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Scientific Article

SURVIVAL AND INITIAL GROWTH OF SEEDLINGS PRODUCED IN DIFFERENT CONTAINERS AND THE USE OF MULCHING IN ANTHROPIZED AREA

Thairini Claudino Zavistanovicz[2], Maristela Machado Araujo[3], Suelen Carpenedo Aimi[3*], Álvaro Luís Pasquetti Berghetti[4], Claudia Costella[5] and Matheus Roberto da Silva[6]

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2 Secretaria de Estado da Infraestrutura e Mobilidade de Santa Catarina, Florianópolis, SC, Brasil. E-mail: <thairini.z@gmail.com>.
3 Universidade Federal de Santa Maria, Departamento de Ciências Florestais, Santa Maria, RS, Brasil. E-mail: <maristela.araujo@ufsm.br> and <suelen.aimi@ufsm.br>.
4 Universidade Federal do Paraná, Departamento de Ciências Florestais, Curitiba, PR, Brasil. E-mail: <alvaro.berghetti@gmail.com>.
5 Universidade Federal de Santa Maria, Programa de Pós-Graduação em Engenharia Florestal, Santa Maria, RS, Brasil. E-mail: <claudiacostella95@gmail.com>.
6 Celulose Riograndense - CMPC, Guaíba, RS, Brasil. E-mail: <matheus-r-da-silva@hotmail.com>.
*Corresponding author.

ABSTRACT

The demand for seedlings of native tree species for the restoration of altered areas has increased considerably. Therefore, knowing the strategies that favor quality seedling production in the nursery, in addition to survival, growth, and development in the field, is important. This study was to evaluate the survival and initial growth of *Inga vera* Will and *Schinus terebinthifolius* Raddi, after 24 months of planting, seedlings in an anthropized area. The experiment was conducted using a factorial scheme (2×2), considering the types of containers used in the production of seedlings and the presence or absence of mulching in the surroundings. The survival of the seedlings, as well as their morphophysiological attributes, was verified 24 months after planting. *I. vera* presented a higher average survival for seedlings grown in plastic bags (86.7%), whereas *S. terebinthifolius* did not show any difference between treatments. The morphological attributes of increased height (IncH), diameter of the stem (IncSD), crown area (AC), and shoot dry mass (SDM) were favored by the use of plastic bags in seedlings of *I. vera*. For *S. terebinthifolius*, the plastic bag favored only IncH, equaling the seedlings produced in containers for the other variables. Using mulching was ineffective in helping the growth of either species, and the physiological attributes were similar for all the treatments tested. Aiming at the high survival and rapid growth of seedlings in the field, it is recommended to produce *I. vera* in 1.5 L plastic bags, while *S. terebinthifolius* seedlings can be produced in 180 cm³ containers. Therefore, using mulching as a culture treatment for both species should be investigated in future studies.

Keywords: *Inga vera*; *Schinus terebinthifolius*; Morphophysiological attributes; Extreme south of the Atlantic Forest biome

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SOBREVIVÊNCIA E CRESCIMENTO INICIAL DE MUDAS PRODUZIDAS EM DIFERENTES RECIPIENTES E USO DE MULCHING EM ÁREA ANTROPIZADA

