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Mini-cutting supports low-input clonal propagation of *Piptadenia stipulacea* under semi-arid conditions

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Abstract

Piptadenia stipulacea is a leguminous tree species native to the Caatinga with potential for ecological restoration in semi-arid environments, but information on its vegetative propagation remains limited. We evaluated sprouting dynamics in a seminal mini-garden and tested whether indole-3-butyric acid (IBA) improved adventitious rooting of mini-cuttings. We treated mini-cuttings with 0, 2,000, 4,000, and 6,000 mg L^{-1} IBA and evaluated rooting, survival, growth, and biomass production. Sprout production varied over time and increased markedly at 90 days, indicating recovery of ministumps after successive pruning. IBA did not improve rooting, survival, growth, or biomass accumulation. The control treatment showed the highest mean rooting and survival values, while the highest IBA concentration reduced overall morphophysiological performance. Intermediate doses produced balanced responses but did not provide a consistent advantage over the absence of growth regulator. We concluded that P. stipulacea can be efficiently propagated by mini-cutting without exogenous auxin under the tested conditions. This response supports a low-input propagation protocol and may reduce operational costs for seedling production aimed at restoration programs in semi-arid regions.

Keywords: Caatinga, IBA, ministumps, adventitious rooting, native seedlings.

Introduction

The production of high-quality seedlings is essential for ecological restoration, reforestation, and agroforestry systems in dry regions. In arid and semi-arid ecosystems, water scarcity, low soil fertility, irregular rainfall, and high seedling mortality limit natural regeneration and make efficient propagation strategies necessary for the establishment of native woody species (Yirdaw et al., 2017; Soto et al., 2025). These constraints are particularly relevant in tropical dry forests, which are highly threatened and still poorly studied when compared with other forest ecosystems (Murphy & Lugo, 1986; Miles et al., 2006; DRYFLOR, 2016).

Seed-based restoration in dry environments often faces additional limitations. Many native species present physical dormancy, irregular germination, seasonal seed availability, and low propagule supply, which reduce the predictability of seedling production and restoration success (Aradóttir & Halldórsson, 2018; Kildisheva et al., 2018; Ratanapongsai, 2020; Siegmund et al., 2025). Therefore, vegetative propagation represents an important alternative for producing uniform seedlings, maintaining selected plant material, and supporting restoration programs when seed supply or germination is limiting (Hartmann et al., 2018; Xavier et al., 2013).

Piptadenia stipulacea (Benth.) Ducke is a leguminous tree species native to the Caatinga and has potential for restoration and agroforestry systems in semi-arid environments. The species is associated with drought tolerance, biological nitrogen fixation, and establishment in degraded areas, traits that increase its ecological relevance for dryland restoration (Sampaio, 1995; Leal et al., 2003). However, seed propagation can be limited by dormancy and irregular germination (Benedito et al., 2019), and information on vegetative propagation protocols for the species remains scarce.

Mini-cutting is a promising technique for native woody species because it allows repeated shoot collection from ministumps and can support the multiplication of selected plant material under nursery conditions. However, the success of mini-cutting depends on the ability of ministumps to resprout after successive pruning and on the capacity of mini-cuttings to form adventitious roots. In many woody species, indole-3-butyric acid (IBA) improves rooting, but the response to exogenous auxin varies among species, types of propagules, physiological age, and environmental conditions (Díaz-Sala, 2021; Kumar et al., 2022). In some species, auxin application may be unnecessary or may even reduce propagation performance when doses exceed the physiological requirement of the propagule.

Despite advances in vegetative propagation of native tree species, we still lack information on whether IBA is required for efficient mini-cutting of *P. stipulacea* under semi-arid conditions. This gap limits the development of simple, low-input, and economically viable protocols for producing seedlings of this species. We hypothesize that *P. stipulacea* mini-cuttings can root efficiently without exogenous auxin because juvenile propagules from a seminal mini-garden may already present high rooting competence under adequate nursery conditions.

Therefore, we evaluated sprouting dynamics in a seminal mini-garden and tested the adventitious rooting response of *P. stipulacea* mini-cuttings treated with different IBA concentrations. Specifically, we assessed whether IBA improves rooting, survival, growth, and biomass accumulation, or whether mini-cutting can support low-input clonal propagation without exogenous auxin. This study focuses on early propagation performance under nursery conditions and does not evaluate field establishment after planting.

Methods

Study area and mother-tree selection. We collected seeds from 20 selected, georeferenced mother trees in a Natural Seed Collection Area located in Mossoró, Assú, and Afonso Bezerra, Rio Grande do Norte, Brazil (Figure 1). These municipalities are located in the hot semi-arid climatic zone according to the Köppen classification (Alvares et al., 2013), with high annual temperatures, short rainy seasons, and prolonged dry periods.

We selected mother trees based on height, stem diameter, seed production, phytosanitary condition, and overall vigor. We maintained a minimum distance of 100 m between trees to reduce the probability of relatedness, following recommendations for semi-arid regions (Sena & Gariglio, 2008). We collected seeds at physiological maturity, processed them, and stored them at 5 °C.

Mini-garden establishment. We manually scarified the seeds to overcome physical dormancy (Farias et al., 2013) and sowed them in 11.46 L polyethylene bags filled with local soil. The soil was predominantly associated with Cambisols and showed neutral to slightly alkaline pH, high base saturation, absence of toxic aluminum, and low available phosphorus, typical of Caatinga soils under semi-arid conditions. Soil chemical characterization is presented in Table S1.

We monitored seedlings until they reached 15 cm in height. Then, we pruned them at 10 cm above the root collar to induce epicormic shoots. After sprouting, we performed a second pruning at 20 cm to form a cup-shaped crown architecture (Figure 2).

