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TECHNICAL ARTICLE

Seed characterization of *Allamanda puberula* A. DC. and seedling production

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Abstract

Allamanda puberula is a native species of the Caatinga biome with ornamental and landscaping potential. However, its potential is little explored due to the lack of information about the biology of its seeds and propagation. In this context, a study was carried out in order to characterize the seeds and their potential to produce seedlings in different containers. The experiments were divided into two phases. The first consisted in the characterization of fruits and seeds by evaluating the number of seeds per fruit, their dimensions (length and width), the weight of a thousand seeds, the number of seeds kg^{-1}, the degree of moisture, germination and emergence. The second phase consisted in the production of seedlings in a nursery, evaluating the growth over the days after sowing (DAS) (15, 30, 45 and 60 DAS) and the effect of the type of container (trays and tubes) for the formation of the seedlings. The species *A. puberula* has small seeds and a significant number of seeds per fruit. Apparently, there is no physical impediment or type of dormancy that impairs the germination process of the seeds. Seedlings grown in tubes were better in terms of growth and allocation of biomass. However, the indication of the best cultivation container for *A. puberula* propagated via seeds will depend on the implantation project and the specific characteristics of the field. The characterization of *A. puberula* seeds showed satisfactory physiological potential for germination and complete seedling formation in the nursery, enabling success in obtaining seedlings through seminiferous propagation.

Keywords: native plants; semiarid; seminiferous propagation; containers.

Resumo

Caracterização de sementes de *Allamanda puberula* A. DC. e produção de mudas

Allamanda puberula é uma espécie nativa do bioma Caatinga com potencial ornamental e paisagístico. No entanto, seu potencial é pouco explorado devido à falta de informações sobre a biologia de suas sementes e propagação. Neste contexto, foi realizado um estudo de caracterização das sementes e seu potencial para produção de mudas em diferentes recipientes. Os experimentos foram divididos em duas fases. A primeira consistiu na caracterização dos frutos e sementes, por meio da avaliação do número de sementes por frutos, suas dimensões (comprimento e largura), peso de mil sementes, número de sementes kg^{-1}, grau de umidade, germinação e emergência. A segunda fase consistiu da produção das mudas em viveiro avaliando o crescimento ao longo dos dias após a semeadura (DAS) (15, 30, 45 e 60 DAS) e o efeito do tipo de recipiente (bandejas e tubetes) para a formação das mudas. A espécie *A. puberula* possui sementes pequenas e um significativo número de sementes por fruto. Aparentemente não há nenhum impedimento físico ou tipo de dormência que prejudique o processo germinativo das sementes. As mudas cultivadas em tubetes foram melhores em termos de crescimento e alocação de biomassa. Porém, a indicação do melhor recipiente de cultivo de *A. puberula* propagadas via sementes dependerá do projeto de implantação e das caracterísitcas específicas do campo. A caracterização de sementes de *A. puberula* demostrou potencial fisiológico satisfatório para à germinação e formação completa de plântulas em viveiro, possibilitando o sucesso na obtenção de mudas por meio da propagação seminífera.

Palavras-chave: plantas nativas; semiárido; propagação seminífera; recipientes.

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Introduction

Native plants that constitute the diversity of the Brazilian flora have gained ground in the landscaping industry, becoming a contemporary trend. Thus, the insertion of native species with ornamental potential in the production chain of ornamental flowers and plants is of extreme importance, representing a significant asset in an already competitive market that is aware of sustainable ecological trends. Furthermore, it provides a socio-environmental role that values the native flora and conserves biodiversity, as most of these species are endangered due to the constant replacement for exotic species. However, the incorporation of these plants in landscaping projects and the widening of their commercial production is still a limiting factor due to the lack of information related to the biological aspects of their seeds, management, and propagation (Stumpf et al., 2009; Beckmann-Cavalcante et al., 2017; Bastos et al., 2020).

Allamanda puberula, commonly known in Brazil as *quatro-patacas*, is a plant species of the Caatinga biome highlighted for its ornamental potential, presenting aesthetical elements that potentialize its use in landscaping. The versatility of uses of this species allows it to be employed in the composition of gardens, either isolated or in the formation of hedges (Beckmann-Cavalcante et al., 2017). This species is typical of dry climates and its distribution is restricted to certain geographic regions, with occurrence records in the Caatinga regions of the states of Piauí, Pernambuco, Ceará, Bahia, Minas Gerais, and Tocantins. Furthermore, it belongs to the genus *Allamanda* L. and the family Apocynaceae. The genus *Allamanda* L. currently comprises 15 species, of which 13 occur in Brazil, and most are endemic to the territory (Sakane and Shepherd, 1986).

