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GERMINATION AND SURVIVAL OF *Nidularium innocentii* Lem. (BROMELIACEAE), ORNAMENTAL BROMELIAD ON LOW-COST SUBSTRATES FOR CULTIVATION: AN ALTERNATIVE TO EXTRATIVISM[1]

GERMINAÇÃO E SOBREVIVÊNCIA DE *Nidularium innocentii* Lem. (BROMELIACEAE), BROMÉLIA ORNAMENTAL EM SUBSTRATOS DE BAIXO CUSTO PARA CULTIVO: UMA ALTERNATIVA AO EXTRATIVISMO

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ABSTRACT - The extractivism of bromeliads in Paraná for ornamental purposes has been occurring since the 70's, due to the easy access in the forests, the high demand of consumers, and the small number of producers in the region. Among the species of this group stands out *Nidularium innocentii* Lem. as the second most extracted species with commercial purpose. The reversal of this situation may be associated with the implantation of agronomic crops, but there are few and sparse studies on the germination of this species. Thus, in this context a study was carried out in order to evaluate seed germination and survival on different substrates. Six alternative types of substrates that were easily accessible to the rural producer were tested: peat, coconut husk fiber, plantmax®, earthworm humus, humid pine bark and sieved agricultural soil. The experiment was carried out in a completely randomized design, with four replicates and 25 seeds per experimental unit, at room temperature, in a greenhouse, with sprinkler irrigation for a period of 90 days. *Nidularium inocentii* showed germination on average at 7 days and maximum germination point was reached at 15.2 days, with an average of 65.8% of germination. Among the substrates tested, coconut husk fiber, peat and humid pine bark obtained the best results on seedling survival after seed germination. The study confirms the feasibility of sexual reproduction of the species for agronomic crops using low cost and locally abundant substrates.

Keywords: Floriculture; Ornamental plants; Paraná coast; Forest extraction.

RESUMO - O extrativismo de bromélias no Paraná, com finalidade ornamental, ocorre desde a década de 70, em função do fácil acesso nas florestas, a alta procura dos consumidores e o pequeno número de produtores existentes na região. Entre as espécies deste grupo destaca-se a *Nidularium innocentii* Lem. como a segunda espécie mais extraída com finalidade comercial. A reversão desta situação pode estar associada a implantação de cultivos agronômicos, porém existem poucos e esparsos estudos sobre a germinação dessa espécie. Assim, neste contexto realizou-se um estudo visando avaliar a germinação de sementes e sobrevivência em diferentes substratos. Foram testados seis tipos alternativos de substratos de fácil acessibilidade ao produtor rural: turfa, fibra de casca de coco, plantmax®, húmus de minhoca, casca de *Pinus* umidificada e solo agrícola peneirado. O experimento foi realizado em um delineamento inteiramente casualizado, com quatro repetições e 25 sementes por unidade experimental, à temperatura ambiente, em casa de vegetação, com irrigação por aspersão por um período de 90 dias. A espécie *Nidularium innocentii* apresentou o início de germinação em média aos 7 dias e o ponto de máxima germinação foi atingido aos 15,2 dias, com médias de 65,8% de germinação. Dentre os substratos testados, fibra de casca de coco, turfa e casca de *Pinus* umidificada obtiveram os melhores resultados na sobrevivência de plântulas após a germinação de sementes. O estudo confirma a viabilidade da propagação seminal da espécie para cultivos agronômicos utilizando substratos de baixo custo e localmente abundantes.

Palavras-chave: Floricultura; Plantas ornamentais; Litoral do Paraná; Extrativismo florestal.

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1 INTRODUCTION

Tropical flowers have shown strong sales growth in the market and they have been conquering traders and consumers due to their favorable characteristics such as resistance during long-distance transport, in addition to being a group of species more resistant to pests and diseases, favoring production and trade (Empresa de Pesquisa Agropecuária de Minas Gerais - Epamig, 2019). Another determining factor is that, while temperate climate flowers have an average pot life from 5 to 10 days, tropical flowers last from 20 to 30 days (Ferreira and Anacleto, 2019). Among the tropical flowers that have been gaining prominence in the trade, the bromeliads stand out, as they have characteristics favorable to commercialization (Nasser et al., 2019; Dias et al., 2020) such as beauty, exotic flowers and inflorescences (Tamaki et al., 2020), in addition to their intense colors (Anacleto and Negrelle, 2019).