RESUMO – A demanda por mudas de espécies nativas arbóreas para restauração de áreas alteradas tem aumentado consideravelmente. Assim é importante o conhecimento de estratégias que favorecem a produção das mudas no viveiro com qualidade, além da sobrevivência, crescimento e desenvolvimento no campo. Este estudo objetivou avaliar a sobrevivência e o crescimento inicial de mudas de *Inga vera* Will. e *Schinus terebinthifolius* Raddi, após 24 meses de plantio, em área antropizada. O experimento foi conduzido em esquema fatorial (2x2), considerando tipos de recipientes utilizados na produção das mudas e presença ou ausência de mulching no seu entorno, no plantio. Aos 24 meses após o plantio verificou-se a sobrevivência das mudas, bem como os atributos morfofisiológicos. Quanto à sobrevivência, *I. vera* apresentou maior média para mudas produzidas em saco plástico (86,7%), enquanto *S. terebinthifolius* não demonstrou diferença entre os tratamentos. Os atributos morfológicos incremento em altura (IncH) e em diâmetro do coleto (IncDC), área da copa (AC) e massa seca da parte aérea (MSPA) foram favorecidos pelo uso do saco plástico em mudas de *I. vera*. Para *S. terebinthifolius*, o saco plástico favoreceu somente o IncH, igualando-se às mudas produzidas em tubetes nas demais variáveis. O uso do mulching não foi eficaz para auxiliar no crescimento de ambas as espécies e os atributos fisiológicos mostraram-se semelhantes para todos os tratamentos testados. Visando elevada sobrevivência e rápido crescimento das mudas a campo, recomenda-se a produção de *I. vera* em sacos plásticos de 1,5 L, enquanto mudas de *S. terebinthifolius* podem ser produzidas em tubetes de 180 cm³. O uso do mulching como trato cultural, para ambas as espécies, deve ser investigado em estudos futuros.

Palavras-Chave: *Inga vera*; *Schinus terebinthifolius*; Atributos morfofisiológicos; Extremo sul do Bioma Mata Atlântica

1. INTRODUCTION

The United Nations has declared that the decade 2021–2030 will be an ecosystem restoration period. This global appeal will bring together political, scientific, and financial support to expand the restoration of deforested and degraded landscapes worldwide (ONU 2020). It is necessary to adopt effective large-scale restoration strategies and develop techniques that adapt to the different realities of each country to achieve these objectives (Meli et al., 2017).

In this sense, the consumer market for forest seedlings has gained emphasis for restoration purposes because planting native tree species accelerates the resumption of functionality in altered environments (Campoe et al., 2014; Resende et al., 2015; Oliveira et al., 2019). This demand has generated the need for studies to find techniques that optimize the production process, combined with low cost and morphological and physiological qualities, capable of meeting planting objectives.

The importance of using an appropriate container, which favors the growth of seedlings and reduces costs, is highlighted for seedlings produced in a nursery (Akpo et al., 2014). However, these imply high investment due to aspects such as greater space occupied, labor, transport, and planting costs (Ferraz and Engel, 2011).

Maintenance and silvicultural treatments applied after planting are also crucial for success (Grossnickle, 2012), considering that the seedling establishment phase in the field is critical (Campoe et al., 2014). Reducing stress in the planting area during the initial stages can increase the chances of seedling survival and growth because it facilitates access to available resources (Campoe et al., 2014). In this way mulching can contribute to the establishment of seedlings in anthropic areas. It is used in plantings around seedlings to control weeds and maintain soil moisture, reducing evaporation and thus contributing to tree growth (Ni et al., 2016).

It is important to identify tree species that are functional in the environment to achieve faster and more complete restoration. Such species, called frameworks, have favorable attributes for a given environmental condition, accelerate the restructuring of the plant community, and trigger ecological processes that are fundamental to ecosystem functioning (Pilon and Durigan, 2013). Among the framework species, *Inga vera* (ingá-banana) and *Schinus terebinthifolius* (aroeira-vermelha), species native to southern Brazil, are suggested to have the potential for this purpose in their region of natural occurrence (Backes and Irgang, 2002; 2009).

I. vera is typically found in riparian forests in the southern region of Brazil; however, it is widely distributed throughout Brazil (Backes and Irgang, 2009). Marcuzzo et al. (2015) recommended using seedlings of this species in restoration projects, aiming to form filling groups owing to their rapid growth. In a study conducted by Campos and Martins (2016) on the process of restoring a mining area by planting 30 tree species, it was found that *I. vera* was one of the few species that had regenerating individuals on site 6 years after planting, confirming its ability to assist in the restoration of altered environments.

S. terebinthifolius is also widely distributed in Brazil. According to Backes and Irgang (2002), this species is a pioneer in the recovery of altered and degraded areas due to its ecological function, as its fruits are widely consumed and disseminated by birds. This species is cited as having the potential for the recovery of areas altered and degraded by mining (José et al., 2005).