We established the mini-garden in a completely randomized design with three replicates of 33 plants, totaling 99 initial experimental units. During the evaluation period, some ministumps died, resulting in 68 remaining plants at the end of the experiment. Mortality was more pronounced near the 75-day evaluation, and no visible

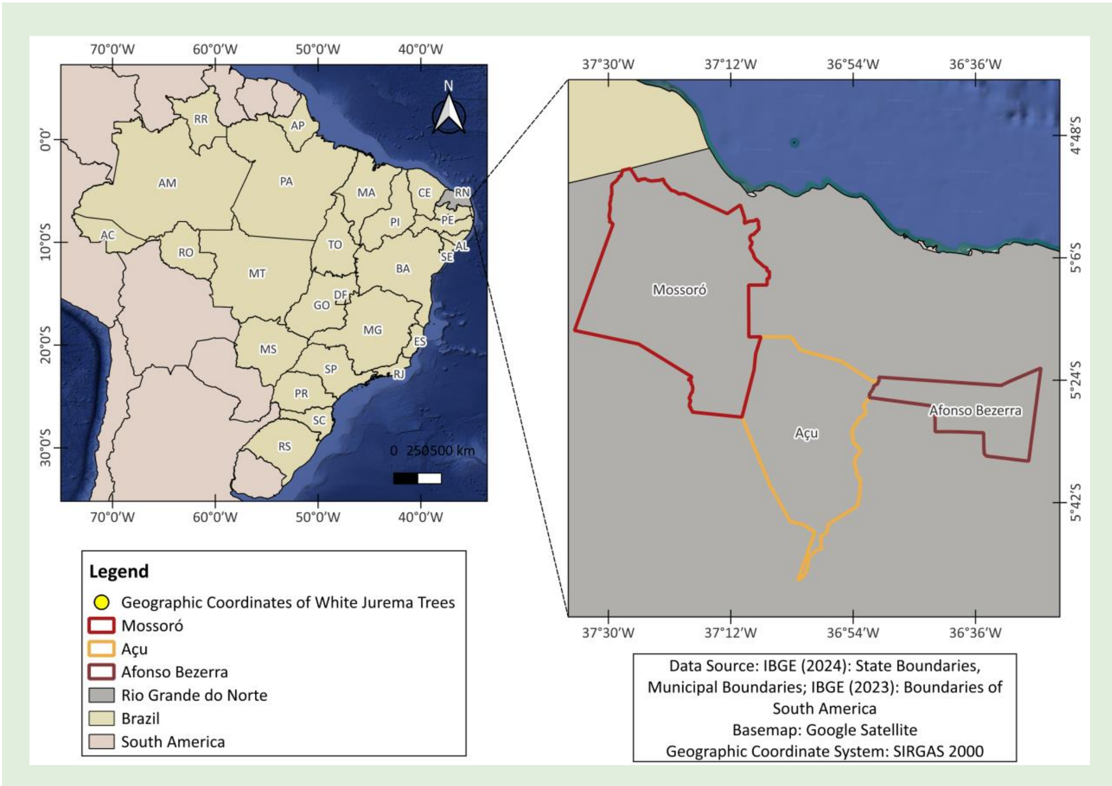

Figure 1. Geographic location of the municipalities in Rio Grande do Norte where *Piptadenia stipulacea* seeds were collected for the establishment of the mini-garden. Yellow points indicate the coordinates of the mother trees. Source: Authors.

Figure 2. Establishment of the mini-garden system and vegetative management of *Piptadenia stipulacea*. (A) Seedlings monitored until reaching 15 cm in height. (B) Plants after pruning to induce sprouting. (C) Individuals managed under the mini-garden system, showing vegetative growth in polyethylene bags**.** Source: Authors.

symptoms of pests or diseases were observed in the affected plants. The remaining ministumps provided sufficient shoots for evaluating sprouting dynamics and supplying mini-cuttings for the rooting experiment. We pruned the ministumps every 15 days for 90 days and recorded shoot number and shoot length at each evaluation.

We fertilized ministumps weekly with a commercial water-soluble mineral fertilizer containing nitrogen (2.4%), potassium oxide (9%) , iron (3.192%), manganese (1.040%), boron (1.04%), copper (0.66%), zinc (0.41%), nickel (0.13%), molybdenum (0.20%), and cobalt (0.05%).

Adventitious rooting. We collected shoots following Dias et al. (2012) and Souza et al. (2024) and standardized mini-cuttings to approximately 13 cm in length, each with one pair of fully expanded leaves.

We conducted the rooting experiment in a completely randomized design with four indole-3-butyric acid concentrations: 0, 2,000, 4,000, and 6,000 mg L^{-1}. Each treatment had four replicates of 14 mini-cuttings. We prepared the solutions by dissolving the regulator in 1% potassium hydroxide and diluting it in distilled water. We immersed the base of each mini-cutting in the solution for 10 seconds. Control mini-cuttings were immersed only in distilled water.

We planted mini-cuttings in 55 cm^3 polyethylene tubes containing a commercial substrate composed of 70% sphagnum peat and 30% vermiculite. The substrate had pH 5.5, electrical conductivity of 0.7 mS cm^{-1}, density of 130 kg m^{-3}, water retention capacity of 300%, and maximum moisture of 60%.

We maintained the mini-cuttings in a transparent plastic-covered mini-greenhouse under intermittent misting for 30 days for rooting. During this period, the air temperature inside the mini-greenhouse was maintained between 26 and 30 °C, and the relative humidity remained above 80%. The mini-cuttings were then transferred to a nursery under 50% shade for 10 days of acclimatization. At the end of the propagation period, we evaluated rooting, survival, shoot length, root length, number of roots, and fresh and dry biomass of shoots and roots.

We considered mini-cuttings rooted when they had roots longer than 2 mm. We calculated survival as the proportion of live propagules relative to the initial number of mini-cuttings. We measured shoot length from the substrate level to the shoot apex and root length as the longest root per mini-cutting. We determined biomass separately for each replicate within each treatment.

Statistical analysis. We tested data normality using the Shapiro-Wilk test. For shoot number, which did not meet normality assumptions, we used the Friedman test for repeated measures, followed by Dunn's *post hoc* test with Holm correction. For shoot length, we used repeated-measures analysis of variance and compared means with Tukey's test.

For the rooting experiment, we analyzed traits using analysis of variance followed by Tukey's test when assumptions were met. When assumptions were not met, we used the Kruskal-Wallis test followed by Dunn's test. We also fitted regression models to evaluate temporal trends in the mini-garden and responses to indole-3-butyric acid concentrations. We performed all analyses in R version 4.4.0 and considered results significant at $P < 0.05$.

Results

In the seminal mini-garden, shoot production varied among collection times. The 90-day evaluation differed from all previous evaluations, whereas the 15, 30, 45, 60, and 75-day evaluations did not differ from each other (Table S2 and S3).

Figure 3A shows the variation in mean shoot production of ministumps in the seminal mini-garden throughout the experimental period. Between 15 and 75 days, shoot production remained relatively stable, ranging from 1.19 ± 0.14 to 1.54 ± 0.14 shoots per ministump. At 90 days, however, shoot production increased to 2.79 ± 0.17 shoots per ministump, representing the highest value recorded during the evaluation period and forming a distinct statistical group from the previous collections (Table S3).

