Scientific Article

EMERGENCE, INITIAL GROWTH, AND SEEDLING QUALITY OF *Eremanthus incanus*: SUBSIDIES FOR GENETIC BREEDING AND CONSERVATION

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ABSTRACT – So far, the commercial production of *Eremanthus incanus* seedlings has been performed with seeds without any genetic control. Thus, we propose two experiments to examine seed-trees' effect on their descendants via the seminal in the nursery phase and verify the correlation between the variables. We installed the first experiment in a greenhouse and evaluated seedling emergence weekly for 42 days. At the exit of the greenhouse, at 60 days, we estimated survival. We conducted the second experiment in a shade house and, later, in full sun. We evaluated seedlings' height, diameter, and survival at 90, 120, 150, and 180 days after sowing. At 180 days, we quantified shoot, root, and total dry matter weight and calculated the Dickson Quality Index (DQI). The effects of *E. incanus* seed-trees on their descendants via the seminal were significant for emergence, growth characteristics, and seedling quality. The seedling survival rate at the greenhouse exit was high for all seed-trees, ranging from 72.2% to 97.2%. All seed-trees showed greater biomass allocation in the shoots of the seedlings, with this proportion being more pronounced in some of them. Although not significant, the correlation estimates between the emergence rate and the other traits were all positive. The correlations between height, diameter, dry mass, and DQI were significant and positive, from moderate to high magnitude. Due to its non-destructive nature, the diameter can be considered the most suitable practical indicator to evaluate the quality of *E. incanus* seedlings. Our results substantially contribute to implementing more effective conservation and breeding strategies, helping to understand the behavior of *E. incanus* in Campos Rupestres environments regarding seedling production and recovery of ecosystem services.

Keywords: Candeia; Seed-trees; Campo Rupestre.

EMERGÊNCIA, CRESCIMENTO INICIAL E QUALIDADE DE MUDAS DE Eremanthus incanus*: SUBSÍDIOS PARA MELHORAMENTO E CONSERVAÇÃO GENÉTICA*

RESUMO – A produção comercial de mudas de ***Eremanthus incanus*** *tem sido realizada, até o momento, com sementes sem nenhum controle genético. Assim, propomos dois experimentos para avaliar o efeito de árvores matrizes sobre suas descendentes por via seminal em fase de viveiro e verificar a correlação entre as variáveis. Instalamos o primeiro experimento em casa de vegetação e avaliamos a emergência das plântulas semanalmente durante 42 dias. Na saída da casa de vegetação, aos 60 dias, avaliamos a sobrevivência. Conduzimos o segundo experimento em casa de sombra e, posteriormente, em pleno sol. Avaliamos a altura, o diâmetro e a sobrevivência das mudas aos 90, 120, 150 e 180 dias após a semeadura. Aos 180 dias, quantificamos o peso de matéria seca da parte aérea, da raiz e total e calculamos o Índice de Qualidade de Dickson (IQD). Os efeitos* *de matrizes de **E. incanus** sobre suas descendentes por via seminal foram significativos para emergência e para os caracteres de crescimento e qualidade de mudas. A taxa de sobrevivência das plântulas na saída da casa de vegetação foi alta para todas as matrizes, variando de 72,2% a 97,2%. Todas as matrizes apresentaram maior alocação de biomassa na parte aérea das mudas, sendo essa proporção mais acentuada em algumas delas. As estimativas de correlação entre a taxa de emergência e as demais características, embora não significativas, foram todas positivas. As correlações entre altura, diâmetro, massa seca e IQD foram significativas e positivas, de moderada a alta magnitude. Devido à natureza não destrutiva, o diâmetro pode ser considerado o indicador prático mais adequado para avaliar a qualidade de mudas de **E. incanus**. Nossos resultados contribuem substancialmente para a implementação de estratégias mais eficazes de conservação e melhoramento, auxiliando na compreensão do comportamento de **E. incanus** em ambientes de Campos Rupestres quanto à produção de mudas e recuperação de serviços ecossistêmicos.*

Palavras-Chave: Candeia; Árvores matrizes; Campo Rupestre.