It is essential to identify the silvicultural characteristics of these tree species to infer their potential for use in restoration projects, which will be confirmed in subsequent studies using ecological indicators. Therefore, the aim of the present study was to evaluate the survival and initial growth of *I. vera* and *S. terebinthifolius* seedlings in an anthropized area according to the container used to produce the seedlings in the nursery and the use of mulching after planting.

2. MATERIAL AND METHODS

2.1 Study area

The experiment was conducted in the Parque Estadual da Quarta Colônia (PEQC) (29º27’57.39’’S and 53º16’51.30’’W), in the municipality of Agudo, Rio Grande do Sul, Brazil, in the Atlantic Forest Biome. According to the Köppen classification, the region’s climate is of the Cfa” type, characterized by average temperature between -3 and 18 °C in the coldest month, and above 22 °C in the hottest month, presenting rainfall well distributed over the months (Alvares et al., 2013). The meteorological data of average temperature (ºC) and precipitation (mm), corresponding to the period of the experiment (October de 2013 a October de 2015), were obtained from the National Meteorological Institute (INMET) (Figure 1).

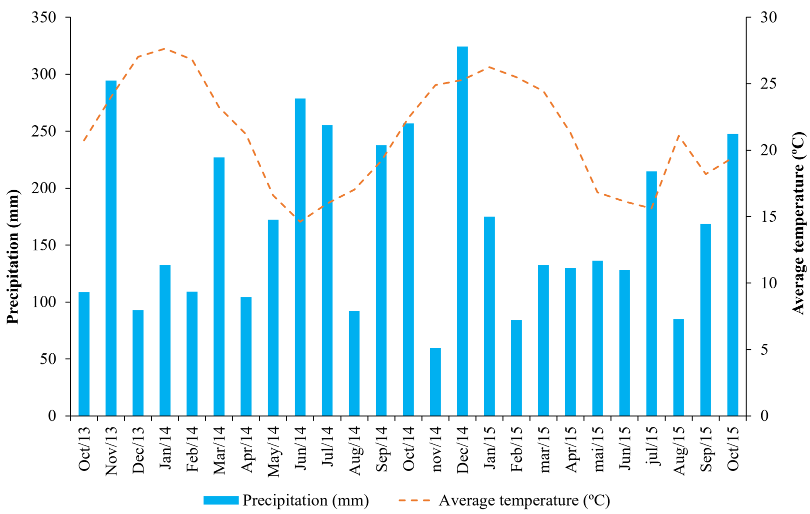

Figure 1. Precipitation (mm) and average temperature (ºC) registered in Santa Maria, RS, between October 2013 and October 2015. Source: www.inmet.gov.br/portal/

Figura 1. Precipitação (mm) e temperatura média (ºC) registrados em Santa Maria, RS, durante a condução do experimento, outubro de 2013 a outubro de 2015. Fonte: www.inmet.gov.br/portal/

Revista ÁRVORE ISSN 1806 – 9088

2.2 Seedling production

The seeds for the production of seedlings were collected in remnants of the Seasonal Deciduous Forest in the central region of Rio Grande do Sul. Immediately after collection, there was seed extraction and processing. The production of seedlings was carried out at the Forest Nursery of the Federal University of Santa Maria, following the methodology described in Zavistanovicz et al. (2021).

After this stage, the seedlings remained in the nursery for eight months, until planting in the field. At the time of shipment from the nursery, the *Inga vera* seedlings had an average height (H) of 110.0 cm and 70.0 cm in the plastic bag and container, respectively, and a stem diameter (SD) of 10.71 and 7.80 mm respectively. *Schinus terebinthifolius* presented mean H of 88.1 and 76.8 cm and SD of 9.06 and 8.50 mm, respectively, for plastic bag and container.