For shoot length, the evaluations also formed different statistical groups over time (Figure 3B; Tables S2 and S3). The highest values occurred at 15 and 90 days, with 55.28 ± 0.33 cm and 55.56 ± 0.27 cm, respectively, both belonging to the same statistical group. Shoot length declined progressively until 75 days, when the lowest value was recorded, with 22.98 ± 0.27 cm, followed by recovery at 90 days.

Regarding the effect of indole-3-butyric acid on adventitious rooting, no significant differences were observed among treatments for rooting, survival, root number, root length, or shoot length, since all treatments remained in the same statistical group (Figure 4; Table S4). Even so, descriptive variation was observed among doses. The control treatment showed the highest numerical values for rooting and survival, both reaching 94.64%. At 2,000 and 4,000 mg L^{-1}, rooting and survival reached 81.48% and 80.36%, respectively. The lowest values occurred at 6,000 mg L^{-1}, with 71.43% rooting and survival.

For the remaining morphological traits, only slight numerical variation was observed among indole-3-butyric acid concentrations. The number of roots was slightly higher at 2,000 mg L^{-1}, with 8.45 ± 0.70 roots, and at 4,000 mg L^{-1}, with 8.22 ± 0.56 roots, compared with 7.79 ± 0.47 roots in the control treatment. Root length was numerically higher at 4,000 mg L^{-1}, with 7.22 ± 0.61 cm, and lower at 6,000 mg L^{-1}, with 5.90 ± 0.50 cm. Shoot length followed a similar

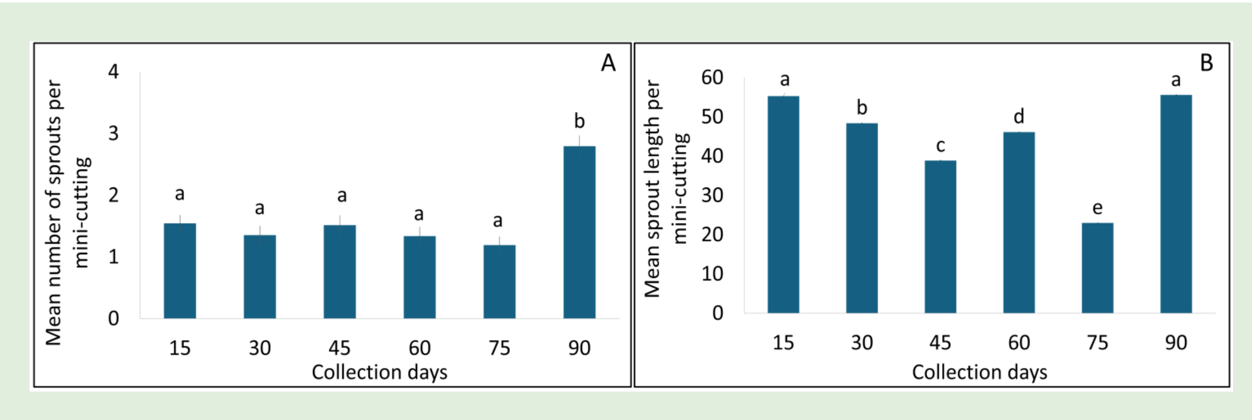

Figure 3. Sprouting dynamics in the seminal mini-garden of *Piptadenia stipulacea* as a function of collection interval. The figure shows the mean number of sprouts per ministump (A) and the mean sprout length per ministump (B) at six collection times (15, 30, 45, 60, 75, and 90 days). Bars represent observed means, and error bars indicate the standard error of the mean. Different letters indicate significant differences among collection times according to *post hoc* tests at the 5% significance level. Source: Authors.

pattern, with the highest numerical values at 2,000 and 4,000 mg L^{-1}, but without statistical separation among treatments (Table S4).

Biomass traits also did not differ among indole-3-butyric acid concentrations, as all treatments remained in the same statistical group (Figure 5; Table S5).

Fresh shoot mass was numerically higher in the control treatment, with 2.49 ± 0.03 g, and lower at 4,000 and 6,000 mg L^{-1}, with 1.70 ± 0.16 g and 1.68 ± 0.18 g, respectively. Dry shoot mass showed the same tendency, with the highest value in the control treatment, 0.44 ± 0.02 g, and the lowest value at 6,000 mg L^{-1}, 0.24 ± 0.03 g.

Root biomass showed smaller variation among treatments. Fresh root mass ranged from 1.47 ± 0.16 g at 2,000 mg L^{-1} to 1.67 ± 0.10 g at 4,000 mg L^{-1}, whereas dry root mass ranged from 0.17 ± 0.02 g at 6,000 mg L^{-1} to 0.22 ± 0.01 g at 2,000 mg L^{-1}. These variations did not indicate a consistent dose-response pattern (Table S5).

Visual evaluation of the root system showed differences in root architecture among treatments (Figure 6). In the control treatment, the root system was more elongated and well distributed along the mini-cutting axis. At 2,000 and 4,000 mg L^{-1}, root formation was evident but less uniform than in the control. At 6,000 mg L^{-1}, the root system appeared more compact, with roots concentrated near the base of the mini-cutting and reduced longitudinal development.

The radar chart summarized the relative performance of treatments across rooting, survival, growth, and biomass traits (Figure 7). The control treatment showed higher relative values for rooting, survival, shoot length, and fresh shoot mass. Intermediate concentrations showed balanced but non-superior responses, whereas 6,000 mg L^{-1} showed lower relative performance for most variables, particularly rooting, survival, shoot length, and root development.

Discussion

The sprouting response observed in the seminal mini-garden indicates that *P. stipulacea* tolerates successive shoot removal and maintains propagule production under nursery conditions. This response is relevant for mini-cutting because the feasibility of the technique depends not only on adventitious rooting, but also on the ability of ministumps to produce shoots repeatedly after pruning. In woody species, resprouting represents an important functional response after cutting, breakage, or other disturbances, allowing recovery of leaf area and maintenance of growth (Bond & Midgley, 2001; Clarke et al., 2013; Pausas & Keeley 2014).

Shoot production remains relatively stable during the first evaluations and increases at the end of the evaluation period, which suggests that the mini-garden requires an adjustment phase before reaching higher sprouting performance. This pattern may reflect the gradual recovery of ministumps after successive pruning and the reorganization of vegetative growth after initial management. Similar responses occur in vegetative propagation systems, in which shoot production depends on the physiological condition of mother plants, nutritional status, pruning intensity, and environmental conditions (Wendling et al., 2014a; 2014b; Stuepp et al., 2018; Souza et al., 2022, Souza et al., 2023; Araujo et al., 2025; Freire et al., 2025).

