Journal of
Zoological and Botanical Gardens

MDPI

Article

Floral Visitors and Florivory in *Tacinga inamoena* (Cactaceae) in the Ex Situ Collection of the Rio de Janeiro Botanical Garden

Diego Rafael Gonzaga [1,2], Ricardo Maximo Tortorelli [3], Thaís Moreira Hidalgo de Almeida [1,*] and Ariane Luna Peixoto [3,4]

[1] Coordenação de Coleção Viva, Diretoria de Operações, Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro 22470-180, Brazil; diego.gonzaga@gmail.com
[2] Instituto de Biodiversidade e Florestas, Universidade Federal do Oeste do Pará, Santarém 68040-255, Brazil
[3] Escola Nacional de Botânica Tropical, Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro 22460-036, Brazil; ricardo.tortorelli@jbrj.gov.br (R.M.T.); ariane@jbrj.gov.br (A.L.P.)
[4] Diretoria de Pesquisa Científica, Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro 22460-030, Brazil
* Correspondence: thidalgo@jbrj.gov.br

Abstract: *Tacinga inamoena* (K. Schum.) N.P. Taylor & Stuppy (Cactaceae, Opuntioideae) is a native Brazilian species found in the Caatinga phytogeographic domain. Although its flowers are adapted for bird pollination (ornithophily), few birds visit these plants in the ex situ collection at the Rio de Janeiro Botanical Garden. Despite this, fruit production occurs, prompting an investigation into the floral visitors and other animals interacting with *T. inamoena* flowers. This study aimed to identify floral visitors and quantify florivory damage to flowers in the Cacti and Succulents thematic collection. During the study, 79 flowers were monitored, along with their floral visitors and 26 instances of florivory, totaling 110 observation hours during the anthesis period. Despite recording only five hummingbird visits, a high fruit set was observed, with 72 fruits formed. Results indicated that bees of the genus *Trigona* sp. were the main floral visitors. Florivory damage, primarily caused by lizards of the species *Tropidurus torquatus* (Wied-Neuwied, 1820), did not negatively impact fruit formation in this cactus species under cultivation. To fully understand the reproductive success of this species, further studies are needed to assess the viability of seeds formed under these conditions, as the species may be self-compatible and autogamous.

Keywords: cacti collection; Caryophyllales; ecological interactions; lizards; *Tropidurus*

Academic Editor: Kevin Cianfaglione

Received: 30 September 2024
Revised: 9 December 2024
Accepted: 20 January 2025
Published: 22 January 2025

Citation: Gonzaga, D.R.; Tortorelli, R.M.; de Almeida, T.M.H.; Peixoto, A.L. Floral Visitors and Florivory in *Tacinga inamoena* (Cactaceae) in the Ex Situ Collection of the Rio de Janeiro Botanical Garden. *J. Zool. Bot. Gard.* **2025**, *6*, 6. https://doi.org/10.3390/jzbg6010006

1. Introduction

In recent years, ex situ conservation has gained importance as a response to the increasing devastation of natural areas. However, little is known about the cultivation conditions of plants in these settings, particularly when they are grown in environments with biotic and abiotic conditions that differ significantly from their original habitats [1]. Ex situ cultivation is essential for the conservation of endangered species, as it allows for the study of species interactions and helps define protocols that can be applied in both controlled environments and natural habitats during reintroduction efforts [2]. Such programs not only maintain genetic diversity but also ensure that species are resilient enough to adapt to changing environments when reintroduced [3].

Floral visitors, animals that seek floral resources like pollen and nectar, play a crucial role in plant reproduction [4]. However, not all visitors contribute to pollination. Effective pollinators must meet several requirements, such as making contact with the anther and stigma, frequent visits, floral fidelity, and following appropriate visitation routes [5,6]. Conversely, floral herbivory, or florivory, involves damage to reproductive structures before fruit and seed development, including harm to petals, sepals, stamens, and pistils, as well as pollen grains and ovules [7]. This process can negatively affect a plant's reproductive success by damaging key floral structures for attraction or reducing their attractiveness to pollinators [8,9].

Cactaceae, a family within the Caryophyllales order [10], comprises approximately 124–150 genera and 1428–1851 species worldwide [11,12]. In Brazil, this family is represented by 35 genera and 289 native species [13], playing an important ecological role in all phytogeographic domains, particularly in the Caatinga where they provide sustenance for both fauna and humans [14], and considered one of the most vulnerable regions in the world to the climate changes forecast for this century [15]. Despite their importance, studies on florivory in Cactaceae are scarce in the literature. For example, Campbell et al. [16] highlighted that beetle florivory reduces floral bee visits and threatens cactus fitness in desert areas. In Brazil, notable studies have addressed vertebrate florivory in *Echinopsis rhodotricha* K. Schum. in the Chaco region of Mato Grosso do Sul [17], as well lizard florivory by *Tropidurus hispidus* (Spix, 1825) in *Tacinga inamoena* in the Caatinga of Rio Grande do Norte [18].