Although the genus *Allamanda* L. is well represented in the Brazilian flora and some of its species are cultivated as ornamental plants, the use of *A. puberula* in scientific studies and in the floristic composition of environments is still limited, and its potential is still little valued (Beckmann-Cavalcante et al., 2017). Conventionally, the propagation of *A. puberula* and the other several *Allamanda* species is performed by stem cuttings, ensuring that the propagated plants are clones of the parent plant (Loss et al., 2008). However, this method presents some disadvantages, due to the limited number of seedlings produced and the low genetic variability, which consequently complicates the improvement of the species and increases the risks of genetic erosion due to the low flexibility and adaptation to adverse conditions (Brown, 2017).

Another alternative for the multiplication of *A. puberula* that results in a higher number of seedlings and gains in genetic variability is seed propagation. However, the success of this method depends on the morphophysiological characteristics of the seeds, which will determine the germination potential and ensure seedling emergence and establishment (Souza et al., 2016). Thus, the morphological characterization of fruits and seeds is an important tool to understand the species, given that it allows the gathering of information in order to subsidize studies on seed germination, besides contributing to improve the reproductive process of plant species, allowing the implementation of alternative techniques to improve seedling production and species conservation (Duarte et al., 2015; Souza et al., 2018).

However, information regarding the aspects related to seed morphology and germination in *A. puberula* is still scarce. Seed characterization studies for this species are essential to make the processes of multiplication and cultivation feasible, generating new perspectives and widening the commercial production and conservation of this species. In this context, this study aimed to characterize the seeds of *A. puberula* and their potential for seedling production.

Material and Methods

Plant material

Ripe fruits of six plants of *Allamanda puberula* A. DC. were collected at the Reference Center for the Recovery of Degraded Areas (CRAD), located at the geographic coordinates 09°21’ south latitude and 40°34’ west longitude. The experiments were conducted in two phases: the first consisted of fruit and seed characterization, while the second consisted of seedling production in the plant nursery. This species is included in the project registered under the SisGen number ADAF5A1.

Fruit and seed characterization

The morphological characterization of fruits was initially performed by classifying them regarding type, shape, color and texture after fruit collection. For the biometric description, three replications of 10 fruits were randomly selected before their dehiscence. Subsequently, fruit length and width were measured with a digital caliper (precision of ±0.02 mm), and the number of intact seeds per fruit was counted. For the seeds, the morphometrical characteristics evaluated were: dimension (length and width), shape and moisture. Furthermore, following the guidelines established by the Rules for Seed Analysis, the seed water content was determined by the forced-air oven method at 105±3ºC for 24 h; the 1,000-seed weight and the number of seeds per kilogram were determined using eight replications of 100 seeds (Brasil, 2009). Based on this, the number of seeds per kilogram and the 1,000-seed dry biomass were also determined.

For the germination and emergence tests, four replications of 25 seeds were used. Prior to sowing, all seeds were disinfected with a solution containing 0.5% sodium hypochlorite for 5 minutes. The germination test was performed by sowing the seeds on “germitest” paper sheets, moistened with an amount of distilled water equivalent to 3.0 times the weight of the dry paper, which were then placed in Gerbox germination boxes (Brasil, 2009). The germination boxes were kept in a B.O.D. germination chamber, under a 12-hour photoperiod at 25ºC. For the emergence test, the seeds were sown in Gerbox boxes filled with the commercial plant substrate Golden Mix®, type 11 (composed of coconut mesocarp fiber added with fertilizers with 1.1 mS cm^{-1} conductivity).

The germinated seeds were counted daily in the germination test, and radicle protrusion (≥2 mm) was used as a germination criterion, while, in the emergence test, the seeds were considered as emerged when the hypocotyl appeared on the substrate surface (Brasil, 2009). The evaluations ended after 15 days, and the final germination percentage, the germination speed index (GSI), and the emergence speed index were obtained according to Maguire (1962). The data was subjected to descriptive analysis by calculating the mean, the maximum and the minimum values, the coefficient of variation, and the standard deviation.

Seedling production

Sowing was performed using two types of containers: 128-cell polyethylene trays (23.60 cm^3) and 280 cm^3 plastic tubes, placing only one seed per cell. Each container was filled with the commercial substrate Golden Mix® (the same as in the laboratory trial). During the entire experimental period, the seedlings were kept on workbenches installed in a plant nursery, provided with 50% shading and a micro-sprinkler irrigation system activated intermittently twice a day. The meteorological data throughout cultivation, corresponding to air temperature (minimum and maximum), air moisture (minimum and maximum), global solar radiation and rainfall were recorded by a weather station located near the experimental area (Table 1).