The commercial exploitation of bromeliads in Brazil according to Anacleto and Negrelle (2019) and Muraro et al. (2019) is largely fueled by Veiling Holambra, the largest flower commercial center in Brazil. The trade of this group of plants already occupied the eighth position in the 90's, in terms of revenue and sales, nowadays the Brazilian production of bromeliads is 2.5 million per year. The same authors argue that since the 90's Paraná has occupied prominence on the national scene, in the production and trade of bromeliads, having been registered in the year of 2000 the third largest production in Brazil, as a result of the activity of 114 producers in 32 municipalities that distributed 250,000 plants in Brazilian trade. It is noteworthy, however, that crops on an agronomic scale were insufficient and due to acceptance in landscape projects, the extraction of bromeliads from the forests of Paraná occurred intensely. Therefore, many species, due to their ornamental importance, are at risk of extinction (Negrelle et al., 2012; Sasamori et al., 2020).

Among the bromeliads with greater commercial relevance, Anacleto and Negrelle (2019) highlight *Nidularium innocentii* var. *innocenti* Lemaire which is classified as the second most extracted species from the Atlantic Rain Forest for commercial purposes, due to both its intense red appearance and the durability of its inflorescences, but it is important to say that this extraction is not regulated, which can put at risk natural populations. According to Anacleto and Negrelle (2019), the ease of access to environments where bromeliads naturally grow, the high density of this resource, associated with the lack of financial resources for extractors, land problems that prevent the legalization of cultivation areas, the lack of technical and environmental limitations are factors that discourage the implementation or expansion of cultivation systems and reinforce the extractive pattern of the species *N. innocentii* in the State of Paraná.

According to Pereira et al. (2010) in addition to its ecological relevance, *N. innocentii* has an important role in the mutualistic interactions, in landscaping and floriculture.

The demand for exotic species, different from those traditionally found on the market, such as the species *N. innocentii*, has shown a significant and growing market value, and the exploitation of this potential in the international trade can promote the development of these regions, especially the small producers. Anacleto et al. (2019) and Tamaki et al. (2020) corroborate this statement and add that the most effective way to combat extractivism is the possibility for extractors to adhere to the agronomic cultivation of the species, and they reveal that among the limiting factors of this migration, is the lack of knowledge about which are the more efficient substrates for each species.

According to Pereira et al. (2010) for a large number of cultivated species there are recommendations for germination processes, however for ornamental native species such as *N. innocentii*, there is still a lack of information, especially with regard to the use of substrates, as also reported by Anacleto et al. (2019).

Alves et al. (2018) describe that several factors must be taken into account when choosing among the different substrates available. Ease of access, cost adequate to the reality of rural producers and according to Monteiro Neto et al. (2019) it is essential that the substrate be able to supply nutrients in sufficient quantity for the development of the seedlings, they also describe that it must be aerated for the development of the roots and present a satisfactory water retention capacity. In this context, Anacleto et al. (2019) affirm that the use of alternative substrates for ornamental plants can facilitate the implementation of new crops, and emphasize that it is urgent to investigate what are the low-cost substrates available to the rural producer, which adapt to the cultivation of ornamental plants, and which are sustainable, and once these conditions are met, it can facilitate cultivation on an agronomic scale and consequently reduce extractivism. It should be noted that many species of bromeliads do not need to reach the flowering stage to be considered ornamental, but this is not the case with the species that only has commercial value with flowering.

Thus, this research aimed to evaluate the seed germination and seedling survival of *N. innocentii* in six types of substrates that are easily accessible and inexpensive to producers Paraná Coast, Brazil, namely: peat, coconut husk fiber, plantmax®, earthworm humus, humid pine bark and sieved agricultural soil available on the properties for horticultural cultivation.