Tacinga inamoena is a Cactaceae species endemic to Brazil, primarily occurring in the Caatinga [19]. Despite not being classified as threatened by IUCN criteria, it is listed as data deficient, highlighting the need for further research. The Caatinga is one of the most vulnerable regions to the climate changes expected in this century [20], and more than 53% of its area has already been deforested [21]. Although *T. inamoena* is not considered endangered, its habitat is under threat, making it a critical subject for study.

This species is part of the thematic cactus and succulent collection at the Rio de Janeiro Botanical Garden (Cactarium). The majority of Brazilian species in the collection originate from southeastern Brazil, particularly from the states of Minas Gerais and Rio de Janeiro, with emphasis on the Espinhaço and Mantiqueira mountain ranges [22].

Research on other Cactaceae, such as *Opuntia ficus-indica*, highlights the reproductive complexities these species face in ex situ settings, where factors like apomixis can limit genetic diversity and challenge effective conservation efforts. Although *Tacinga inamoena* differs ecologically, these shared characteristics suggest that conservation through cultivation must address both biotic interactions, like floral visitors, and inherent reproductive traits, such as autogamy or potential apomixis, to enhance survival and adaptability upon reintroduction to natural habitats [23].

The aim of this study was to detect floral visitors and florivory damage to *T. inamoena* individuals grown under ex situ conditions, contributing to a better understanding of this species' interactions in these settings.

2. Materials and Methods

The study was conducted from May 2021 to August 2022 at the JBRJ (Cactarium), which houses a collection of native and exotic cacti and other succulent plants. The collection currently comprises approximately 5500 individuals and around 450 species [24].

Specimens of *Tacinga inamoena*, collected in 2015 near the border of the municipalities of Cristália and Grão Mogol, Minas Gerais, during an expedition by the curatorial team of the JBRJ living collections (Record: RBvc 205), have been cultivated in the Cactarium since then. Two voucher specimens for this study are deposited in the RB herbarium of the

Rio de Janeiro Botanical Garden, with duplicates at the HUNI herbarium of the Federal University of the State of Rio de Janeiro (D.R. Gonzaga et al. 478 and R.M. Tortorelli 16 & D.R. Gonzaga).

Over the 15 months of observation, the *T. inamoena* individuals were monitored to count floral buds, flowers, and fruits. During and after anthesis, daily morning observations were conducted to record floral visitation, florivory, flower damage, and photographic records. A spreadsheet was used to document data on floral visitors, including the date, time, type of visitor, damage caused, and the responsible agent. Some damaged flowers were bagged with nylon protection to assess whether fruit formation occurred, including two flowers protected before anthesis and four after damage by florivory.

Observations of floral visitors and image recording were conducted from a distance of 3 to 3.5 m on flowering days, from the start of anthesis until flower closure (approximately 07:30 am to 14:00 pm), totaling 110 observation hours. Data on visitors, time of visit, and damage caused by florivory were compiled in spreadsheets.

Flower damage was categorized into four types: D1—perianth segments partially consumed; D2—perianth segments completely consumed; D3—perianth segments completely consumed, gynoecium and androecium partially consumed; and D4—perianth segments, gynoecium, and androecium completely consumed (adapted from [18]). Damage assessment was conducted at the end of each day's observation period.

After the flowering period, the formed fruits were monitored, and weekly counts were performed to assess the number of successful fruit formations over the eleven-month period (October 2021 to August 2022).

Photographic records of floral visitors were sent to specialists in the relevant groups for the most accurate identification possible based on the images, as no visitors were captured during the study.

3. Results

The *Tacinga inamoena* specimens have been cultivated since 2016 in bed number 24, a Brazil-themed flower bed in the open visiting area of the Cactarium. Since then, they have consistently flowered and fruited annually (Figure 1).

For this study, the first floral buds (Figure 1C) were recorded on 27 July 2021, and the flowering period occurred from 27 August to 27 September 2021, during which 79 flowers were counted (Figure 1D–F). The flowers began opening before 6:00 a.m., and observations commenced at around 7:00 a.m., when the flowers had fully reached anthesis, and ended at around 12:00 p.m., when the flowers started to close, fully closing by 2:00 p.m. Throughout this process, the flowers maintained the same color from opening to closing. The duration of anthesis was only one day, with the flowers remaining closed on subsequent days and lacking fragrance. By the end of the flowering period (Figure 1G), 72 immature fruits had been recorded.