1. INTRODUCTION

Eremanthus incanus (Less.) Less (Asteraceae), commonly known as candeia, is a native tree of Espinhaço Range, southeastern Brazil. It occurs mainly in the Campos Rupestres, Cerrado biome, at altitudes between 800 and 1840 m (Terra et al., 2017; Rocha et al., 2020). The species forms partially pure populations and develop a fundamental role in the ecosystem services, such as pollination, biodiversity conservation, regulation of the hydrological cycle, carbon sequestration, and mitigation of climate change (Silveira et al., 2016; Lourenço et al., 2020). The main commercial use of the species is for the production of poles and fence posts (Scolforo et al., 2012). Due to its development in shallow, sandy, stony, and low fertility soils, it has potential for use in the recovery of degraded ecosystems (Gomes et al., 2015; Nunes et al., 2016). It is also of commercial interest to the cosmetic and pharmaceutical industries to produce secondary metabolites with antioxidant, anti-inflammatory, antimicrobial, and analgesic effects (Gimenes et al., 2018).

The exploration and trade of *E. incanus* represent alternative income-generating practices for rural producers and the recovery of environmental quality in degraded areas (Scolforo et al., 2012). However, the illegal exploitation of native candeais for socioeconomic reasons is concerning and has led to a significant increase in the demand for seedlings of this species for establishing new plantations (Melo et al., 2012).

Commercial production and planting of *E. incanus* seedlings in degraded areas of Campos Rupestres are performed exclusively via the seminal, using genetic materials without any degree of breeding (Melo et al., 2012; Gomes et al., 2015). Seeds of the species have also been used in direct sowing, although with low percentages of germination and establishment, due to the large proportion of empty seeds (Figueiredo et al., 2021).

Thus, studies at the level of seed-trees are essential for selecting superior genotypes and the consequent increase in the productive potential of the stands (Baldoni et al., 2020) since, within the same population, there are individual phenotypic variations between trees (Moraes et al., 2018). While there are incipient genetic breeding programs underway for *Eremanthus erythropappus* (Avelar et al., 2021), the species *E. incanus* still lacks initiatives in this regard. Through breeding programs with native species, it is possible to explore their variability, promoting the species' appreciation, conservation, and cultivation (Santos et al., 2014).

Due to the socioeconomic and environmental importance of *E. incanus*, this research aimed to evaluate seed-trees' effect on direct descendants via the seminal in the nursery phase and verify the existence and degree of correlation between the variables of emergence, growth, survival, and seedling quality. We aimed to contribute to the *E. incanus* genetic breeding and conservation comprehension.

2. MATERIAL AND METHODS

2.1. Seed collection area

The seed-trees of *E. incanus* used in this study are in the Campo Rupestre phytophysiognomy, Southern Espinhaço Range, Diamantina, Minas Gerais, Brazil. The area presents 2.15 hectares, located at coordinates

18º12′17″ S and 43º34′08″ W, at 1400 m. The seed-trees are in a deactivated solid waste disposal, in restoration since 2002 (Machado et al., 2012). According to Köppen's classification, the region’s climate is of the Cwb type, typically tropical, with mild and humid summers between October and April and cooler and drier winters from June to August. The average annual temperature is approximately 18 to 19 °C, and the average annual precipitation varies from 1250 to 1550 mm (Alvares et al., 2013).

2.2. Seed collection, processing, and storage

We collected open-pollinated seeds from ten seed-trees of *E. incanus* in October 2018. We transported them to the Integrated Center of Forest Species Propagation (CIPEF) of the Federal University of the Vales do Jequitinhonha e Mucuri (UFVJM). This species is in the Jeanine Felfili Dendrological Herbarium (HDJF-UFVJM) database (exsiccate record HDJF-3988). We manually processed the seeds, macerating the chapters with a fine sieve, and subsequently used a blower to remove empty or very small seeds and concentrate those of higher quality (Davide et al., 2011). We stored the seeds of each seed-tree in a cold chamber at 6° C and 40% relative humidity until the installation of the experiment (12 months).

2.3. Emergence and survival of seedlings in a greenhouse

In September 2019, we conducted the sowing in plastic tubes of 180 cm^3 (six seeds per tube). We used a mixture of 40% vermiculite, 40% coconut fiber, and 20% rice husk. To every 1000 L of this mixture, we added 5 kg of simple superphosphate and 600 g of Osmocote® (15-9-12) with slow release for 12 to 14 months. The trays were placed in a greenhouse covered with a 150 micron thick PVC film and a shading screen with 50% luminosity reduction, where they remained for 60 days. Irrigation was provided daily by nebulization (FOGGER nebulizer with a flow rate of 28 L h^{-1}) for 30 s every 20 min. The experimental design was in randomized blocks, with ten treatments (progeny), four replications, and 54 tubes per plot. We performed emergence assessments weekly until we reached a constant value. Thirty days after sowing, we thinned the seedlings, leaving only the most vigorous. We removed the seedlings from the greenhouse to evaluate their survival after 60 days.