2 MATERIAL AND METHODS

The experiment in order to analyze the germination and survival of *Nidularium innocentii* Lem. seeds in different substrates was carried out in a greenhouse, with no temperature control. The climate in the region is Köppen Af type (superhumid tropical) with an average temperature of the warmest month above 22ºC and of the coldest month above 18ºC.

The coastal region of Paraná was selected due to its potential production and extractivism of bromeliads, becoming a recognized regional center of commercialization, associated with a growing increase in extractivism. Another factor to be considered is that another 100 coastal communities can be found in Brazil that present similar conditions that may also constitute future cultivations of the species, as reported by Negrelle and Anacleto (2012) and Anacleto and Negrelle (2019).

Similar to what was proposed by Anacleto et al. (2019), initially, berry type fruits were collected from 30 randomly selected plants. From each selected plant, an average of 10 fruits were collected at physiological maturity point as described by Pereira et al. (2010) that indicated the ideal point for physiological maturity for the species *N. innocentii* with ripe fruits with intense reddish color, uniform and shiny (Figure 1A and 1B). At this stage, it was also carried out on the availability of seeds by floral scape, with an average of four thousand seeds per plant being measured.

After collecting the fruits, the seeds were removed from the berries and washed in running water in order to remove the mucilage from the seeds of this species. Seeds were shade-dried on newsprint for seven days, then placed on substrates for germination.

Similar to what was proposed by Anacleto et al. (2019) and Pereira et al. (2010) a completely randomized statistical design was adopted, with each substrate classified as a treatment. Four replicates with 25 seeds per experimental unit were used.

Sowing was done in plastic tray-type boxes (20 x 10 x 5 cm) with a perforated bottom to prevent water accumulation.

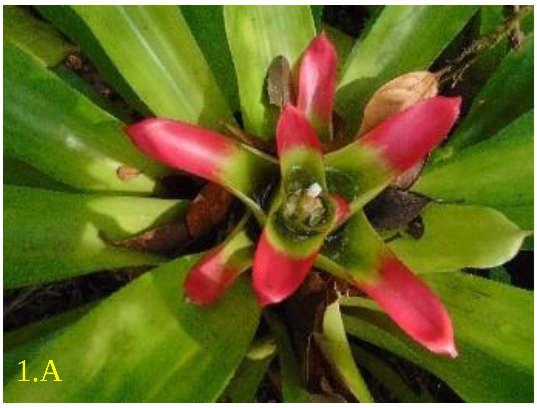

Figure 1. A: Inflorescence of *Nidularium innocentii* (Photo: Adilson Anacleto). B: *Nidularium innocentii* berry at seed collection point (Photo: Carlise Pereira).

Figura 1. A: Inflorescência de *Nidularium innocentii* (Foto: Adilson Anacleto). B: Bagas de *Nidularium innocentii* no ponto de coleta de sementes (Foto: Carlise Pereira).

The substrates were previously moistened by micro sprinkler, and the seeds were deposited on the layer in order to avoid burial, and then again, irrigation by micro sprinkler occurred.

Automated micro-sprinkler irrigation was performed with nebulization every 4 hours for 3 minutes, all treatments and repetitions were exposed to the same conditions of humidity, temperature and light.

Germination was tested on six types of substrates, the substrates being chosen in addition to accessibility, also due to their abundance in the producing region, namely: peat, coconut husk fiber, plantmax®, earthworm humus, humid pine bark and sieved agricultural soil available on the properties for horticultural cultivation.

The tested substrates were sent for chemical analysis (Table 1) according to the Instituto Agronômico de Campinas – IAC methodology described by Camargo et al. (2009), and the results of the analyzes were similar to those observed by Anacleto et al. (2019) and revealed that all substrates met the minimum nutritional requirements required by bromeliads.

The evaluation of the quantity of germinated seeds began on the first day after the implementation of the experiment, with daily observations and counts being carried out.