During the observation period, visits from seven species of social and solitary bees (Figure 2A–G), four species of butterflies (Figure 2H–J,L), one species of moth (Figure 2K), one species of wasp (Figure 2M), two species of flies (Figure 2N,O), one species of hummingbird (Figure 2P), and one species of lizard (Figure 3) were recorded (Table 1). The majority of visits were from bees of the genus *Trigona* (68 visits), a group of stingless social bees. Only five hummingbird visits were observed. Additionally, 45 visits were recorded from the lizard species *Tropidurus torquatus* (Table 1).

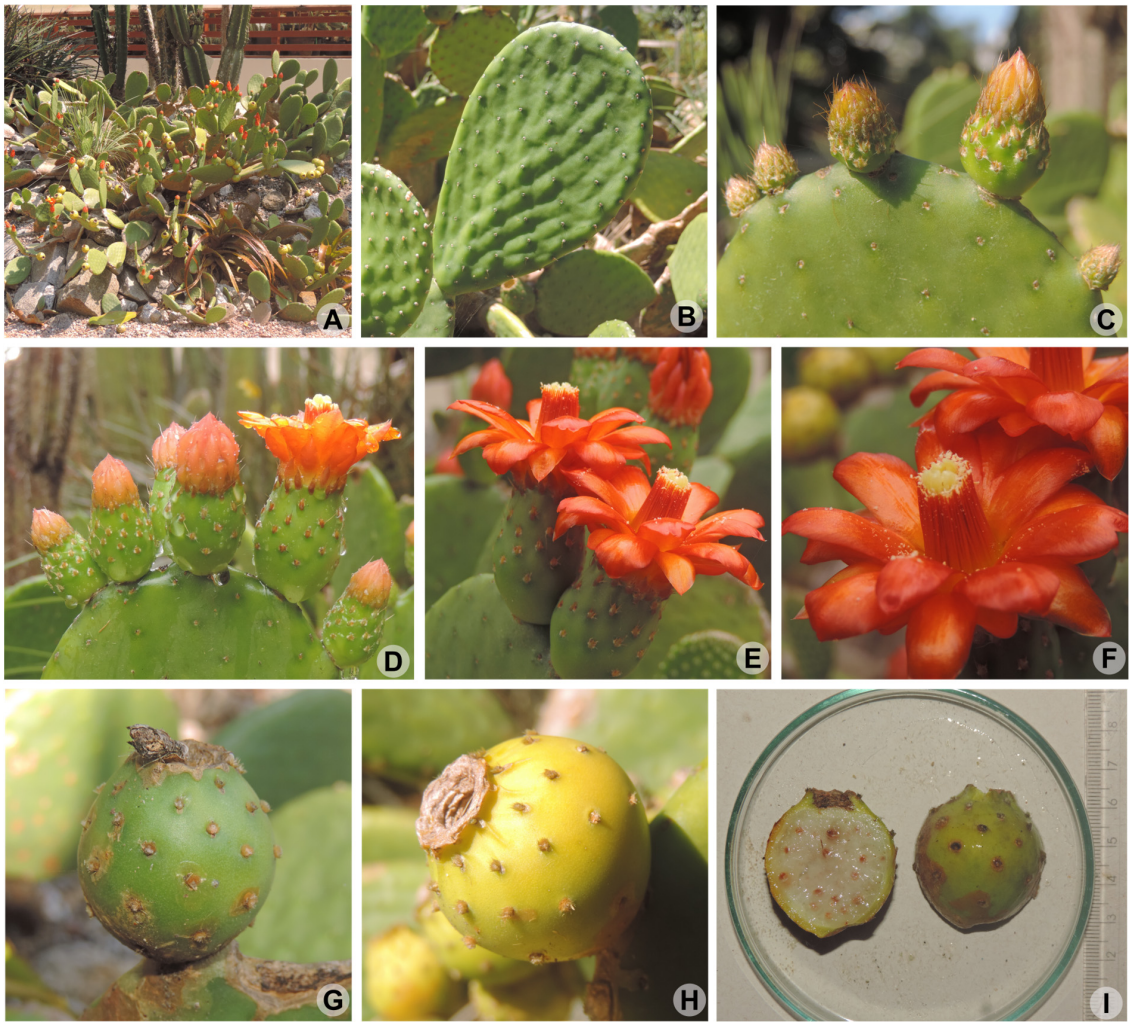

Figure 1. *Tacinga inamoena.* (**A**) Growth habit; (**B**) cladode; (**C**) flower buds; (**D**) flower buds and open flowers; (**E**) open flowers; (**F**) top view showing details of stamens and stigma; (**G**) unripe fruit; (**H**) ripe fruit; (**I**) longitudinal section of the fruit. Photos by Diego R. Gonzaga and Ricardo M. Tortorelli.

Table 1. Floral visitor records during the flowering period (27 August to 27 September 2021) of *Tacinga inamoena* in the ex situ collection of the Rio de Janeiro Botanical Garden, Brazil.