At 15, 30, 45, and 60 days after sowing (DAS), the shoot height (SH) and stem diameter (SD) of the emerged seedlings were evaluated in randomly selected plants. The SH, expressed in cm, was measured with a millimeter ruler, from the growing media surface to the apical bud; and the SD, expressed in mm, was measured in contact with the growing media surface, using a digital caliper (Digimess®) with accuracy of 0.01 mm. Given the number of emerged seedlings at 15 DAS, it was possible to select three seedlings per plot for destructive evaluations, such as root volume (RV), shoot dry matter (SDM), and root dry matter (RDM). The seedlings were removed from the containers, washed, and cut, separating the shoot from the root system. In the laboratory, the RV, expressed in cm^3, was performed by measuring the displacement of the column of water in a graduated cylinder, that is, placing the roots, after washing, in a beaker containing a known volume of water (100 mL), according to the methodology described by Rossiello et al. (1995). By the difference, the direct response of the root volume was obtained by the equivalence of units (1 mL = 1 cm^3). Shoot and root dry matter were determined by drying the plant material in a forced-air oven at 65±5ºC for 48 hours, followed by weighing in an analytical balance with a precision of 0.0001 g. Finally, the SDM/RDM ratio and the robustness index were determined, the latter given by the relationship between shoot height and diameter (SH/SD).

The experiment was designed in randomized blocks in a split-plot arrangement, in which the main plots

Table 1. Climatic characterization with biweekly data media of air temperature, air moisture, global solar radiation and rainfall during the seedling production phase.

DAS	Air temperature (ºC)		Air moisture	Global Solar Radiation	Rainfall
	Maximum	Minimum	(%)	(MJ m^2 day^{-1})	(mm)
15*	36.51	24.14	10.28	46.50	0.00
30	36.80	24.86	9.30	49.68	0.05
45	35.19	24.61	10.53	48.55	0.45
60	34.80	24.34	8.35	52.33	1.27

DAS: days after sowing. The first cycle of data corresponds to November 19, 2019.

corresponded to the two types of containers and the four subplots corresponded to the different evaluation times (15, 30, 45, and 60 DAS). Four replications were used, each composed of 18 seedlings. The data was subjected to the Shapiro-Wilk test to assess the normality of errors. Data correction was required for the RV, SH/SD, and SDM/RDM variables using the square root transformations ($\sqrt{(X+k)}$, in which k was equal to zero). All data was subjected to analysis of variance, and the means of the treatments belonging to the cultivation container factor were compared by Tukey's test (p>0.05), while the means referring to the evaluation times were subjected to regression analysis (p>0.05). All statistical analyses were performed using the software SISVAR.

Results

Fruit and seed characterization

The fruits of *A. puberula* develop from flowers with a syncarpous, bicarpellary, unilocular gynoecium, ovary superior, and parietal placentation (Figure 1). The capsules show a green coloration when young (Figure 2A), evolving into brown upon reaching maturity (Figure 2B). Besides, the fruits of *A. puberula* are dehiscent, dry, and light, with an elliptically compressed septicidal capsule shape (Figures 2A-2D; 2F), ornamented with spine-like structures (Figures 2A-2D). Furthermore, the fruits present dehiscence through two marginal longitudinal structures, which, upon rupturing, form two valves (Figures 2C and 2D), exposing several seeds. The seeds are winged and striated, showing shape variation that may vary from elliptical to orbicular, presenting a central seminiferous nucleus, in which it is possible to visualize the raphe in one of the faces (Figure 2E).

Regarding size, fruit length varied from 3.01–5.80 cm, while fruit width varied from 2.30–3.80, characterizing an elliptical fruit. Regarding the number of seeds per fruit, an expressive number of seeds was observed, varying from 13 to 36 (Table 2). Regarding the 1,000-seed weight, this

Figure 1. (A and B) General characteristics of *Allamanda puberula* flower, and (C) details of its internal morphology.