2.3 Treatments and experimental design

The experiment consisted of four treatments in a 2x2 factorial scheme, with two types of containers: seedlings produced in containers and transplanted into plastic bags, where they remained until planting, and seedlings produced and maintained in containers until planting; and presence or absence of mulching around seedlings during planting. The analysis was carried out individually for *I. vera* and *S. terebinthifolius*. The experiment was conducted in subdivided plots, with the plot consisting of the treatments of containers used in production, and in the subdivided plots the presence or absence of mulch, in a randomized block design, with five blocks. Each plot of 10.5 m x 10 m consisted of a single species, with 35 individuals, depending on the treatments, and a space of 1.5 m x 2.0 m between plants and 2 m between blocks, with five blocks. The preparation and planning of the area were carried out according to the methodology described in Zavistanovicz et al. (2021). The mulching was obtained in the area adjacent to the experiment. Replacements with the same material were done, every four months, during the first year.

2.4 Assessments of morphophysiological attributes

At 24 months after planting, the survival of the seedlings was evaluated. The height (H) and stem diameter (SD) were measured using a graduated ruler and digital caliper, respectively, at the time of planting and 24 months later. Subsequently, the H/SD ratio (cm mm^{-1}) was calculated by dividing the height value by the duct diameter value; the increase in height (IncH) and increase in stem diameter (IncSD) were also calculated through the difference between the values obtained at 24 months and at the time of planting.

At 24 months, the crown diameter (CrownD) of the plants was also measured, taking two perpendicular measurements (CrownD1 and CrownD2), with the aid of a graduated ruler, for later calculation of the crown area (CA), where CA= [(CrownD1+CrownD2)/4]2*π. (Resende et al., 2015). For the morphological attributes mentioned (survival, H, SD, H/SD, CrownD), the six central plants of each subplot were measured. The evaluation of the shoot dry mass (SDM) also occurred 24 months after planting, sectioning a plant per repetition, in the coleto region. Then the plant material (leaves, branches and stem) was placed in brown paper envelopes and dried in an oven with forced air circulation at 65 ºC, until constant weight. Subsequently, the material was weighed on a digital scale to obtain the SDM.

For the physiological analyzes of the seedlings, the relative levels of chlorophyll a (Cla) and b (Clb) were verified; and chlorophyll a fluorescence, in one plant per repetition, 24 months after planting. The evaluation of relative chlorophyll levels was carried out between 08:00 and 10:00 h, with a chlorophyll meter (ClorofiLOG, CF 1030, Falker), in expanded leaves oh the upper third of the plant, in points located in the middle third of the leaf. One leaf per plant was measured (two readings per leaf, one on each side of the central vein). The relative chlorophyll content was expressed as Chlorophyll Falker Index (ICF), which is calculated considering the combination of light wavelengths analyzed.

Chlorophyll a fluorescence was determined using a portable modulated light fluorimeter (Junior-Pam Chlorophyll Fluorometer Walz), in fully expanded leaves attached to the plant, on sunny days, between 08:00 and 11:00 h. Healthy leaves were selected from the upper third of the plant, which were wrapped in aluminum foil for 30 minutes to adapt to the dark. Subsequently, fluorescence measurements were carried out, obtaining the values of initial fluorescence (Fo), maximum fluorescence (Fm) and maximum quantum yield of photosystem II (Fv/Fm). After obtaining, the data were transferred to a computer using the Wincontrol computer program.

Variables relating to the environment under the plant canopies were also collected. Soil moisture was measured according to the treatments in the portion below the seedling canopy, with the aid of a soil moisture sensor (ML3 ThetaProbe) coupled to a display (HH2 Delta-T), which provided immediate results of the moisture content (m^3m^{-3}). The luminosity was also verified at three points located under the canopy of the seedlings (LC), at a distance of 30 cm from the stem and 1.20 m in height, using a pair of digital lux meters (Mlm1011 Minipa) with simultaneous measurements at each point and in the open.

The data were checked regarding the assumptions of normality of error distribution and homogeneity of variance, respectively, using the Shapiro-Wilk and Bartlett tests ($p>0.05$), using the Action supplement. Those that did not present normality and/or homogeneity of variance were transformed by Box-Cox. Subsequently, the data were subjected to analysis of variance (ANOVA) and, when a difference was found between treatments using the F test, means were compared using the Student's t test ($p<0.05$), in the statistical software SISVAR (Ferreira, 2019).