Table 1. Chemical analysis of tested substrates.

Tabela 1. Análise química dos substratos testados.

Parameters/Substrates		Coconut husk fiber	Humid Pine bark	Peat	plantmax®	Earthworm Humus	Agricultural Soil
pH	--	5,6	5,6	6,7	6,6	8,9	6,7
EC*	dS m^{-1}	1,2	0,9	3,2	3,4	2,5	0,5
N-Nitrate	----mg L^{-1}----	7	69	155	213	8	22
Phosphorus		12,7	0,3	3,2	4,4	10,9	0,1
Chloride		234	4	90	101	554	1
Sulphur		2	21	112	146	17	16
N- Ammonia		4,2	6,3	4,2	4,9	4,9	4,2
Potassium		346	148	680	728	810	81
Sodium		137	17	80	81	191	6
Calcium		0,3	44,8	60,2	151,9	10,2	26,0
Magnesium		4,6	27,9	24,6	97,3	22,9	11,3
Boron		0,2	0,1	0,1	0,1	0,0	0,1
Copper		0,01	0,01	0,01	0,02	0,11	0,01
Iron		0,1	0,2	0,1	0,1	0,6	0,7
Manganese		0,01	0,01	0,01	0,01	0,01	0,01
Zinc		0,04	0,03	0,01	0,01	0,03	0,01
Aluminum		0,2	0,3	0,1	0,1	0,2	2,2

*Electric conductivity

*Condutividade elétrica.

After the emission of leaf primordia, monitoring was started with the daily counting of seedlings for 90 days, after which the survival of germinated seedlings was evaluated.

After the monitoring period, as proposed Santana and Ranal (2000), the average germination percentage (x%) and the average germination time (t) were determined. These calculations were performed considering the period between the beginning of the experiment and the germination peak, and the percentage of seedling survival was determined considering the total germinated seeds at the germination peak and the final number of seedlings alive on the 90th day of monitoring.

Data were evaluated by analysis of variance (ANOVA) comparing among the classes as proposed by Santana and Ranal (2000), and the homogeneity of the variances was verified by Bartlett's test, and comparison of germination averages was performed by Tukey's test, both at 5% of probability.

3 RESULTS AND DISCUSSION

The beginning of the germination of *N. innocentii* started on the 7th day after sowing, with the maximum quantity of germinated seeds occurring 15 days after the implementation of the experiment. The results of germination time were similar to the laboratory study developed by Pereira et al. (2010), when it was found that seeds of this same species showed satisfactory germination rates when exposed to temperatures from 20°C to 30°C, in which case the leaf primordia appeared on the 10th day after sowing.

The results of the analysis of variance for germination speed (Table 2) revealed that there were statistically significant differences among the substrates evaluated, but due to the high germination rates with an average of 61% among all treatments, all substrates proved to be viable for use in field conditions in relation to germination speed.

Table 2. Germination speed, point of maximum germination survival of *N. innocentii* seeds, and seedling survival submitted to different substrates, Paranaguá, PR.

Tabela 2. Velocidade de germinação, ponto máximo de germinação de sementes de *N. innocentii*, e sobrevivência de plântulas em diferentes substratos, Paranaguá, PR.

Substrate	Germination speed (days)	Maximum germination point (days)	90 day survival (%)
plantmax®	12.30 a	16.26 a	60 c
Agricultural soil	14.30 b	14.00 c	56 c
Earthworm humus	14.80 b	13.00 c	48 c
Humid pine bark	15.00 b	18.25 b	68 b
Peat	15.80 c	17.00 b	72 b
Coconut husk fiber	19.30 c	20.25 a	80 a
Overall average	15.25	16.45	64

Averages followed by the same letter do not differ statistically from each other (Tukey $p<0.05$).

Média seguida da mesma letra não difere estatisticamente(Tukey $p<0.05$).

