, P. P. et al. Direct seeding reduces the costs of tree planting for forest and savanna restoration. **Ecological Engineering**, v.148, p.1057-88, 2020. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0925857420300768>. Accessed: Aug. 15, 2022. doi:10.1016/j.ecoleng.2020.105788.

ROSS, J. L. S. et al. **Ordenamento territorial do Brasil**: potencialidades naturais e vulnerabilidades sociais, Osasco, SP: Ed. dos Autores, 2022. 585p. Available from: <https://journals.openedition.org/confins/45519>. Accessed: Nov. 15, 2020. doi: 10.29327/560402.