2.4. Initial growth and quality of seedlings

We conducted the experiment initially in a shade house and later in a full sun area from November 2019 to March 2020. Thus, 60 days after sowing, we transferred the surviving seedlings from each seed-tree to a shade house covered with a 50% shading screen and rinsed five times a day for five minutes each (inverted ballerina micro sprinkler, with a flow rate of 85 L h^{-1}). We designed the experiment in randomized blocks, with four replications, nine treatments (progeny), and ten plants per plot. We did not include seed-tree 31 because of the few seedlings available. We kept the experiment in a shade house for 105 days, after which we transferred the seedlings to the hardening area in full sun, where they remained until 180 days. We used a micro sprinkler irrigation system, with a flow of 200 L h^{-1}, for five min, six times a day. At 90, 120, 150, and 180 days after sowing, we assessed the height of the aerial part (H, cm) with the aid of a millimeter ruler, the stem diameter (SD, mm) with a digital caliper, and the percentage of survival (S) of the seedlings. At 180 days after sowing, we quantified the shoot (SDMW, g), root (RDMW, g), and total dry matter weights (TDMW, g) with an analytical balance. We removed all the seedlings from the tubes, separated the shoot from the root system, and washed the roots under running water to remove the substrate. We inserted each part of the plant in Kraft paper bags and dried it in a forced air circulation oven at 65° C until a constant weight was achieved. With the data, we calculated the Dickson Quality Index (DQI) (Dickson et al., 1960) to assess the seed-trees concerning seedling quality.

2.5. Data analysis

We subjected the collected data to the Shapiro-Wilk test to verify the normality of the residuals and the Bartlett test to verify the homogeneity between the variances. Once the assumptions were met, we proceeded with the analysis of variance, followed by the Scott Knott test at 5% significance. When the assumptions were not met, the data were transformed using the Box-Cox method. We used the Pearson correlation coefficient (r) at 5% significance to verify the evaluated traits' existence and degree of correlation. The analyses were performed using R software (R Core Team, 2021) with the help of the ExpDes.pt package, version 1.2.1 (Ferreira et al., 2021).

3. RESULTS

3.1. Emergence and survival of seedlings in a greenhouse

The seedlings of 50% *E. incanus* seed-trees began emerging seven days after sowing. On the 14th day of evaluation, all seed-trees had at least one emerged seedling. At 42 days, we ended the emergence counts and verified significant differences ($p< 0.05$) among the seed-trees. According to the Scott-Knott test, seed-trees 146 and 13 comprised the groups with the highest means, with emergence values of 84.3 and 79.2%, respectively (Figure 1). Seed-tree 31 constituted the group with the lowest mean (9.3%) in isolation.

We verified that there was no significant difference ($p> 0.05$) between the seed-trees about seedling survival at the exit of the greenhouse at 60 days (Figure 2). The average survival rate was high (87.8%) and ranged from 72.2% (seed-tree 31) to 97.2% (seed-tree 146).

3.2. Initial growth and quality of seedlings

We verified significant differences ($p< 0.05$) between the seed-trees in height growth, stem diameter, and percentage of seedling survival at 90, 120, 150, and 180 days after sowing. We also found variations in the classification of seed-trees within classes over the evaluation period (Table 1).

Considering the height growth, the seed-tree 170 constituted an isolated group at 90, 120, 150, and 180 days, with the highest averages. From 90 to 120 days, there was an increase of 88.2%, which represented a substantial growth. Then, from 120 to 150 days, there was an additional growth of 25.9%. Finally, from 150 to 180, the seed-tree recorded an increase of 13.4%. Seed-trees 146, 11, 159, 192, and 151 composed the group with the lowest averages at 90 days. However, over 120, 150, and 180 days, seed-tree 11 emerged as an isolated group, consistently demonstrating the lowest average height. It is noticeable in the height development a phase of accelerated growth, followed