3. RESULTS

3.1 Morphological attributes of *Inga vera*

I. vera seedlings showed high survival 24 months after planting in the field when transferred from a plastic bag (86.7%), compared to those kept in containers until planting (63.3%), but with no difference in the mulching factor (Table 1).

Regarding growth variables (Table 1), it

Table 1. Survival (S), increment in height (IncH), increment in stem diameter (IncSD), height and diameter ratio of the stem (H/SD), crown area (CA), shoot dry mass (SDM) and light under the canopy (LC) of *I. vera* seedlings, produced in different types of containers and use of mulching, 24 months after planting in the field

Tabela 1. Sobrevivência (S), incremento em altura (IncH), incremento em diâmetro do coleto (IncDC), relação altura e diâmetro do coleto (H/DC), área da copa (AC), massa seca da parte aérea (MSPA) e luminosidade sob a copa (LC) de mudas de *I. vera*, produzidas em diferentes tipos de recipientes e uso de mulching, aos 24 meses após o plantio a campo

Container	**S (%)**	**IncH (cm)**	**IncSD (mm)**	**H/SD (cm mm^{-1})**	**CA (m^2)**	**SDM (g)**	**LC (%)**
Plastic Bag	86.67a*	179.78 a	50.14 a	4.78^{ns}	6.90 a	2,360.60 a	15.75 a
Container	63.33b	143.96 b	32.17 b	5.43	2.57 b	503.50 b	34.05 b
Mulching	**S (%)**	**IncH (cm)**	**IncSD (mm)**	**H/SD (cm mm^{-1})**	**CA (m^2)**	**SDM (g)**	**LC (%)**
Presence	75.00^{ns}	164.94^{ns}	42.71^{ns}	5.07^{ns}	4.73^{ns}	1,603.60 a	24.05^{ns}
Absence	75.00	158.79	39.60	5.13	4.74	1,260.50 b	25.75
CV1 (%)	19.88	15.38	15.11	1.14	16.85	5.25	1.34
CV2 (%)	15.71	11.18	11.76	0.57	16.71	3.53	1.31
Means	75.00	161.90	41.16	5.10	4.74	1,432.05	24.89

*Means not followed by the same letter in the column differ by the t test at the 5% probability level. CV1: Coefficient of variation of the plot. CV2: Coefficient of variation of the subplot. ^{ns} - not significant.

*Médias não seguidas da mesma letra na coluna diferem pelo teste t ao nível de 5% de probabilidade. CV1: Coeficiente de variação da parcela. CV2: Coeficiente de variação da subparcela. ^{ns} - não significativo.

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was found that, for *I. vera*, there was an effect of the type of container on the variables IncH, IncSD, AC and SDM. For these variables, the highest values were found in plastic bag seedlings, with averages of 179.78 cm IncH; 50.14 mm IncSD, 6,905 m² AC; and 2,360.60 g SDM.

There was also a difference between the levels of the mulching factor on the SDM of *I. vera*, with a higher average obtained in the presence of mulch (1,603.60 g). The H/SD variable demonstrated similar means between the treatments (5.10 cm mm^{-1}).

3.2 Morphological attributes of *S. terebinthifolius*

S. terebinthifolius had similar survival rates among all treatments, with an overall average survival rate of 81.7% (Table 2). The analysis also indicated a difference only in IncH between the containers tested. For this variable, the highest value was found in seedlings from plastic bags (201.46 cm), which was higher than those from containers (166.88 cm), regardless of the presence or absence of mulching (Table 2).

The other growth variables showed no difference among the treatments tested, with general averages of 37.86 mm for IncSD; 5.79 cm mm^{-1} for H/SD; 3.25 m³ for AC; and 1,064.45 g for SDM (Table 2).

3.3 Physiological attributes

Analysis of the physiological attributes of *I. vera* and *S. terebinthifolius* seedlings revealed no differences among the treatments. In *I. vera*, the mean values of the physiological variables were 35.72 for Cla ICF, 15.56 for ICF of Clb, 233.35 for Fo, 778.85 Fm, and 0.694 for Fv/Fm. In contrast, *S. terebinthifolius* seedlings presented overall averages of 32.69 and 11.92 for ICF of Cla and Clb, respectively, 250.85 for Fo; 844.7 for Fm and 0.704 for Fv/Fm.