After the end of germination, a small mortality of seedlings of *N. innocentii* was observed among most of the evaluated substrates. The highest seedling survival value at the end of the monitoring period was obtained in the coconut fiber substrate (80%), with a significant difference between this and the other substrates tested (Tukey, $p<0.05$) (Table 2).

Specifically with regard to germination and seedling survival, substrates with more alkaline pHs showed a lower maximum germination point than substrates with more acidic pHs. At the end of the experiment, the substrate with the best performance was coconut husk fiber, which presents a pH of 5.6, pointing to a preference of this species for more acidic substrates for germination and survival. According to Anacleto et al. (2019), the germination of bromeliads at satisfactory levels only happens when the substrate is at an ideal concentration for the species, as it depends on adherence, water retention and other factors that interfere in the capacity of leaf primordia emission.

Thus, the better performance of the coconut husk fiber substrate may be associated at first with the availability in the crops of the required characteristics and the ideal microclimate for plants with C3 type, such as the species N. innocentii, in particular the aeration capacity and water retention, which may have avoided the plant water stress by keeping the water available for a longer time, and these characteristics together may have conferred a higher germination rate and low seedling mortality.

The coconut shell fiber substrate, according to Carvalho et al. (2021) presents porosity satisfying, water retention capacity and aeration in addition to being resistant to environmental variations and long-lasting, maintaining its physical characteristics.

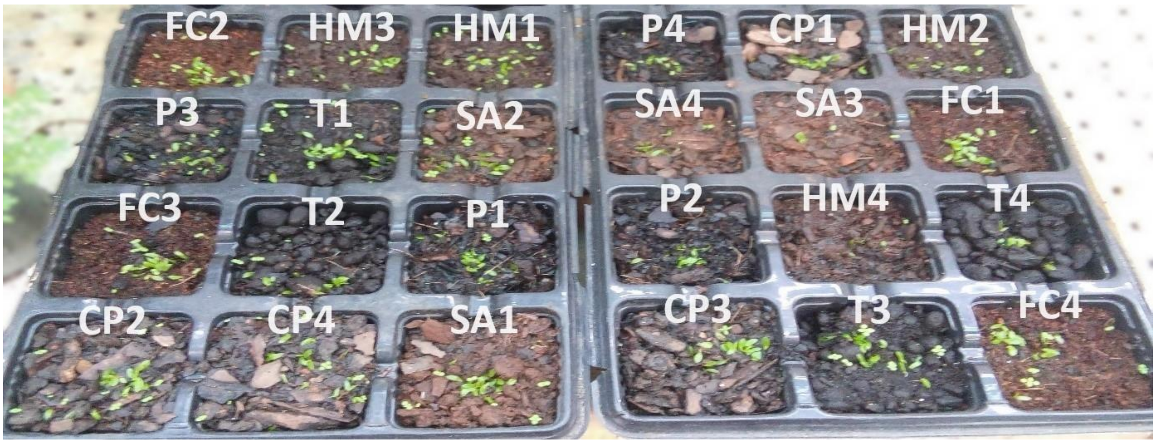

Figure 2. A: Survival of *Nidularium innocentii* after 90 days. FC = Coconut husk fiber; CP = Humid pine bark; T = Peat; P = Plantmax®; HM = Earthworm humus; SA = Agricultural soil. (Photo: Pamela Natali Ferreira de Jesus).

Figure 2. A: Sobrevivência de *Nidularium innocentii* após 90 dias. FC = Fibra de casca de coco; CP = Casca de pinus; T = Turfa; P = Plantmax® ; HM = Húmus de minhoca; SA = Solo agrícola (Foto: Pamela Natali Ferreira de Jesus).

Coconut husk fiber showed the best results in terms of survival, in addition to this issue, the material that gives rise to this substrate also has strong importance in the regional ecological context. Paraná Coast is strongly influenced by seasonal tourism, and annually, during the summer season, thousands of people visit the region, and among the most sold typical products is the green coconut water. According to Anacleto et al. (2019), Paraná Coast annually generates approximately 300 tons of coconut husk, which, in addition to occupying large volumes at the time of collection, almost all of this material is discarded in landfills in the municipalities of the region, Mattos et al. (2021) describes the urgent need to correctly dispose of coconut husk waste on the beaches of Brazil, and that in some regions this material represents up to 70% of the solid waste collected and discarded during the summer season, thus, when submitted to the processes of transformation into agricultural substrates, the production of this type of residue would decrease, and would also become a source of income with its commercialization.