Shoot emission and shoot elongation appear to respond differently to successive pruning. While shoot production increases at the

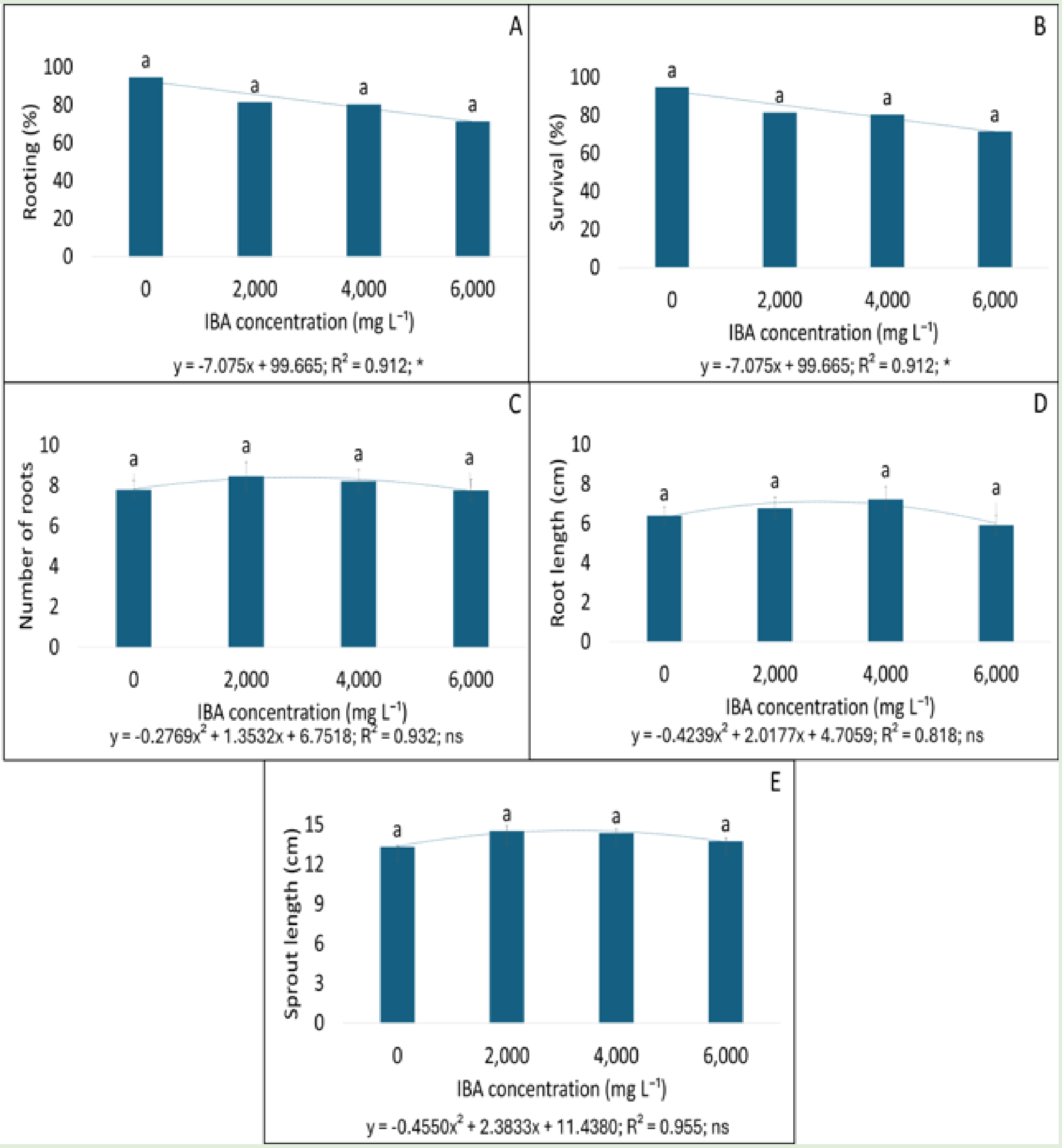

Figure 4. Effect of different concentrations of indole-3-butyric acid (IBA) on morphological traits of mini-cuttings of *Piptadenia stipulacea* cultivated in a mini-garden. The figure shows rooting percentage (A), survival percentage (B), mean number of roots (C), mean root length (D), and mean shoot length (E). Blue bars represent mean values per treatment, while red lines indicate the standard error of the mean. Statistical significance is indicated in each panel as follows: * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, ns = not significant. Source: Authors.

final evaluation, shoot length decreases during the intermediate period and later recovers. This pattern indicates that the number of shoots does not necessarily limit shoot elongation and that both traits may be regulated by different physiological and environmental factors. The recovery observed at the end of the evaluation period also suggests that short-term assessments may underestimate the productive potential of seminal mini-gardens, especially for native species from semi-arid environments.

The high rooting and survival observed in the control treatment show that *P. stipulacea* mini-cuttings root efficiently without indole-3-butyric acid under the tested conditions. This result has practical importance because exogenous auxin is commonly used to