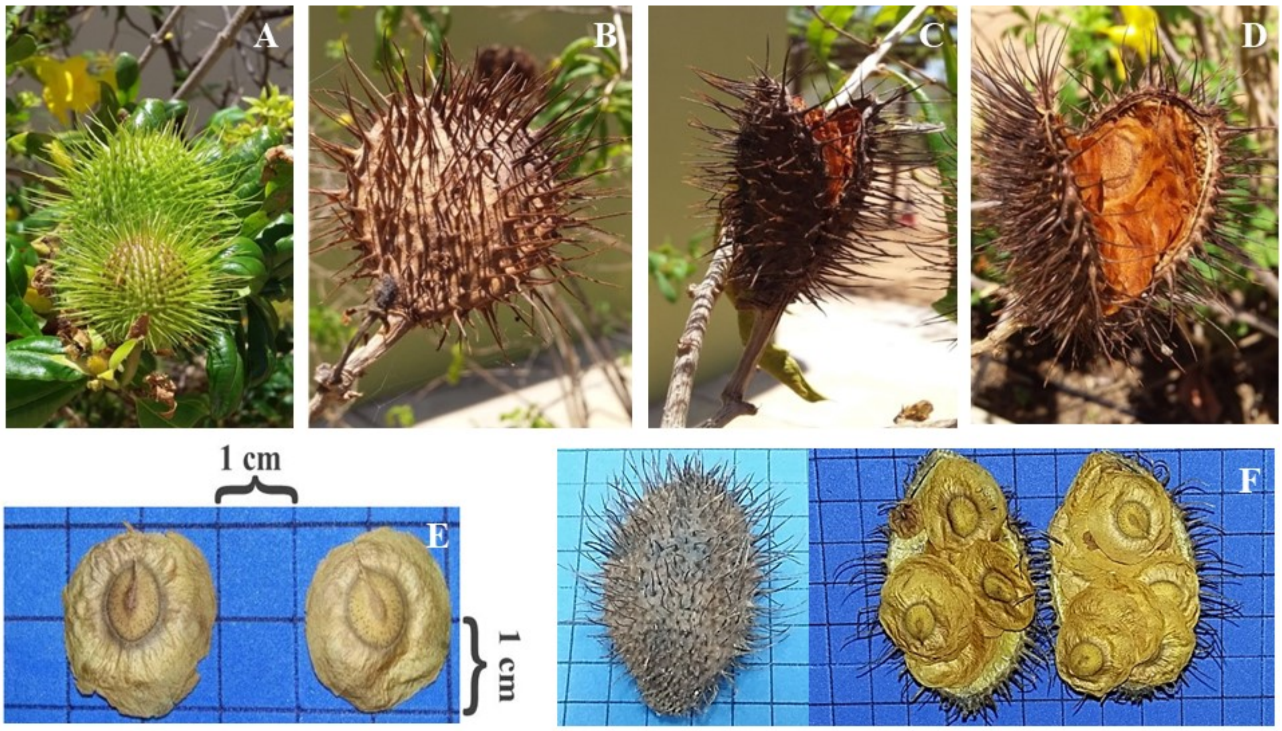


Figure 2. (A-D) Evolution of fruit ripening stages; (E) general aspects and dimensions of seeds and (F) details of the external and internal of the fruits of *Allamanda puberula*.

Table 2. Dimensions of fruit length and width; number of seeds per fruit; weight of a thousand seeds; number of seeds per kilogram; moisture content; germination percentage; germination speed index; emergence percentage and emergence speed index of *Allamanda puberula* seeds.

Evaluations	Maximum (cm)	Medium (cm)	Minimum (cm)	Standard deviation	C.V. (%) *
Fruit Lenght	5.80	4.38	3.01	0.69	15.67
Fruit Width	3.80	3.16	2.30	0.37	11.78
Number of seeds per fruit	36.00	27.20	13.00	6.41	23.56

Weight of a thousand seeds (g)	Number of seeds kg^{-1}	Moisture content (%)	Germination (%)	GSI (--)	Emergence (%)	ESI (--)
55.73	17,943.86	7.61	37%	1,05	31%	

*C.V. (%): coefficient of variation; GSI: germination speed index; ESI: emergence speed index.

variable showed a mean value of 55.73 g, corresponding to about 17,943.86 seeds kg^{-1}. The moisture content was around 7.61%. For the germination and emergence tests, the first signs of radicle protrusion were verified under laboratory conditions at 7 DAS. At the end of the germination test (15 days), a 37% germination rate was verified, with a germination speed index of 1.05. Seedling emergence was detected by the rupture of the substrate, which occurred eight days after sowing. A 31% emergence rate was verified at 15 DAS, with an emergence speed index of 0.68 (Table 2).

Seedling production

Regarding growth parameters, a significant effect of the interaction between factors was verified for the SD, RV, RDM, and SDM/RDM ratio variables (Figure 3). For the container factor, there was a significant difference only for the SH and SH/SD ratio variables (Table 3).

With respect to shoot height, a gradual increase was verified as a function of the evaluation times for the seedlings grown both in trays and in tubes, showing estimated maximum values, respectively, of 6.65 cm at 55 DAS and 8.19 cm at 47 DAS (Figure 3A). The same trend was observed for the robustness index (SH/SD) (Figure 3D).

For the stem diameter (SD) and root volume (RV) variables, an increasing linear behavior was observed as a function of the evaluation times both for the seedlings grown in trays and those grown in tubes (Figures 3B and 3C, respectively). However, the data showed a significant difference for these parameters regarding the cultivation container, demonstrating that the root volume was superior in the seedlings grown in tubes from 30 DAS. For stem diameter, it was verified that the seedlings grown in trays showed superior SD at 60 DAS.