In this context, the substrate based on coconut fiber, can represent an excellent alternative in the germination processes of bromeliads that, in addition to the results obtained being considered satisfactory, there is still great ease in obtaining this low-cost raw material.

Despite the satisfactory results for the species *N. innocentii*, it should be noted that the use of coconut husk fiber for other species, as reported by Kanashiro et al. (2008), different from the present study, did not prove to be the most efficient substrate. The likely explanation may be related to the fact that coconut husk fiber provides low electrical conductivity and low levels of nutrients needed by the plants in their initial stage, and epiphytes need low density and permeable substrates and reinforces that organic matter can be a relevant factor for growth in the initial stages of the plant.

Specifically in the case of *N. innocentii*, the likely explanation for why it has adapted better than other species in this type of substrate may also be related to the fact that, according to Anacleto and Negrelle (2019), this species is classified as proto tank bromeliads, which are those that present rudimentary phytotelma, that retains a small amount of water and for a limited time, and as a nutrition mechanism from the early stages, they have more developed functional roots, which adapt more easily to terrestrial substrates. While in other the bromeliad species classified as dependent tank, the nutrient absorption occurs less markedly by the roots and more by leaf trichomes on their leaves, and in species classified as atmospheric, leaf trichomes are the main route of nutrient absorption, being the roots only for fixation.

The peat substrates and humid pine bark showed the best second averages for maximum germination point and seedling survival, and they did not differ statistically from each other. Similar to coconut husk fiber, these materials also have good porosity and water retention capacity, favorable conditions for the development of the tested species.

Peat results from the incomplete decomposition of organic matter under high humidity conditions, it is associated with flooded regions, such as Paraná Coast, where there is an accumulation of mosses, mainly *Sphagnum* and *Hypnum*, and plant remains, such as tree barks, although the use of this type of substrate is allowed, environmental groups are against the exploitation of peat bogs, because such exploration destroys habitats of various species. The characteristics of peat are its lightness, high water retention capacity, easy to handle, sterile, its porosity is around 95%, (Ristow et al., 2012), contains high organic matter content, high buffer solution and 12% aeration (Ristow et al., 2012).

Thus, the physicochemical characteristics are similar to the coconut husk fiber substrate.

The pine bark according to Muraro et al. (2014) presents fragments of various sizes, and the smaller the particles, the greater the water retention capacity and the lower the aeration, and argues that the characteristics of this substrate predispose to low porosity, medium aeration and high retention of water, which can favor the germination process and seedling development. Another important fact highlighted is the industrial waste generated by lumber companies. Muraro et al. (2014) also says that these are sustainable alternatives for the development of substrates based on tree bark. In this way, the pine bark represents an economical and efficient alternative for the development of the species under study, and according to Anacleto and Negrelle (2019) the pine bark is an abundant material at Paraná Coast due to the large reforestation masses.

Earthworm humus (n=48%), as well as plantmax® (n=60%) and agricultural soil (n=56%) had the worst results for germination and survival, however when compared with the worst substrate results obtained by Anacleto et al. (2019) in the survival of a species of the genus *Aechmea*, earthworm humus with 24%, sand with 25% and the substrate plantmax® with 42%, yet *N. innocentii* showed much higher average germination rates, a fact that is linked to the high natural availability of seeds of the species, may conjure that when it is impossible to use substrates with higher efficiency, substrates with lower performance could also be considered alternatives to the germination of the species.