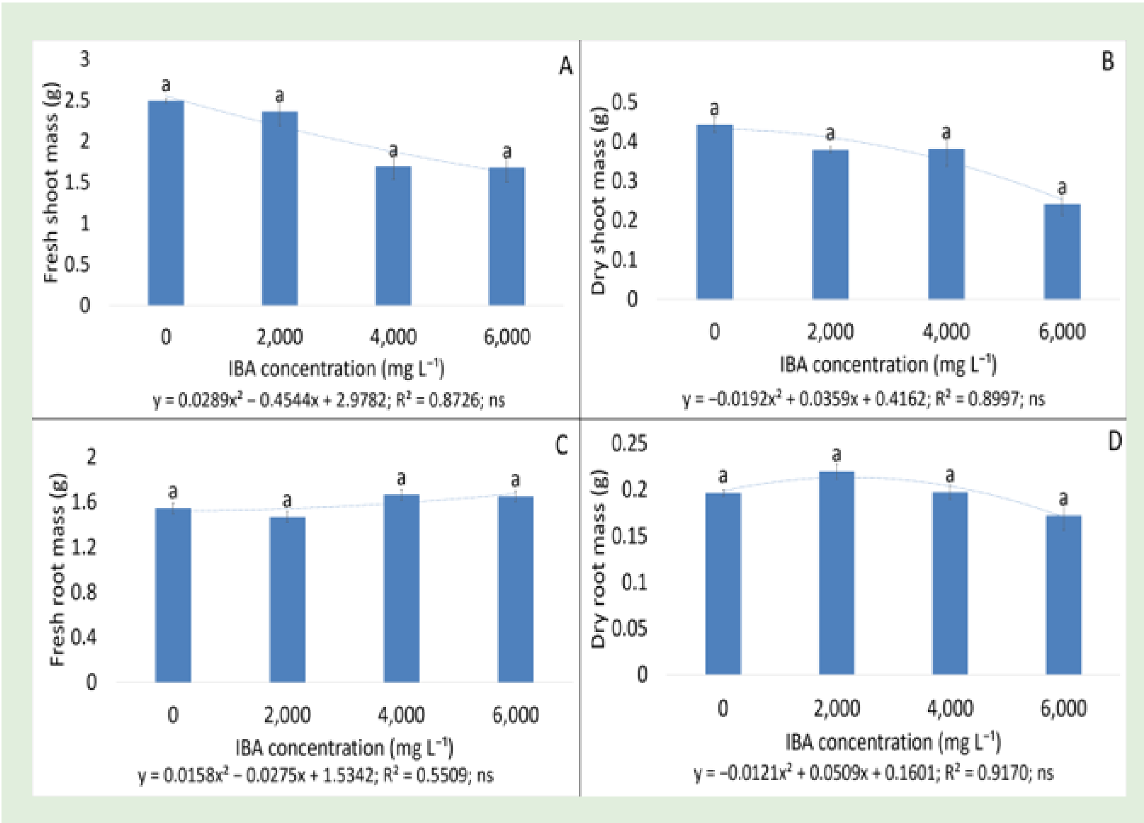

Figure 5. Effects of different IBA concentrations on biomass accumulation in mini-cuttings of *Piptadenia stipulacea*. The figure shows fresh shoot mass (A), dry shoot mass (B), fresh root mass (C), and dry root mass (D). Bars represent mean values ± standard error. Dashed lines indicate second-order polynomial regressions. Coefficients of determination (R^2) and statistical significance are shown in each panel, ns = not significant. Source: Authors

stimulate adventitious rooting in woody species, although its effect varies according to species, propagule type, physiological age, and propagation environment (Díaz-Sala, 2021; Kumar et al., 2022). In this study, indole-3-butyric acid does not improve rooting, survival, growth, or biomass accumulation, indicating that its application is unnecessary for the juvenile material evaluated.

The absence of statistical differences among indole-3-butyric acid concentrations does not eliminate the practical relevance of the observed numerical pattern. Rooting and survival are higher in the control treatment and decrease numerically at the highest concentration. In addition, the visual evaluation shows a more elongated and better-distributed root system in the control treatment, whereas the highest concentration produces a more compact root system, with roots concentrated near the base of the mini-cutting. These responses suggest that increasing auxin concentration does not improve propagation performance and may reduce root system quality under the tested conditions.

Similar responses have been reported for other native woody species, in which rooting occurs efficiently without growth regulators or shows limited response to exogenous auxin. In juvenile propagules, high rooting capacity may be associated with greater tissue responsiveness and fewer maturation-related barriers to adventitious root formation (Stuepp et al., 2018; Deloso et al., 2020; Souza et al., 2022; Souza et al., 2023; Souza et al., 2024; Souza et al., 2026; Silva et al., 2022; Araújo et al., 2025; Freire et al., 2025). Therefore, the use of juvenile shoots from a seminal mini-garden may contribute to the high rooting percentages observed in *P. stipulacea*.

From an operational perspective, the results support mini-cutting as a low-input strategy for propagating *P. stipulacea*. Eliminating indole-3-butyric acid from the protocol reduces costs, simplifies nursery routines, and decreases dependence on synthetic growth regulators. This is especially relevant for restoration programs in semi-arid regions, where the demand for native seedlings is high and propagation protocols need to be simple, reproducible, and economically viable.

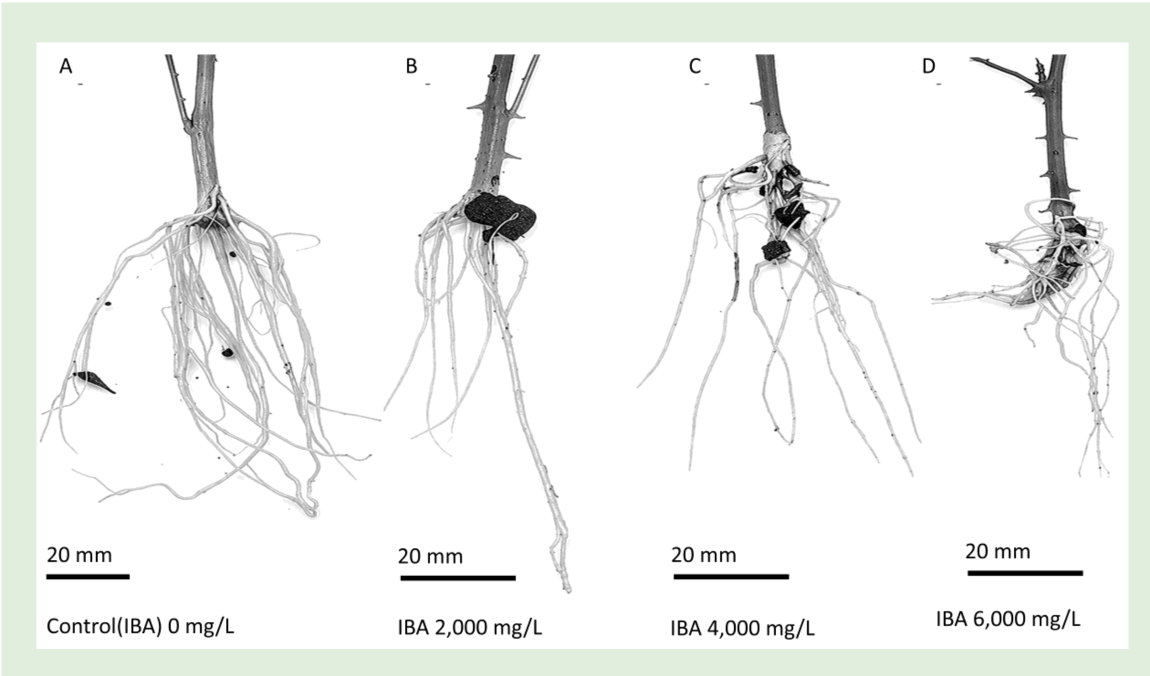

Figure 6. Visual aspects of the root system of *Piptadenia stipulacea* mini-cuttings subjected to different IBA concentrations after the experimental period. Root systems of mini-cuttings treated with 0 mg L^{-1} (A), 2,000 mg L^{-1} (B), 4,000 mg L^{-1} (C), and 6,000 mg L^{-1} (D). Source: Authors.