Table 2. Survival (S), increment in heigh (IncH), increment in stem diameter (IncSD), height and diameter ratio of the stem (H/DC), crown area (CA), shoot dry mass (SDM), soil moisture (SM) and light under the canopy (LC) of *S. terebinthifolius* seedlings, produced in different types of containers and use of mulching, 24 months after planting in the field

Tabela 2. Sobrevivência (Sob.), incremento em altura (IncH), incremento em diâmetro do coleto (IncDC), relação altura e diâmetro do coleto (H/DC), área da copa (AC), massa seca da parte aérea (MSPA), umidade do solo (US) e luminosidade sob a copa (LC) de mudas de *S. terebinthifolius*, produzidas em diferentes tipos de recipientes e uso de mulching, aos 24 meses após o plantio a campo

Container	**S (%)**	**IncH (cm)**	**IncDC (mm)**	**H/DC (cm mm^{-1})**	**CA (m²)**	**SDM (g)**	**SM (m³ m^{-3})**	**LC (%)**
Plastic Bag	76.66^{ns}	201.46 a	39.89^{ns}	6.06^{ns}	3.51^{ns}	1.151,30^{ns}	0.139^{ns}	19.71^{ns}
Tube	86.67	166.88 b	35.84	5.52	2.99	977.6	0.119	19.85
Mulching	**S (%)**	**IncH (cm)**	**IncSD (mm)**	**H/SD (cm mm^{-1})**	**CA (m²)**	**SDM (g)**	**SM (m³ m^{-3})**	**LC (%)**
Presence	76.66^{ns}	189.65^{ns}	38.78^{ns}	5.80^{ns}	3.36^{ns}	1.100,20^{ns}	0.130^{ns}	19.45^{ns}
Absence	86.67	178.68	36.94	5.78	3.13	1.028,70	0.128	20.12
CV1 (%)	30.95	12.80	15.84	10.66	26.29	25.65	28.48	7.49
CV2 (%)	16.77	7.35	16.15	15.96	17.32	21.83	8.90	16.67
Means	81.67	184.16	37.87	5.79	3.25	1.064,45	0.129	19.78

*Means not followed by the same letter in the column differ by the t test at the 5% probability level. CV1: Coefficient of variation of the plot. CV2: Coefficient of variation of the subplot. ^{ns} - not significant.

*Médias não seguidas da mesma letra na coluna diferem pelo teste t ao nível de 5% de probabilidade. CV1: Coeficiente de variação da parcela. CV2: Coeficiente de variação da subparcela. ^{ns} - não significativo.

3.4 Environment under the canopies

As for the variables obtained in the environment under the *I. vera* canopies, soil moisture showed an interaction between the factors studied (Table 3), with the highest value observed being under seedlings originating from plastic bags, with the presence of mulching during planting (0.104 $m^3 m^{-3}$). The variable light under the canopy (LC) showed a difference between the levels of the container factor, with greater light passing under the canopy of seedlings from the containers (34.05%) (Table 1).

Table 3. Soil moisture ($m^3 m^{-3}$) under the canopy of *I. vera* seedlings, produced in different types of containers and use of mulching, 24 months after planting in the field

Tabela 3. Umidade do solo ($m^3 m^{-3}$) sob a copa de mudas de *I. vera*, produzidas em diferentes tipos de recipientes e uso de mulching, aos 24 meses após o plantio a campo

Factors	Presence of mulching	Absence of mulching
Plastic Bag	0.104 Aa*	0.087 Ba
Tube	0.069 Ab	0.067 Aa
CV1(%)	27.17	
CV2(%)	8.22	

*Means not followed by the same letter in the column differ by the t test at the 5% probability level. CV1: Coefficient of variation of the plot. CV2: Coefficient of variation of the subplot.

*Médias não seguidas da mesma letra na coluna diferem pelo teste t ao nível de 5% de probabilidade. CV1: Coeficiente de variação da parcela. CV2: Coeficiente de variação da subparcela.