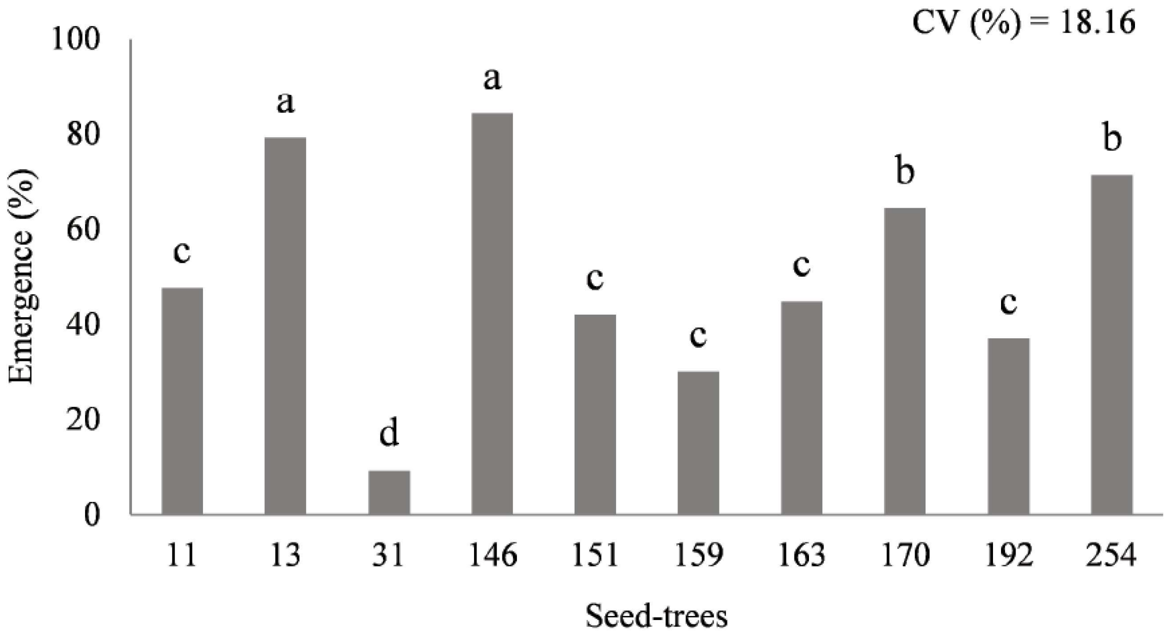

Figure 1 – Emergence percentage of seedlings of ten *Eremanthus incanus* seed-trees 42 days after sowing. Means followed by the same letter do not differ from each other by the Scott-Knott test at 5% significance. CV (%): Experimental coefficient of variation.
Figura 1 – *Percentual de emergência de plântulas de dez matrizes de* ***Eremanthus incanus*** *42 dias após a semeadura. Médias seguidas por uma mesma letra não diferem entre si pelo teste Scott-Knott a 5% de significância. CV (%): Coeficiente de variação experimental.*

by a phase of slower growth, in which the rate of increase starts to decelerate.

Regarding the stem diameter, at 90 days, we found the highest average for the seed-tree 254 (2.86 mm), which was statistically equal to the values of seed-trees 13, 170, 146, 163, and 11. At 120 days, the same seed-trees, except for seed-tree 11, constituted the group with the highest averages. At 150 and 180 days, the most increased mean diameter was obtained with seed-tree 170 (4.65 mm and 5.34 mm, respectively), which was statistically equal to seed-tree 163 (4.59 mm and 5.24 mm, respectively). In general, seed-trees 11, 151, and 159 had the lowest diameter growth.

As for the survival of seedlings, at 90 days, six of the nine seed-trees formed a single group, with survival ranging from 95 (seed-trees 192 and 254) to 100% (seed-trees 13, 146, and 151). At 120 days, seed-trees 13, 146, 151, and 159 remained in the group with the highest averages, while seed-trees 192 and 254 joined seed-trees 170 and 163 in the second group. At 150 and 180 days, the seed-trees were regrouped, and in both evaluations, the highest survival average was observed for seed-tree 13 (100%), which was statistically equal to seed-tree 151 (97.5% and 95%, respectively). We emphasize that seed-tree 11 constituted an isolated group at 90, 120, 150, and 180 days, with a substantial decline in the survival rate throughout the entire experimental period.

At 180 days after sowing, we verified significant differences between the seed-trees for SDMW, RDMW, TDMW, and DQI (Table 2). Evaluating SDMW, seed-tree 170 had an average of 3.82, surpassing all other seed-trees. The lowest SDMW averages were observed for seed-trees 159, 11, and 146 (1.70, 1.71, and 1.95, respectively). A similar result was observed for RDMW, where seed-tree 170 also had the highest average (3.51) compared to the others. The lowest value for this characteristic was observed for seed-tree 11 (1.41), which was statistically similar to the values found for seed-trees 146, 151, 159, 192, and 254. When comparing the total dry matter weight