The substrate according to Estevan et al. (2010) can influence in the germination process, as factors such as texture, aeration and water retention capacity can be different among the substrates, providing differences in the amount of water that is available for the seeds, which can lead to changes in the percentage or change the emergency speed. Thus, the sexual propagation of *N. innocentii* carried out by the rural producers Paraná Coast should seek to replicate conditions similar to those found in the natural habitat of the species. According to Pereira et al. (2010) *N. innocentii* is a species that requires places with hot climate, mild luminosity and abundant water.

Apparently, despite the substrate based on the coconut husk fiber has proved to be the most efficient in the cultivation of the species, it must be considered that given the high supply of seeds under natural conditions, which was an average of four thousand seeds per plant, and the survival rates observed in this study, all substrates can be considered in the reproduction of *N. innocentii* under growing conditions.

The results obtained in this study, especially in relation to species survival, fill a gap existing in the agronomic crops as reported by Pereira et al. (2010) and Negrelle et al. (2012) who reveal that the species, despite having great ornamental potential, was not produced on a commercial scale, in part due to the lack of knowledge about the germination performance of the seeds and the most suitable substrates.

The need to develop global strategies in order to make the conservation of native plants, according to Estevan et al (2011) should be one of the premises and among the goals, the development of models with protocols for the conservation and sustainable use of vulnerable species can result in the preservation of natural stocks of bromeliads. Thus, specifically for the species *N. innocentii*, in the early stages of agronomic cultivation, considering the results obtained, as well as the accessibility, availability and low cost, this study confirms the viability of the species reproduction based on seed reproduction, which reinforces the propositions of Anacleto et al. (2019), Anacleto and Negrelle (2019), Pereira et al. (2010), Negrelle et al. (2012) and Muraro et al.(2014), who attest that this reproduction model is suitable for small producers in Paraná Coast, due to its low cost and the use of simple techniques that are already widespread in rural communities. This reproduction model can also reduce the pressure on the extraction of the species by expanding the supply of bromeliads from agronomic cultivation, allowing the ornamentation of this species in gardens across Brazil (Figure 3

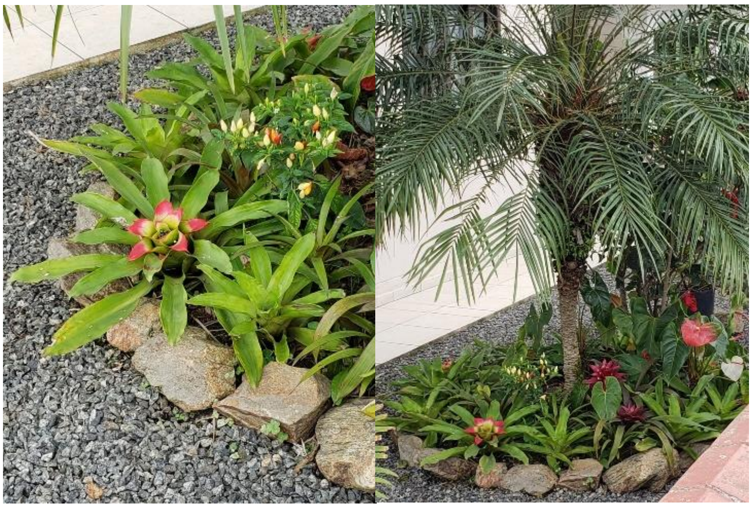

Figure 3. *Nidularium innocentii* in an urban garden in Paraná Coast (Photo: Adilson Anacleto).

Figura 3. *Nidularium innocentii* em jardim urbano no litoral do Paraná (Foto: Adilson Anacleto).

5 CONCLUSIONS

The species *N. innocentii* showed the beginning of germination on average at 7 days and the point of maximum germination was reached at 15.2 days after planting, with an average of 65.8% germination, which confirms the viability of reproduction through seeds for agronomic cultivation. Among the substrates tested, coconut husk fiber, peat and humid pine husk obtained the best results in the survival of *N. innocentii* seedlings in the first 90 days after seed germination. The study confirms the feasibility of using a low-cost substrate, with easy access and easy handling by rural producers, which could reduce production costs, make cultivation easier and, consequently, reduce the extraction of *N. innocentii* from forests.

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