For *S. terebinthifolius*, there was no significant difference between the environments tested, obtaining a general average of 0.129 $m^3 m^{-3}$ of soil moisture and 19.78% for light under the canopy (Table 2).

4. DISCUSSION

I. vera seedlings required a large container volume (1.5 L plastic bags) during their production in the nursery to obtain high survival values for IncH, IncSD, AC, and SDM in the field. This is because the choice of container used in the production of seedlings influences the level of resources available to them (Luna et al., 2009), which is decisive for some species.

When using containers with higher volumes, plants have greater availability of substrates, nutrients, and water, which favors the development of the root system. According to Close et al. (2010), seedlings produced in larger volume containers may have a high ratio between roots and shoots and greater biomass, which are determining factors for survival and growth in the field. The authors also emphasized that biomass accumulation indicates the reserves of total available carbohydrates, which can be used to promote rapid establishment soon after planting.

According to Lambert et al. (2010), the factors influencing the establishment and growth of forest species seedlings in plantations, especially in restoration areas, are numerous and difficult to control. However, the size and quality of the seedlings used are factors that can be controlled and influence the success of planting. These factors are directly related to the choice of container used. The selection of a container for seedling production is generally based on an analysis of the growth attributes of the seedlings in the nursery and their cost, ignoring the main objective, which is the response of the seedlings when planted in the field (Abreu et al., 2015). Generally, smaller containers are chosen to reduce production costs by reducing the substrate, occupied area, and transportation.

However, containers with less than adequate volume can compromise the quality of the seedlings and their performance after planting (Akpo et al., 2014). Therefore, the benefits of larger containers can offset costs, for example, by obtaining high survival and growth in the field (Mariotti et al., 2015).

According to Luna et al. (2009), one should choose to produce seedlings of tree species in larger-volume containers whenever the destination is a plantation with high vegetative competition. This is because these containers favor the growth of seedlings in terms of height, stem diameter, and biomass, making them more efficient in capturing water and nutrients and contributing to their survival and growth, as confirmed in the present study.

The observed survival rate was similar to that reported by Marcuzzo et al. (2015) (75%) for *S. terebinthifolius* seedlings in a restored planting located in an area adjacent to that of the present study. Similar survival results were described by Zavistanovicz et al. (2021) for *Casearia sylvestris* Sw and *Handroanthus heptaphyllus* Vell. Mattos, and *Parapiptadenia rigida* Benth. Brenan (72.5, 85.0, and 80.0%, respectively). The high survival observed in all treatments in this study demonstrates the rusticity of the species, which grows and develops easily, even in unsuitable locations, as observed by José et al. (2005).

Despite this, *S. terebinthifolius* seedlings were susceptible to attack by leaf-cutter ants, even with the use of granulated baits, a fact that caused the death of some seedlings in this study. Therefore, intensive control of ants in the area is necessary before and after planting in restoration projects using this species.

The present study also showed that containers only affected the IncH. Although a significant difference was found for this variable between the containers, it can be considered that, in general, the field growth of *S. terebinthifolius* seedlings produced in containers was satisfactory, considering that the other morphological attributes (IncSD, H/SD, AC, SDM, soil moisture, and light under the canopy) were similar between treatments.

The results obtained are in accordance with those of José et al. (2005), who found no difference between the types of containers used in the production of seedlings of this species 250 days after planting in an area altered by mining, proving the high adaptability of the species in adverse environments, even when produced in smaller containers. The possibility of producing *S. terebinthifolius* seedlings in smaller-volume containers reduces planting costs when using this species. This is because tube-grown seedlings, which require less substrate and fertilizer, have lower values than those produced in plastic bags (Ferraz and Engel, 2011).

Furthermore, these seedlings can be planted in a mechanized or semi-mechanized way, as the clod is generally well aggregated, resulting in faster, easier, and more economically viable activity, enabling the revegetation of large areas by planting seedlings (Bruel et al., 2010).