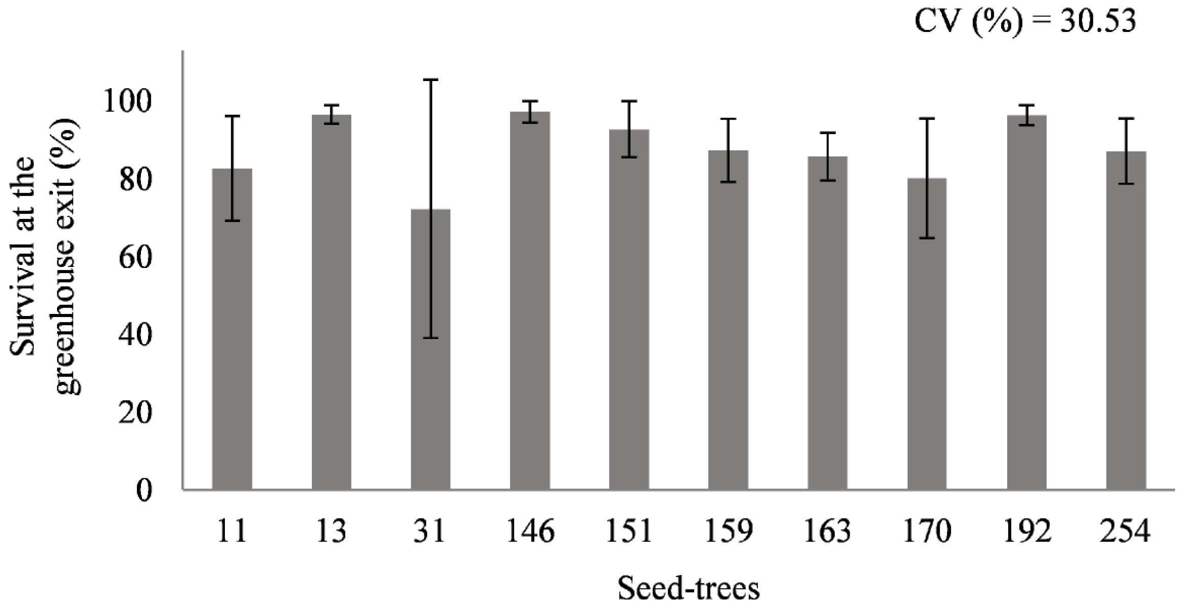

Figure 2 – Survival percentage of seedlings of ten *Eremanthus incanus* seed-trees at the greenhouse exit at 60 days. Bars indicate standard deviation. CV (%): Experimental coefficient of variation.
Figura 2 *– Percentual de sobrevivência de plântulas de dez matrizes de* ***Eremanthus incanus*** *na saída da casa de vegetação aos 60 dias. As barras indicam o desvio padrão. CV (%): Coeficiente de variação experimental.*

Table 1 – Height, stem diameter, and survival of seedlings from nine *Eremanthus incanus* seed-trees at 90, 120, 150, and 180 days after sowing.
Tabela 1 – *Altura, diâmetro do coleto e sobrevivência de mudas de nove matrizes de* ***Eremanthus incanus*** *aos 90, 120, 150 e 180 dias após a semeadura.*

Height (cm)				
Seed-trees	90 days	120 days	150 days	180 days
11	4.18 c	6.40 e	8.02 e	8.85 d
13	6.33 b	9.79 c	11.75 c	13.03 c
146	4.52 c	7.77 d	9.83 d	11.25 c
151	3.81 c	7.98 d	10.63 c	12.18 c
159	4.15 c	8.21 d	10.92 c	12.58 c
163	6.03 b	10.82 b	13.19 b	14.77 b
170	7.31 a	13.76 a	17.33 a	19.66 a
192	4.13 c	8.27 d	11.01 c	12.83 c
254	5.46 b	8.32 d	10.44 c	11.95 c
CV (%)	10.92	9.07	8.26	7.87
Stem diameter (mm)				
Seed-trees	90 days	120 days	150 days	180 days
11	2.54 a	3.32 c	3.90 c	4.30 c
13	2.82 a	3.90 a	4.55 a	5.08 b
146	2.67 a	3.71 a	4.39 b	4.89 b
151	2.18 b	3.38 c	4.01 c	4.58 c
159	2.29 b	3.29 c	3.94 c	4.36 c
163	2.65 a	3.93 a	4.59 a	5.24 a
170	2.75 a	3.88 a	4.65 a	5.34 a
192	2.23 b	3.58 b	4.32 b	4.96 b
254	2.86 a	3.83 a	4.44 b	5.05 b
CV (%)	6.42	3.80	12.43	3.87
Survival (%)				
Seed-trees	90 days	120 days	150 days	180 days
11	75.0 c	67.5 c	60.0 c	55.0 c
13	100.0 a	100.0 a	100.0 a	100.0 a
146	100.0 a	100.0 a	87.5 b	87.5 b
151	100.0 a	97.5 a	97.5 a	95.0 a
159	97.5 a	95.0 a	90.0 b	87.5 b
163	87.5 b	87.5 b	87.5 b	87.5 b
170	90.0 b	90.0 b	90.0 b	90.0 b
192	95.0 a	87.5 b	85.0 b	85.0 b
254	95.0 a	90.0 b	80.0 b	77.5 b
CV (%)	9.18	35.08	8.86	17.54