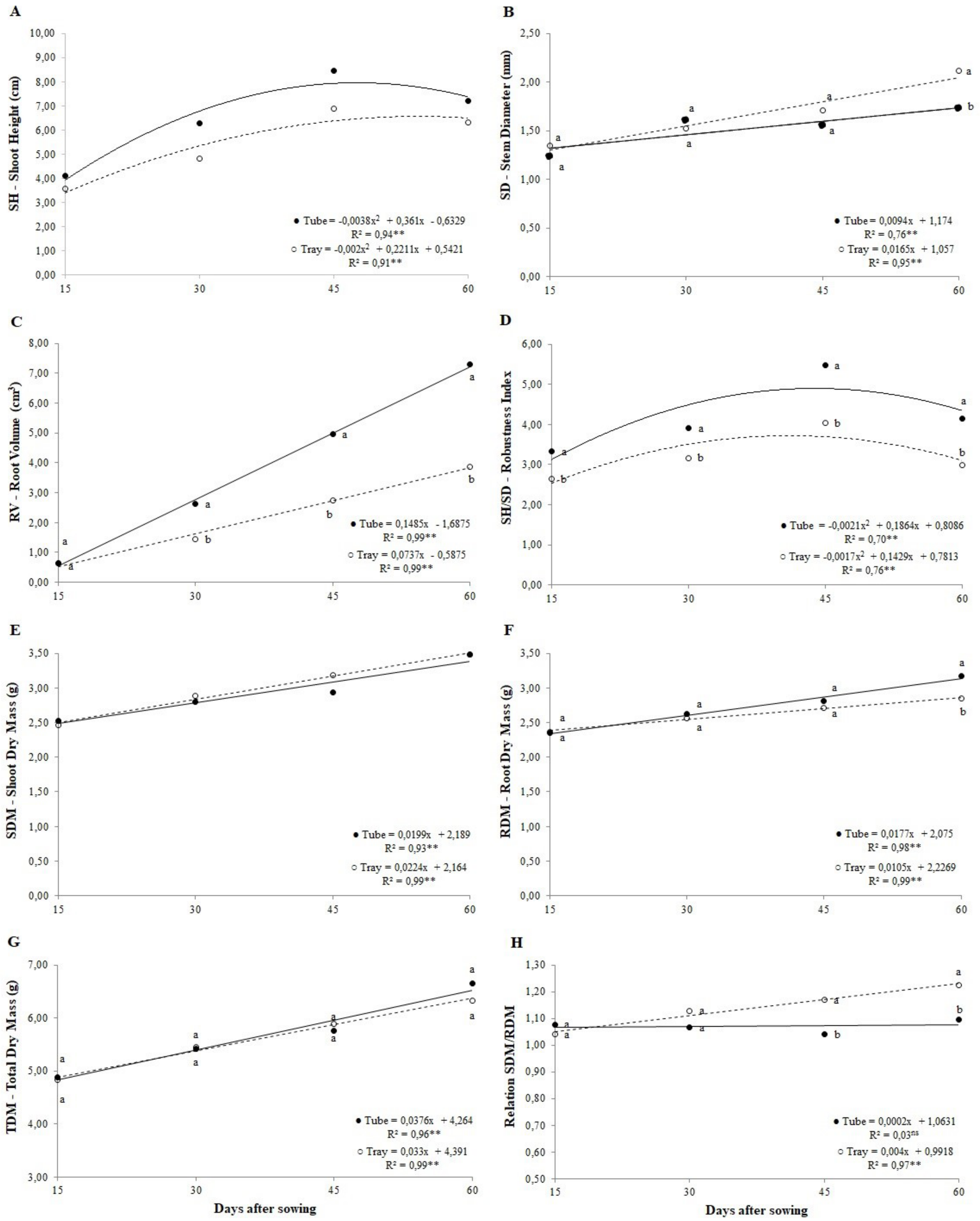
The data referring to biomass accumulation for the seedlings grown in both containers fit a linear regression model, showing a progressive increase throughout time (Figures 3E, 3F and 3G). Furthermore, the RDM and the SDM/RDM ratio were significantly affected by the type of container used (Figures 3D and 3H, respectively). Therefore, it was verified that the seedlings grown in tubes showed higher RDM values at 60 DAS when compared to the seedlings grown in trays, while the SDM/RDM ratio at 45 and 60 DAS was superior for the seedlings grown in trays.

Discussion

The results demonstrate that the species has a significant number of seeds per fruit (Table 2), highlighting its reproductive success potential due to the expressive seed production (Camacho-Velázquez et al., 2018). Furthermore, the biometric characterization of the seeds of this species (Table 2) allows describing them as small seeds based on the values found for the 1,000-seed weight and the number of seeds per kg^{-1} (Brasil, 2009). According to Radny et al. (2018), small seeds are an important success indicator in the establishment of native plants, demonstrating high competitivity in environments with high density and easy dispersal.

Another important characteristic verified in the seeds of *A. puberula* is the low moisture content (Table 2). This factor is essential for the maintenance of seed viability and vigor, as it can determine how long these seeds can be stored and conserved in germplasm banks. Seeds with low moisture contents typically present easier long-term storage, since they are less prone to physical and mechanical injuries and the deterioration caused by pathogen incidence. However, the moisture degree by itself cannot confirm whether the seed of a species can be stored without losing viability after a certain time, as this characteristic varies across species and depends on other factors, such as changes in seed maturity, chemical composition, and seed sensitivity to dehydration (Li et al., 2020). Therefore, further studies to assess the behavior of seeds of *A. puberula* under storage are required in order to confirm their long-term conservation potential.