It is also noteworthy that *I. vera* and *S. terebinthifolius* presented some individuals in fruiting, in the second year after planting. Considering that these fruits are attractive to avifauna, their use in anthropic areas shows another functionality of these species, which favors the increase of local fauna richness, facilitating the beginning of the restoration process.

It was also evident that the use of mulching did not demonstrate the expected effect on the growth of seedlings of both species. Only for *I. vera* was SDM and higher soil moisture in those plots with the presence of mulching, while the others attributes were similar, regardless of their use. Possibly, the mulching was not very effective on these species, as they demonstrated growth very quickly, and are therefore little affected by competing vegetation, even in those plots with no mulching. Furthermore, there was adequate rainfall throughout the during the first months after planting, a fact that may have contributed to the establishment of seedlings in the field, regardless of the use of mulch to increase soil moisture.

The differences found in the morphological attributes of both species were not expressed in the physiological attributes. According to the results obtained in this study, although some treatments were morphologically superior, it is possible to infer that all seedlings for both *I. vera* and *S. terebinthifolius* were subjected to similar physiological conditions and that the treatments used did not cause stress to the plants.

Notably, the Fv/Fm attribute of both species presented a general average below that of the recommended level (0.694 for *I. vera* and 0.704 for *S. terebinthifolius*), considering that under appropriate environmental conditions, this attribute ranges from 0.75 to 0.85, and decreases when plants are exposed to stressful factors such as weed competition, water, and nutritional deficiency (Baker, 2008; Araújo and Deminicis, 2009). However, it is common to observe Fv/Fm values lower than those considered ideal or close to the lower limit (i.e., 0.75) in studies conducted in areas with a subtropical climate.

Therefore, considering that the planting site in the present study presented adverse conditions for the seedlings and that the two species demonstrated satisfactory growth, the values obtained were adequate for the local situation.

The values obtained for the variable light under the canopy (LC) reflect the behavior observed in the morphological attributes, in which larger seedlings provide greater humidity under their canopy and greater light interception. Thus, the variables obtained in the environment under the canopies showed the efficiency of the area covered by the aerial parts of *I. vera* seedlings from plastic bags, mulching at planting, and *S. terebinthifolius* seedlings in all treatments.

This effect is important, considering that it is difficult to establish native tree species in areas with a high incidence of weeds, making it necessary to adopt measures that modify the location and make it less suitable for developing these plants (Ewing, 2002).

Among the measures adopted, covering the area with tree canopies provides shading, which can reduce surface occupation by weeds and favor the establishment of tree species of more advanced successional stages (Ignácio et al., 2007). Furthermore, the increase in soil moisture, with consequent water availability, is essential for introducing new seedlings in a plantation (Grossnickle, 2005). It should also be noted that seedlings with high height and a large canopy area can generate higher rates of litter deposition in the soil, contributing to the accumulation of organic matter and nutrients in its surface layer (Brun et al., 2013).

The rapid coverage of the area, as evidenced in this study for *I. vera* and *S. terebinthifolius* seedlings, is one of the functions of projects based on the framework, which often uses exotic tree species in restoration plantings to supply such functions. This is because of the lack of knowledge regarding the behavior of native species, making it necessary for more studies to be carried out.

5. CONCLUSION

I. vera seedlings must be produced in larger volume containers (1.5 L plastic bags), with the aim of increasing their survival and growth in the field. *S. terebinthifolius* seedlings can be produced in 180 cm³ containers to obtain adequate survival and growth of seedlings in the field, along with savings in the production process.

The use of mulching was ineffective in favoring the survival and growth of either species, and it is recommended that further research be carried out to evaluate its effect when used in larger quantities or on a total area.

I. vera and *S. terebinthifolius* could be used in restoration projects in anthropized areas, given their silvicultural behavior, confirming them as framework species.

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AUTHOR CONTRIBUTIONS

T.C.Z: Conceptualization, methodology, formal analysis, investigation, writing - review and editing. M.M.A: Supervision, funding acquisition, conceptualization, methodology, writing - review and editing. S.C.A: Methodology, investigation, writing - review and editing; A.L.P.B., C.C. and M.R.S.: Methodology, review.

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