Means followed by the same letter in the column do not differ from each other by the Scott-Knott test at 5% significance. CV (%): Experimental coefficient of variation.
Médias seguidas pela mesma letra na coluna não diferem entre si pelo teste Scott-Knott a 5% de significância. CV (%): Coeficiente de variação experimental.

(TDMW), the behavior of the seed-trees was the same as observed for RDMW, with averages ranging from 7.33 (seed-tree 170) to 3.12 (seed-tree 11). Evaluating the average masses of shoots and roots together, it is noticeable that this distribution was more uneven for seed-trees 11 and 151, which allocated approximately 20% more biomass to the aboveground part at the expense of the root. For seed-trees 159, 163, and 254, this distribution was more uniform, with differences in masses below 5%. Regarding DQI, seed-trees 170 and 13 presented superior results compared to the others.

According to Pearson's correlation analysis, we found that SDMW, RDMW, and TDMW correlated strongly and positively ($0.8 \leq r < 1$) with each other, height, and Dickson's quality index (Table 3). We found a moderate positive correlation ($0.5 \leq r < 0.8$) with stem diameter concerning height, seedling dry matter weight, DQI, and between height and DQI. Regarding seedling survival, we found a weak and positive correlation between this variable and the growth, vigor, and quality traits of the seedlings ($0.1 \leq r < 0.5$). We verified that emergence did not correlate

Table 2 – Shoot (SDMW), root (RDMW), total dry matter weights (TDMW), and Dickson's Quality Index (DQI) of seedlings from nine *Eremanthus incanus* seed-trees at 180 days after sowing.
Tabela 2 *– Peso de matéria seca da parte aérea (SDMW), da raiz (RDMW) e total (TDMW) e Índice de Qualidade de Dickson (DQI) de mudas de nove matrizes de* ***Eremanthus incanus*** *aos 180 dias após a semeadura.*

Seed-trees	SDMW(g)	RDMW(g)	TDMW(g)	DQI
11	1.71 d	1.41 c	3.12 c	0.94 c
13	2.89 b	2.61 b	5.49 b	1.49 a
146	1.95 d	1.72 c	3.66 c	1.06 c
151	2.17 c	1.79 c	3.96 c	1.02 c
159	1.70 d	1.65 c	3.35 c	0.86 c
163	2.59 c	2.54 b	5.13 b	1.34 b
170	3.82 a	3.51 a	7.33 a	1.54 a
192	2.27 c	2.11 c	4.38 c	1.19 b
254	2.15 c	2.11 c	4.25 c	1.25 b
CV (%)	14.33	15.76	14.29	13.86

Means followed by the same letter in the column do not differ from each other by the Scott-Knott test at 5% significance. CV (%): Experimental coefficient of variation.
Médias seguidas pela mesma letra na coluna não diferem entre si pelo teste Scott-Knott a 5% de significância. CV (%): Coeficiente de variação experimental.

Table 3 – Estimates of Pearson's correlation coefficients (r) between the variables height (H), stem diameter (SD), shoot (SDMW), root (RDMW), and total dry matter weight (TDMW), Dickson's Quality Index (DQI), survival (S), and emergence (E).
Tabela 3 *– Estimativas dos coeficientes de correlação de Pearson (r) entre as variáveis altura (H), diâmetro do coleto (SD), peso de matéria seca da parte aérea (SDMW), da raiz (RDMW) e total (TDMW), Índice de Qualidade de Dickson (DQI), sobrevivência (S) e emergência (E).*

Variables	SD	SDMW	RDMW	TDMW	DQI	S	E
H	0.665*	0.861*	0.882*	0.883*	0.650*	0.463*	0.067
SD		0.741*	0.731*	0.746*	0.785*	0.380*	0.485
SDMW			0.949*	0.988*	0.879*	0.452*	0.325
RDMW				0.987*	0.916*	0.461*	0.296
TDMW					0.909*	0.462*	0.309
DQI						0.425*	0.494

*p< 0.05.
*p< 0,05

significantly with any of these variables (p> 0.05), but the estimates were all positive.