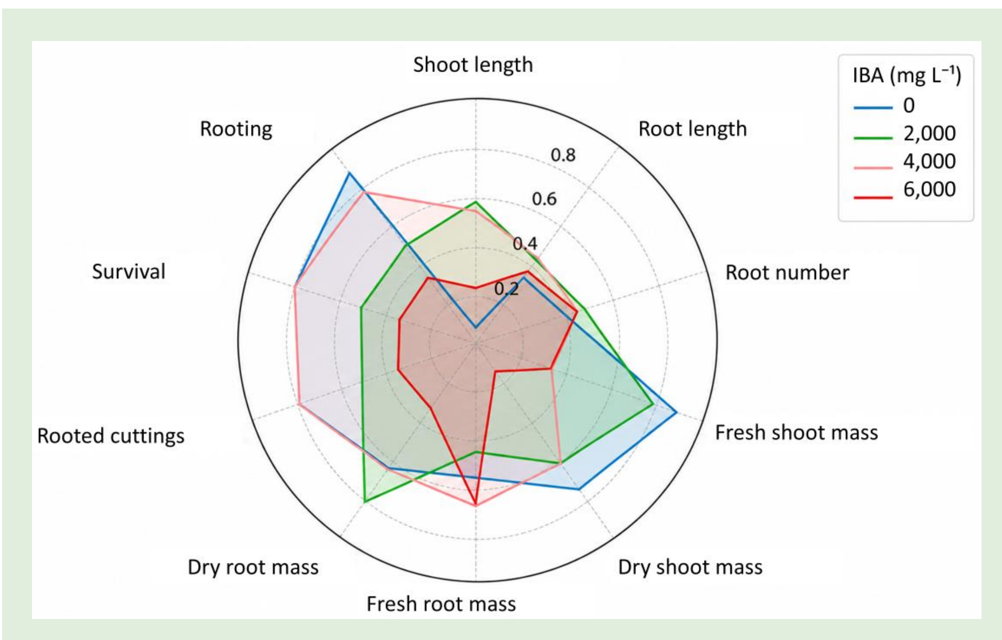

Figure 7. Radar chart representing the relative performance of morphological and physiological variables in the vegetative propagation of *Piptadenia stipulacea* under four IBA concentrations (0, 2,000, 4,000, and 6,000 mg L^{-1}). The evaluated variables include shoot length, root length, number of roots, fresh shoot mass, dry shoot mass, fresh root mass, dry root mass, rooted cuttings, and survival. Values were standardized on a 0 –1 scale to allow simultaneous comparison among variables and treatments. Source: Authors.

This study focuses on early propagation performance under nursery conditions using juvenile material from a seminal mini-garden. Therefore, field establishment, long-term seedling performance, seasonal variation in shoot production, and the response of adult selected genotypes still require further evaluation. Even with these limitations, the high rooting and survival rates observed without indole-3-butyric acid indicate that *P. stipulacea* has strong potential for low-input clonal propagation under semi-arid conditions.

Conclusion

Piptadenia stipulacea shows suitable performance for management in seminal mini-garden systems, as ministumps maintain shoot production after successive pruning. The increase in shoot production at the end of the evaluation period indicates that the mini-garden requires an initial adjustment phase before reaching higher sprouting performance.

Mini-cuttings root efficiently without indole-3-butyric acid under the tested conditions. The application of indole-3-butyric acid does not improve rooting, survival, growth, or biomass accumulation, which supports the use of an auxin-free protocol for this species.

These results indicate that mini-cutting represents a low-input strategy for the clonal propagation of *P. stipulacea* and can support seedling production for restoration programs in semi-arid environments. Future studies should evaluate seasonal variation in shoot production, field establishment, long-term seedling performance, and the response of selected adult genotypes to mini-cutting.

Author contributions

Cleyton dos Santos Souza and Poliana Coqueiro Dias Araujo designed the study and experimental approach. Gleydson Vinicius dos Santos Silveira and Maria Janaina Nascimento Silva conducted the experimental work and collected the data. Cleyton dos Santos Souza analyzed the data and prepared the first version of the manuscript. Evandro Luiz Mendonça Machado critically revised the manuscript and contributed to the interpretation and discussion of the results. All authors reviewed and approved the final version of the manuscript.

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AI use declaration

The authors used ChatGPT (OpenAI, GPT-4.5) to translate the manuscript from Portuguese into English and to adapt the language to the academic and editorial standards required by the journal. The entire translated manuscript was subsequently reviewed, verified, and edited by one of the authors, Poliana Coqueiro Dias Araujo. All scientific content, data, analyses, interpretations, and conclusions were produced and verified by the authors, who take full responsibility for the final version of the manuscript.

References

Alvares, C. A., Stape, J. L., Sentelhas, P. C., de Moraes Gonçalves, J. L., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, *22*(6), 711–728. https://doi.org/10.1127/0941-2948/2013/0507

Aradóttir, Á., & Halldórsson, G. (2018). Colonization of woodland species during restoration: Seed or safe site limitation? *Restoration Ecology*, *26*(6), 1040–1048. https://doi.org/10.1111/rec.12645

Araújo, J. K. P., Santos, D. F., Araújo, J. S. O., Silva, F. E., Freire, Á. C., Nicolau, J. P. B., Pacheco, M. V., & Araújo, P. C. D. (2025). Propagule age and adventitious rooting in cuttings of *Cordia oncocalyx*. *Revista Árvore*, *49*(1), e49263888. https://doi.org/10.53661/1806-9088202549263888

Benedito, C. P., Ribeiro, M. C., Paiva, E., & Medeiros, H. L. S. (2019). Dormancy overcoming and germination test in *Piptadenia stipulacea* (Benth.) Ducke seeds. *Revista Ciência Agronômica*, *50*(3), 333–340. https://doi.org/10.5935/1806-6690.20190040

Bond, W. J., & Midgley, J. J. (2001). Ecology of sprouting in woody plants: The persistence niche. *Trends in Ecology & Evolution*, *16*(1), 45–51. https://doi.org/10.1016/S0169-5347(00)02033-4

Clarke, P. J., Lawes, M. J., Murphy, B. P., Russell-Smith, J., Nano, C. E. M., Bradstock, R., Enright, N. J., Fontaine, J. B., Gosper, C. R., Radford, I., Midgley, J. J., & Gunton, R. M. (2013). Resprouting as a key functional trait: How buds, protection and resources drive persistence after fire. *New Phytologist*, *197*(1), 19–35. https://doi.org/10.1111/nph.12001