An overall analysis of the seed's biometric and germination characteristics indicates that there is no apparent physical hindrance or any type of dormancy that compromises the germination process. This was concluded because, although the seeds used for the germination test underwent no dormancy breaking treatment or pre-treatment to improve the germination process, a 37% germination rate was obtained at 15 DAS under laboratory conditions (Table 2). Besides, under plant nursery conditions, a high mean emergence percentage of



**Significant difference between treatments (Tukey tests, p>0,01); ns: not significant.

Figure 3. (A) Shoot height; (B) stem diameter; (C) root volume; (D) robustness index; (E) shoot dry mass; (F) root dry mass; (G) total dry mass and relation SDM/RDH of *Allamanda puberula* seedlings in function of evaluation period (15, 30, 45 and 60 days after sowing) and type of container (Styrofoam trays and tubes).

78% was verified at 15 DAS (data not presented, only observed).

Germination is a critical process in the plant's life cycle that is highly regulated by genetic and environmental factors (López et al., 2019). Although it was not the source of comparisons, it was observed that the seeds of *A. puberula* showed high germination rates under plant nursery conditions when compared to laboratory conditions, which

Table 3. The effect of containers (tray and tube) used for seedling production of *Allamanda puberula*.

Variation Sources	SH*	SD	RV	SDM^{ns}	RDM^{ns}	TDM^{ns}	SDM/RDM^{ns}	SH/SD*
	(cm)	(mm)	(cm^3)	----------- (g) ------------			(---)	(---)
Tray	5.41 b	1.68	2.18	3.00	2.62	5.63	1.14	3.21 b
Tube	6.50 a	1.53	3.88	2.94	2.74	5.68	1.07	4.21 a

*The means per column with different letters are significant at Tukey tests (p>0,01); ns: not significant; SH: shoot height; SD: stem diameter; RV: root volume; SDM: shoot dry mass; RDM: root dry mass; TDM: total dry mass; SDM/RDM: relation shoot dry mass and root dry mass; SH/SD: robustness index.

reinforces the role of environmental conditions in the germination process of this species, especially temperature. Considering that, under plant nursery conditions, throughout the whole experimental period, temperatures from 24.14 to 36.51ºC were recorded in the first 15 days (Table 1), while under laboratory conditions the temperature used was 25ºC, it can be observed that temperature constitutes one of the environmental factors that affects the germination potential of nondormant seeds the most, playing an important role in the germination rate (Shi et al., 2019). The success of seed germination in *A. puberula* under plant nursery conditions indicates the existence of a local adaptation to the natural habitat of the species (López et al., 2019), considering that this species is adapted to regions with dry, semiarid climate, characterized by high temperatures (Sakane and Shepherd, 1986).

The cultivation of *A. puberula* from seeds was well-succeeded, with the different cultivation containers tested showing no apparent influence on germination and seedling emergence. However, seedling growth and quality were affected by the type of container used. In general, growth parameters are very relevant and constitute important indicators of plant vitality and quality. In addition to being an essential process in plant life, plant growth is characterized by a gradual increase that results from the division and the increase in cell volume until reaching maximum growth, which is highly regulated by environmental conditions (Mariotti et al., 2015; Liu et al., 2020). In this context, several studies have shown that the growth rate and seedling quality are highly sensitive to variations in the size, shape, and volume of cultivation containers (Chirino et al., 2008; Lima Filho et al., 2019).

Plant height, diameter, root length, and total dry biomass accumulation are used as seedling quality indicators, being interpreted jointly and depending on the purposes of the implantation project (Mariotti et al., 2015; Liu et al., 2020). Therefore, the robustness index is one of the indices used to assess seedling quality and the balance in growth in height of the aerial part and stem diameter, indicating when there is excessive growth in plant height, detrimentally to stem diameter. This index demonstrates that the lower this ratio, the lower the risk that the seedlings will be harmed after transplantation, as they will become more robust and able to survive (Chirino et al., 2008). The results obtained in the present study demonstrate that seedlings grown in tubes showed higher values for the robustness index, while those grown in trays showed lower indexes (Figure 3D). This indicates that seedlings grown in trays presented, in the evaluated time, high growth balance between height and diameter. However, this is a variable that should not be used as the only quality parameter, since it disregards other parts of the plants.

Another widely used parameter that indicates seedling vitality and quality is root growth, which is significantly affected by the cultivation container. This can be confirmed in our study, in which trays and tubes significantly influenced the root volume (Figure 3C) and root dry matter variables (Figure 3F). Therefore, it was verified that, until 15 DAS, the containers did not affect root volume; however, from 30 DAS on, the root volume of the plants grown in tubes was superior in all evaluated periods (Figure 3C), similarly to the RDM. This result makes it clear that deeper containers favor root growth, providing greater space for root development and increasing the water and nutrient uptake capacity, which is essential for the maintenance of seedling growth and vitality (Liu et al., 2020). Therefore, the lower volume provided by the trays probably restricted root growth and expansion from 30 DAS.