4. DISCUSSION

The planning of the production of *E. incanus* seedlings must be thorough, as the development time in nursery conditions is reasonably long (approximately 5 to 6 months) (Melo et al., 2014). The ecophysiological versatility of this species, combined with its socioeconomic value, makes it favorable for commercial planting in Brazil and other tropical and subtropical regions (Machado et al., 2013).

Our results show that the emergence of *E. incanus* seedlings starts in the first week after sowing but can take up to two weeks, depending on the seed-tree. Rapid and uniform seed germination, followed by immediate seedling emergence, are highly desirable aspects of seedling production. The longer durations for the emergence and remaining in the early stages of development make the seedlings more susceptible to environmental adversities (Marcos-Filho, 2015). However, in species native to Campos Rupestres, the success of seed germination and seedling emergence is variable and can reach extreme values depending on the species (Lima et al., 2014).

As the fruits were collected during the same period and at a similar stage of maturation, we believe that the differences in the percentage of the emergence of the seed-trees are due, in large part, to genetic components. Genetic differences between individuals in a population represent an essential component of the total variation to be explored in breeding programs toward selecting potential seed-trees to produce seeds and seedlings (Miranda et al., 2019).

Although candeia seeds are classified as orthodox (Nery et al., 2014), long-term storage may have contributed to the low emergence percentages of some seed-trees. One of the possible causes of the low production of viable seeds in the Asteraceae family is the occurrence of inflorescences with several capitula and many flowers per capitulum, which leads to the scarcity of maternal resources and the abortion of ovules and seeds (Marzinek and Oliveira, 2019). The cancelation of maternal investment should be seen as a potential reproductive loss and an adaptive response to the limits imposed by available resources (Lloyd, 1980). Furthermore, studies suggest that self-incompatibility may be one of the possible causes of the reduced production of viable seeds in *Eremanthus* (Velten and Garcia, 2005).

The seed-trees of the present study are located in a geographically limited area and in close proximity to each other. The ability of bees to pollinate, mainly *Trigona spinipes*, *Apis mellifera*, and *Bombus pauloensis* (Vieira et al., 2012; Santos et al., 2019), strongly points to the existence of a significant component of inbreeding. This inbreeding, in turn, manifests itself in several ways, and one of them is the decrease in seed vigor (Price et al., 2021). Thus, it is possible to infer that the limited genetic diversity resulting from inbreeding may have negatively affected seed quality and, consequently, influenced the results obtained in this study.

The degree of conservation of the seed-trees area is an important aspect to discuss. Environments with signs of degradation can influence the routes of dispersers and pollinators and, consequently, the reproduction of the species (Gao et al., 2021). The decrease or even the complete lack of resources, such as food, shelter, and nesting areas, can result in a reduction in the presence of floral visitors, compromising the efficiency of pollination and the interaction with the seed-trees. The behavior of allogamous crossbreeding and the anemochoric seed dispersal are factors that contribute to genetic variability in the candeia population (Barreira et al., 2006). However, it is essential to consider the interaction between population size, existing genetic diversity, and gene flow between different populations for a more comprehensive understanding of genetic variability in *E. incanus*.

The high survival of seedlings at the greenhouse exit and the absence of significant differences between the seed-trees for this variable indicate that the *E. incanus* has a high ability to survive in the first months after emergence. The greenhouse environment control (less temperature fluctuation and less sun exposure) contributed to the maintenance of this survival. Therefore, it is beneficial to produce seedlings initially under controlled nursery conditions before the transfer them to the planting area.

Eremanthus incanus is beneficial for seedling production to reestablish ecological processes in degraded areas (Gomide et al., 2014; Nunes et al., 2016). On the other hand, a direct sowing study using *E. incanus* without a previous selection process in a degraded area post-mined revealed a low seedling establishment (Figueiredo et al., 2021). The explanation is that *E. incanus* has a high proportion of empty seeds (Davide et al., 2011) and its successful establishment in the field can be difficult. The use of blowers considerably increases the quality of seed lots, as it eliminates empty or very small seeds. This reflects on the germination result, as already observed by Scolfoto et al. (2012), where germination increased from 13% among manually processed seeds to 74% after passing through the blower.