Deloso, B. E., Lindström, A. J., Camacho, F. A., & Marler, T. E. (2020). Adventitious root formation of *Zamia*. *HortScience*, *55*(9), 1463–1467. https://doi.org/10.21273/HORTSCI15212-20

Dias, P. C., Xavier, A., Oliveira, L. S., Paiva, H. N., & Correia, A. C. G. (2012). Vegetative propagation of *Anadenanthera macrocarpa*. *Revista Árvore*, *36*(3), 389–399. https://doi.org/10.1590/S0100-67622012000300001

Díaz-Sala, C. (2021). Adventitious root formation in tree species. *Plants*, *10*(3), 486. https://doi.org/10.3390/plants10030486

DRYFLOR. (2016). Plant diversity patterns in neotropical dry forests and their conservation implications. *Science, 353*(6306), 1383–1387. https://doi.org/10.1126/science.aaf5080

Farias, R. M., Freitas, R. M. O., Nogueira, N. W., & Dombroski, J. L. D. (2013). Overcoming seed dormancy in jurema-branca (*Piptadenia stipulacea*) seeds. *Revista de Ciências Agrárias*, *56*(2), 160–165. https://doi.org/10.4322/rca.2013.024

Freire, Á. C., Maciel, E. R. F., Silva, F. S., Araújo, J. K. P., Cavalcante, B. P., & Araújo, P. C. D. (2025). Clonal propagation of *Mimosa caesalpiniifolia*: Effects of phenotype, IBA, and leaf area reduction on rooting and plant propagation. *Rhizosphere*, *36*, 101232. https://doi.org/10.1016/j.rhisph.2025.101232

Hartmann, H. T., Kester, D. E., Davies, F. T., & Geneve, R. L. (2018). *Plant propagation: Principles and practices* (8th ed.). Prentice Hall.

Kildisheva, O. A., Erickson, T. E., Madsen, M. D., Dixon, K. W., & Merritt, D. J. (2018). Seed germination and dormancy traits of forbs and shrubs important for restoration of North American dryland ecosystems. *Plant Biology*, *21*(3), 458–469. https://doi.org/10.1111/plb.12892

Kumar, P., Chaturvedi, A., & Vaishnav, V. (2022). Relationship between endogenous auxin (indole-3-acetic acid) and adventitious rooting in *Dalbergia* species of different rooting ability. *Journal of Tropical Forest Science*, *34*(2), 149–159. https://doi.org/10.26525/jtfs2022.34.2.149

Leal, I. R., Tabarelli, M., & Silva, J. M. C. (Eds.). (2003). *Ecology and conservation of the Caatinga*. Editora Universitária UFPE.

Miles, L., Newton, A. C., DeFries, R. S., Ravilious, C., May, I., Blyth, S., Kapos, V., & Gordon, J. E. (2006). A global overview of the conservation status of tropical dry forests. *Journal of Biogeography*, *33*(3), 491–505. https://doi.org/10.1111/j.1365-2699.2005.01424.x

Murphy, P. G., & Lugo, A. E. (1986). Ecology of tropical dry forest. *Annual Review of Ecology and Systematics*, *17*, 67–88. https://doi.org/10.1146/annurev.es.17.110186.000435

Pausas, J. G., & Keeley, J. E. (2014). Evolutionary ecology of resprouting and seeding in fire-prone ecosystems. *New Phytologist*, *204*(1), 55–65. https://doi.org/10.1111/nph.12921

Ratanapongsai, Y. (2020). Seedling recruitment of native tree species in active restoration forest. *Forest and Society*, *4*(1), 243–255. https://doi.org/10.24259/fs.v4i1.9421

Sampaio, E. V. S. B. (1995). Overview of the Brazilian Caatinga. In S. H. Bullock, H. A. Mooney, & E. Medina (Eds.), *Seasonally dry tropical forests* (pp. 35–63). Cambridge University Press.

Sena, C. M. de, & Gariglio, M. A. (2008). *Sementes florestais: Colheita, beneficiamento e armazenamento* (Guias Técnicos, Vol. 2). Ministério do Meio Ambiente.

Siegmund, G.-F., Schlaepfer, D. R., Andrews, C. M., Bennion, L. D., Ferguson, J., Jeffries, M. I., Olwell, P., Pilliod, D. S., Simler-Williamson, A. B., Stears, A. E., Zweng, R., & Bradford, J. B. (2025). Supporting dryland restoration success with applied ecological forecasting of seeding outcomes. *Restoration Ecology*, *34*(2), e70179. https://doi.org/10.1111/rec.70179

Silva, A. K. V. da, Aguiar, T. S., Santos, M. E. C. dos, Araújo, J. K. P. de, Freire, Á. C., Salami, G., & Araujo, P. C. D. (2022). Vegetative propagation of *Mimosa caesalpiniifolia* by mini-cuttings technique. *Revista Árvore*, *46*, e4631. https://doi.org/10.1590/1806-908820220000031

Soto, M. A. S., Ávalos, J. G., Lazcano, A. H., Ávalos, R. G., León, S. H., & López, N. A. F. (2025). Growth in nursery and plant quality of selected trees of *Pinus cembroides* Zucc. *Revista de Gestão Social e Ambiental - RGSA*, *19*(3), e011741. https://doi.org/10.24857/rgsa.v19n3-126

Souza, C. S., Araújo, P. C. D., Silva, D. Y. B. O., Nogueira, G. A., & Silva, M. J. N. (2022). Vegetative rescue of *Azadirachta indica* by cuttings. *Revista Árvore*, *46*, e4632. https://doi.org/10.1590/1806-908820220000032

Souza, C. dos S., Machado, E. L. M., Titon, M., Silveira, G. V. dos S., Botrel, R. T., Paiva Neto, E. E. de, Gonzales, D. E., Silva, M. J. N., & Araújo, P. C. D. (2024). Propagação vegetativa por miniestaquia de *Mimosa tenuiflora* (Mart.) Benth. *Observatório de la Economía Latinoamericana*, *22*, e4758. https://doi.org/10.55905/oelv22n5-131

Souza, L. S., Diógenes, F. E. G., dos Santos Silveira, G. V., da Silva, C. J., & Araujo, P. C. D. (2023). Mini-cutting as a technique to propagate *Tabebuia aurea*, an important tree found in tropical dry forests. *Australian Journal of Crop Science*, *17*. https://doi.org/10.21475/ajcs.23.17.08.p3892