A study conducted by Poorter et al. (2012), aiming to perform a meta-analysis of 65 studies that assessed the effect of pot sizes on the growth rate, revealed that, at the beginning of the experiments, the seedlings grew well in the different containers; however, after 30 days of cultivation, differences began to appear in the growth rate of the plants cultivated in the different containers, resulting in growth reduction for the plants grown in smaller containers. According to Mariotti et al. (2015), depending on the container used for cultivation, plants tend to increase biomass accumulation, increasing the growth rate proportionally to the volume of the container, eventually reaching a moment in which no container is large enough to guarantee unrestricted growth.

Smaller containers are usually employed in order to provide substrate economy, in addition to quick seedling uniformity. However, seedlings should undergo transplantation as soon as they reach uniformity in order to be implanted, considering that, with time, their permanence in smaller containers results in both root growth restriction and limitation in the process of water and nutrient uptake. Consequently, there is a reduction in biomass accumulation and a higher risk of water stress and seedling senescence due to the lower water retention capacity of smaller containers, which dry faster (Poorter et al., 2012). Based on these data, it can be inferred that the significant differences verified in root growth at 30 DAS for the seedlings grown in trays compared to those grown in tubes is an indication that, from this moment, it would be opportune to transplant these seedlings to larger containers in order to provide better root growth conditions, consequently providing better support for total growth and biomass accumulation, making them more suited for implantation under field conditions.

In addition to root length and volume, the root structure is another critical factor in the evaluation of seedling quality, as thinner roots and root hairs are the structures that most effectively contribute to the absorption process, with a significant influence on root dry matter (Mariotti et al., 2015). This happens because thinner roots and root hairs weigh less than lignified roots, showing greater branching. The results of this study reveal that, although the root volume of the seedlings grown in tubes is significantly higher than the root volume of the seedlings grown in trays from 30 DAS, the root dry matter was only higher from 60 DAS (Figure 3F). This occurred because the roots that were prevented from growing in the trays remained short, but the lignification process began along with the increase in lateral branching (Figure 4A), contributing to increase the root mass in a similar way to the seedlings grown in tubes (Figure 4B), showing difference only at 60 DAS.

Plants normally develop a balance regarding their shoot and root parts in relation to environmental conditions, prioritizing biomass allocation to aboveground or belowground organs, according to their respective functions, whose usefulness is related to the future development of the seedling in the field (Mariotti et al., 2015; Liu et al., 2020). In the present study, what we verified regarding biomass allocation is that, from 45 DAS, the seedlings grown in trays showed a significantly higher SDM/RDM ratio compared to those grown in tubes (Figure 3H), indicating that the limitation imposed on root growth from 30 DAS (Figure 3C) reflected on a change in the biomass allocation pattern, resulting in the prioritization of biomass allocation to the shoot in relation to the root. In turn, the lower SDM/RDM ratio of the seedlings grown in tubes demonstrates a prioritization of biomass allocation to the root system. Several studies (Chirino et al., 2008; Mariotti et al., 2015; Liu et al., 2020) demonstrate that the biomass allocation pattern directed to the root system during the early stages of seedling development is an important strategy of resistance