Regarding the seedlings' initial height and diameter growth, our results indicate that *E. incanus* has a slow growth, which is an expected behavior for most species in the Cerrado environment (Maracahipes et al., 2018; Giles et al., 2022). These species tend to invest more energy in the growth of the root system, making them less susceptible to water stress (Saboya and Borghetti, 2012) and possibly useful for restoring degraded sites (Gomes et al., 2015). Thus, root elongation promotes greater soil aggregation and better capture of limited resources, such as water and nutrients, for the maintenance and development of plants under normally stressful environmental conditions (Sena et al., 2021). The partition of biomass between root and shoot is often related to plants' ability to compensate for limited resources in the environment. It is normally observed that higher proportions of biomass are allocated to leaves and stems in nutrient-rich environments, while in nutrient-poor environments, a greater proportion is allocated to the roots (Mašková and Herben, 2018). The distribution of biomass among parts of the plant may represent a selection criterion for individuals with better survival capacity in environments with limitations, such as Campos Rupestres. In our study, for all seed-trees, a greater allocation of dry matter was observed in the shoot of the seedlings, with this proportion being more accentuated for some seed-trees. This response may be related to adequate conditions for cultivation and seedling nutrition. However, the ultimate success of a seedling depends not only on the development of its resource-acquiring organs (leaves and roots), but also on how well they can respond to the environment. This relative investment in leaves versus roots can change over time (McConnaughay and Coleman, 1999).

Variations in the classification of seed-trees within classes over the evaluation period may be associated with the juvenile age at which we evaluated the *E. incanus* progenies, which is when the formation of vegetative structures occurs, and many environmental and physiological factors influence the expression of its development (Laviola et al., 2010). This demonstrates the importance of understanding the behavior of seedlings from different seed-trees before the implementation of a genetic breeding program (Souza et al., 2015).

In the correlation analysis, we found significant coefficients for most pairs of variables. Estimates between height, diameter, dry mass (shoot, root, and total), and Dickson's quality index indicate that selection based on these traits will positively influence the remaining factors. This situation is advantageous and can lead the breeding program to accelerated progression by obtaining gains in a trait that is difficult to measure (SDMW and RDMW) through the prior selection of a readily measurable attribute (height and, or diameter of seedlings) (Bianchi et al., 2017). Despite the strong correlations between SDMW, RDMW, and TDMW with DQI, dry mass is a destructive evaluation method that requires specific infrastructure, such as forced air circulation stoves and scales. For this reason, its use is limited in assessing the quality of seedlings in forest nurseries (Tsakaldimi et al., 2013). On the other hand, seedling diameter stands out as a non-destructive and effective evaluation method to evaluate the performance of seedlings after field planting (Tsakaldimi et al., 2013). Under stress conditions, such as high evaporative demands or low soil water availability, plants may face an imbalance between water loss through transpiration and the ability of roots to absorb water. In these critical moments, a robust and larger diameter stem acts as a water buffer, offering significant advantages for the survival and growth of plants (Swaef et al., 2015).

The weak correlation between seedling survival and the other variables shows that, although it can provide some guidance, it should not be the only parameter considered in selecting the best seed-trees of *E. incanus*. Regarding emergence, despite the absence of a significant correlation with the seedling's morphological traits, all estimates were positive, representing if the selection is made to increase the value of the variables in question.

Given the growing threats to Campo Rupestre, our study contributes to the implementation of more effective conservation and breeding strategies. Furthermore, it has positive implications for the resumption of ecosystem services vital to environmental quality and human well-being, such as carbon sequestration, which helps mitigate climate change, biodiversity resilience, including genetic diversity, fundamental to the stability of ecosystems, and conversion of degraded landscapes to multifunctional regions, which play a vital role in the sustainability of communities and environmental health (Ciccarese et al., 2012; Neves et al., 2016). The species *E. incanus* has the potential to be used in restoration projects, and our results help to understand the behavior of populations of the species in Campos Rupestres regarding seedling production.

5. CONCLUSIONS

The effects of *E. incanus* seed-trees on their descendants via the seminal are significant for the emergence character and for the characters: height, stem diameter, dry matter weight (shoot, root, and total), and Dickson's quality index. All seed-trees showed greater biomass allocation in the shoots of the seedlings, with this proportion being more pronounced in some of them. Although not significant, the correlation estimates between the attributes in question and the emergence rate are all positive, with no problems in the correlated responses for selecting any of these traits. Due to the non-destructive nature, the diameter can be considered as the most suitable practical indicator to evaluate the quality of *E. incanus* seedlings.

AUTHOR CONTRIBUTIONS

Conceptualization: Maravilha LF, Titon M. Formal analysis: Maravilha LF, Titon M. Investigation: Maravilha LF, Titon M. Methodology: Maravilha LF, Titon M. Writing - original draft: Maravilha LF. Writing - review and editing: Maravilha LF, Titon M,

Mucida DP, Miranda NA, Fernandes JSC, Gonçalves JF, Canguçu VS. Supervision and coordination of research: Titon M.

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