Souza, C. dos S., Silveira, G. V. dos S., Holanda, A. C. de, Braz, R. L., Freitas, E. C. S. de, Araujo, P. C. D., & Silva, M. J. N. (2026). Morphoanatomical aspects of adventitious rooting and the establishment of an efficient vegetative propagation protocol for *Mimosa ophthalmocentra*. *New Forests, 57*, 29. https://doi.org/10.1007/s11056-026-10174-5

Stuepp, C. A., Wendling, I., Xavier, A., & Zuffellato-Ribas, K. C. (2018). Vegetative propagation and application of clonal forestry in Brazilian native tree species. *Pesquisa Agropecuária Brasileira*, *53*, 985–1002. https://doi.org/10.1590/S0100-204X2018000900002

Wendling, I., Trueman, S. J., & Xavier, A. (2014a). Maturation and related aspects in clonal forestry—Part I: Concepts, regulation and consequences of phase change. *New Forests*, *45*, 449–471. https://doi.org/10.1007/s11056-014-9421-0

Wendling, I., Trueman, S. J., & Xavier, A. (2014b). Maturation and related aspects in clonal forestry—Part II: Reinvigoration, rejuvenation and juvenility maintenance. *New Forests*, *45*, 473–486. https://doi.org/10.1007/s11056-014-9415-y

Xavier, A., Wendling, I., & Silva, R. L. (2013). *Clonal silviculture: Principles and techniques*. Editora UFV.

Yirdaw, E., Tigabu, M., & Monge, A. (2017). Rehabilitation of degraded dryland ecosystems – review. *Silva Fennica*, *51*(1B), Article 1673. https://doi.org/10.14214/sf.1673

DOI: 10.4206/bosque.e4714

Supporting information

Table S1. Chemical characterization of the soil used for seedling production and establishment of the seminal mini-garden of *Piptadenia stipulacea*. Samples were collected at two depths (0 – 20 and 20 – 40 cm). Values are expressed in cmolc dm^{-3} for exchangeable bases and acidity parameters, except for phosphorus (P), expressed in mg dm^{-3}, and pH measured in water.

Sample	Depth (cm)	P (mg dm^{-3})	pH (H_2O)	Ca	Mg	Na	K	Al	H	SB	CEC	V (%)	M (%)
AM.1	0–20	1	7.5	8.4	1.5	0.03	0.34	0	1.48	10.3	11.8	87	0
AM.2	20–40	1	8.1	8.2	1.6	0.03	0.24	0	1.32	10.1	11.4	88	0
AM.3	0–20	2	8.2	12.3	1.2	0.05	0.73	0	–	–	–	–	–
AM.4	20–40	1	8.0	14.7	1.05	0.09	0.28	0	–	–	–	–	–

Note: SB = sum of bases; CEC = cation exchange capacity; V = base saturation; m = aluminum saturation; (–) = not determined. Source: Authors' data.

Table S2. Statistical grouping of sprouting and sprout length in the seminal mini-garden of *Piptadenia stipulacea* as a function of collection time. Sprouting data were analyzed using the Friedman test, and sprout length data were analyzed using repeated measures ANOVA. Different letters indicate significant differences among collection times according to *post hoc* tests at the 5% significance level.

Variable	15 days	30 days	45 days	60 days	75 days	90 days
Sprouting (Friedman)	a	a	a	a	a	b
Sprout length (Repeated measures ANOVA)	a	b	c	d	e	a

Source: Authors' data.

Table S3. Sprouting dynamics in the seminal mini-garden of *Piptadenia stipulacea* as a function of collection time (15, 30, 45, 60, 75, and 90 days). Values represent mean ± standard error (SE) for the number of sprouts per mini-cutting and sprout length. Different letters within each row indicate significant differences among collection times according to *post hoc* tests at the 5% significance level.

	Collection days					
Character	15	30	45	60	75	90
Sprouting (number of shoots per mini-cutting^{-1})	1.54 ± 0.14 a	1.35 ± 0.15 a	1.51 ± 0.16 a	1.34 ± 0.15 a	1.19 ± 0.14 a	2.79 ± 0.17 b
Sprout length (cm)	55.28 ± 0.33 a	48.37 ± 0.35 b	38.87 ± 0.27 c	46.11 ± 0.32 d	22.98 ± 0.27 e	55.56 ± 0.27 a

Source: Authors' data.

Table S4. Effects of different indole-3-butyric acid (IBA) concentrations on rooting, survival, number of roots, root length, and sprout length of *Piptadenia stipulacea* mini-cuttings. Values for number of roots, root length, and sprout length are expressed as mean ± standard error (SE). Values for rooting and survival are presented as the ratio between responsive mini-cuttings and the total number of evaluated mini-cuttings, followed by the corresponding percentage in parentheses. Different letters within each row indicate no significant differences among IBA concentrations according to mean comparison tests at the 5% significance level

Variable	0 mg L^{-1}	2,000 mg L^{-1}	4,000 mg L^{-1}	6,000 mg L^{-1}
Rooting (%)	94.64 a	81.48 a	80.36 a	71.43 a
Survival (%)	94.64 a	81.48 a	80.36 a	71.43 a
Number of roots	7.79 ± 0.47 a	8.45 ± 0.70 a	8.22 ± 0.56 a	7.77 ± 0.54 a
Root length (cm)	6.39 ± 0.45 a	6.77 ± 0.56 a	7.22 ± 0.61 a	5.90 ± 0.50 a
Sprout length (cm)	13.32 ± 0.10 a	14.52 ± 0.38 a	14.36 ± 0.34 a	13.74 ± 0.26 a

Source: Authors' data.

Table S5. Effects of different indole-3-butyric acid (IBA) concentrations on morphological and physiological characteristics of *Piptadenia stipulacea* mini-cuttings. Values are expressed as mean ± standard error (SE). Different letters within each row indicate no significant differences among IBA concentrations according to mean comparison tests at the 5% significance level.

Variable	0 mg L^{-1}	2,000 mg L^{-1}	4,000 mg L^{-1}	6,000 mg L^{-1}
Fresh shoot mass (g)	2.49 ± 0.03 a	2.36 ± 0.17 a	1.70 ± 0.16 a	1.68 ± 0.18 a
Dry shoot mass (g)	0.44 ± 0.02 a	0.38 ± 0.01 a	0.38 ± 0.04 a	0.24 ± 0.03 a
Fresh root mass (g)	1.55 ± 0.13 a	1.47 ± 0.16 a	1.67 ± 0.10 a	1.65 ± 0.17 a
Dry root mass (g)	0.20 ± 0.00 a	0.22 ± 0.01 a	0.20 ± 0.01 a	0.17 ± 0.02 a

Source: Authors' data.