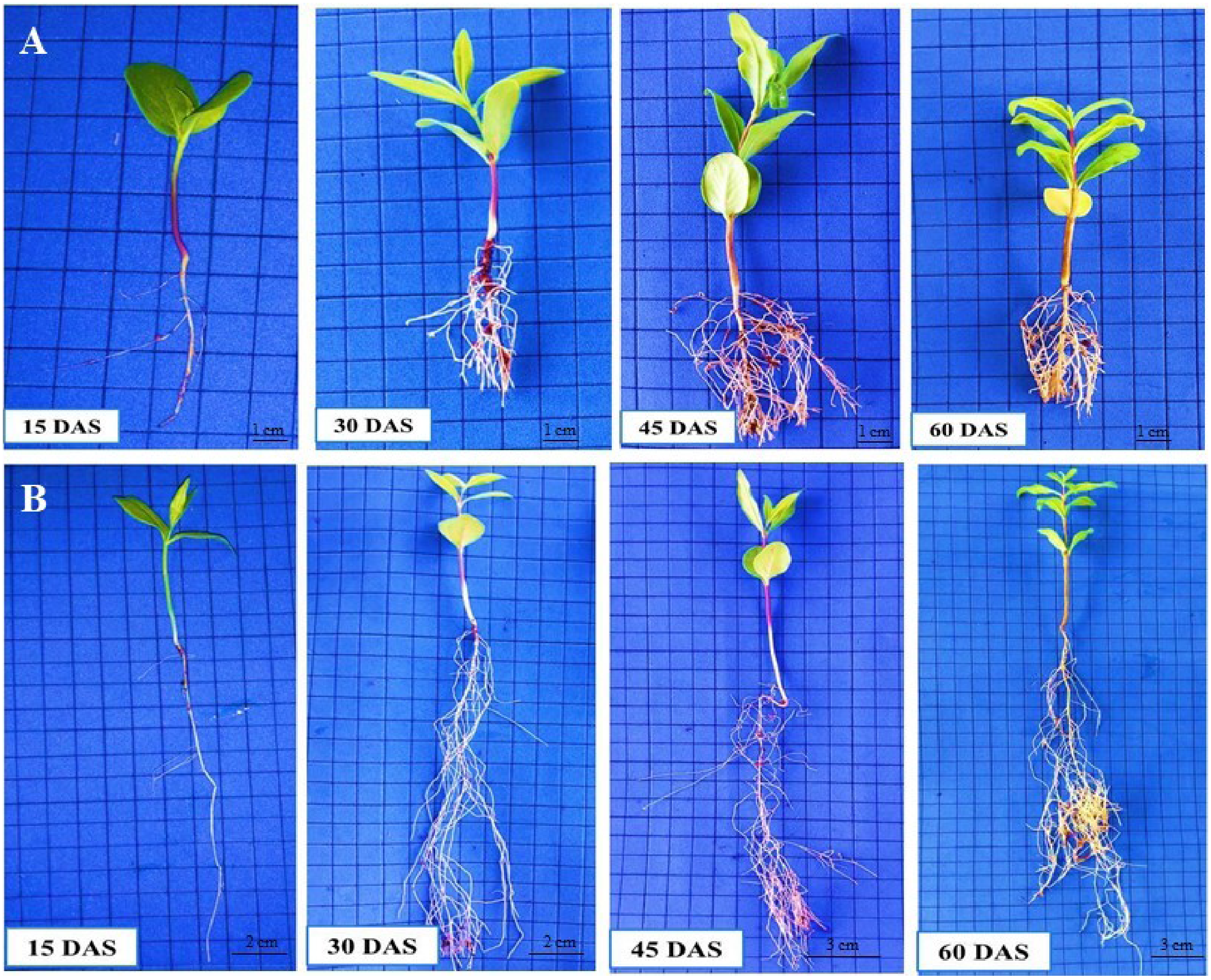


Figure 4. Development aspects of *Allamanda puberula* seedlings at 15, 30, 45 and 60 days after sowing in (A) Styrofoam trays and (B) tubes.

induction to transplantation and adverse conditions, especially in semiarid regions.

The results obtained in this study indicate that the seedlings grown in tubes performed better in terms of growth and biomass allocation. However, the interpretation of the different morphological attributes observed and the indication of the better cultivation container for *A. puberula* propagated via seeds depends on the implantation project and the specific characteristics of the field. Therefore, if the purpose is to use seeds to restore the local flora or reforestation, it is necessary to use more developed seedlings, with a higher permanence time in the plant nursery, which is why larger containers, such as tubes, are recommended. If the seedlings are used for ornamental purposes, such as pot cultivation or well-structured plant beds, the use of smaller containers may be recommended, such as trays.

What has been observed regarding the traditional propagation method for the species of the genus *Allamanda*, that is, via stem cuttings (Loss et al., 2008), is that the success of vegetative propagation via rooting induction does not depend on root emission only, but also that these structures are normal and functional. This is one of the factors that influence the seedling survival and establishment rates in the field the most, as adventitious roots shall acquire functionality, becoming the main organs responsible for the uptake of water and nutrients necessary for the maintenance of growth and water balance, requiring a longer time for the acclimatization process in the plant nursery (Souza et al., 2015; Souza et al., 2019). In this context, the propagation method via stem cuttings, besides presenting the disadvantage of lower genetic variability compared to seed propagation, results in less vigorous seedlings, a lower number of plants, and longer time for seedling obtainment.

Although studies of vegetative propagation are necessary for the researched species, the results obtained indicate that the characteristics of the seeds of *A. puberula* have great potential for germination and seedling formation, contributing to the success of sexual propagation. In addition, the information obtained will serve to subsidize the production of seedlings and the conservation of this native species.

Conclusion

The characterization of the seeds of *Allamanda puberula* demonstrated a satisfactory physiological potential for germination and full seedling formation under plant nursery conditions.

Under the experimental conditions evaluated, the use of tubes is recommended for seedling production. From 30 days after sowing, growth restriction occurs for the seedlings grown in trays.

Author Contribution

RSB: Investigation, methodology, writing original draft; **PML:** Investigation; **SGA:** Investigation; **MDGF:** Investigation, software; **RRS:** Writing review and editing; **MZBC:** conceptualization, supervision, writing review and editing.

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