Visitor Type	Species	Number of Visits
Bee	*Augochlorini* sp.	45
Bee	*Euglossa* sp.	1
Bee	*Eulaema* sp.	1
Bee	*Plebeia* sp.1	1
Bee	*Plebeia* sp.2	1
Bee	*Tetragonisca angustula*	19
Bee	*Trigona* sp.	68
Butterfly	*Ascia monuste*	8
Butterfly	*Hermeuptychia* sp.	1
Butterfly	*Phoebis philea*	1
Butterfly	*Ministrymon una*	1
Moth	Hesperiidae	2
Fly	Diptera (sp.1)	1
Fly	Diptera (sp.2)	1
Wasp	*Brachimelia* sp.	1
Hummingbird	*Thalurania glaucopis*	5
Lizard	*Tropidurus torquatus*	45

Figure 2. Floral visitors. (**A**–**G**) Bees—(**A**) *Plebeia* sp.1; (**B**) *Trigona* sp.; (**C**) *Plebeia* sp.2; (**D**) *Augochlorini* sp.; (**E**) *Euglossa* sp.; (**F**) *Tetragonisca angustula*; (**G**) *Eulaema* sp.; (**H**–**L**) butterflies—(**H**) *Ascia monuste*; (**I**) *Ministrymon una*.; (**J**) *Hermeuptychia* sp.; (**K**) Hesperiidae; (**L**) *Phoebis philea*.; (**M**–**O**) wasp—(**M**) *Brachimelia* sp. (Chalcididae); (**N**) flies—Diptera (sp.1); (**O**) Diptera (sp.2); (**P**) hummingbird, *Thalurania glaucopis*. Photos by Diego R. Gonzaga and Ricardo M. Tortorelli.

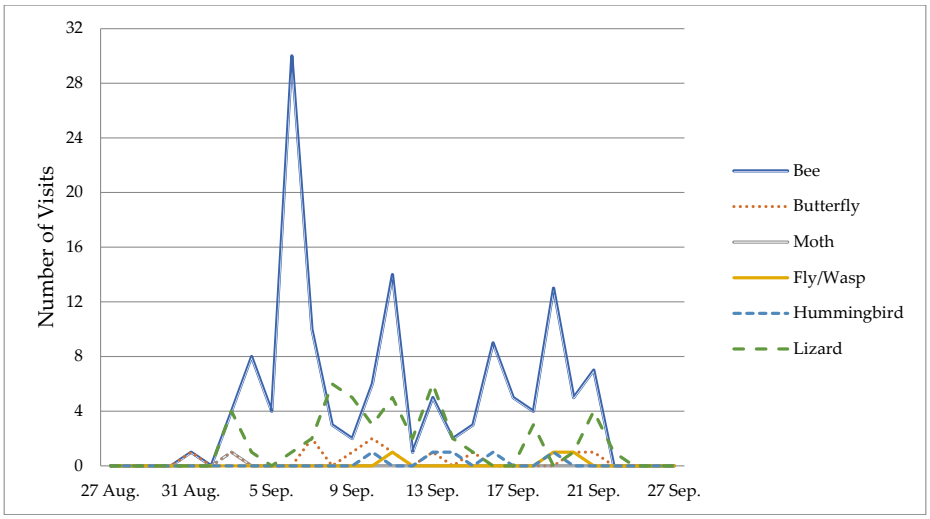

Figure 3. Number of visits by each type of floral visitor over the observation period.

The frequency of visits also varied across observation days (Figure 3), and throughout the flowering period, no specific visitor type showed a preference for particular visiting hours. However, peak bee visits coincided with cloudy days, while peak lizard visits occurred mainly on sunny days.

Regarding flower damage caused by florivory, lizards of the species *Tropidurus torquatus* consumed floral parts almost daily. The observed behavior showed a preference for flowers that were more accessible and closer to the ground, likely to minimize energy expenditure (Figure 4F). Climbing behavior was also noted, where the lizards ascended the vegetative branches of the plants to reach higher flowers at the tips of the branches (Figure 4A–C). Another observed behavior involved direct jumps, where the lizards leaped toward flowers at heights typically twice their body length, tearing off parts of the flowers (Figure 4D,E).

Figure 4. Florivory on *Tacinga inamoena*. (**A**–**E**) Consumption of floral parts by the lizard *Tropidurus torquatus*; (**F**) floral parts completely consumed—Damage D3 (perianth segments completely consumed, androecium and gynoecium partially consumed); and (**G**,**H**) floral parts partially consumed—Damage D1 (perianth segments partially consumed, androecium and gynoecium intact). Photos by Alexandre Machado, Diego R. Gonzaga and Ricardo M. Tortorelli.

Over 32 days and 110 h of observation, florivory by *T. torquatus* was recorded in 45 instances. The damage was categorized as D1 (partial consumption of perianth segments) in 21 cases and D3 (partial consumption of gynoecium and androecium) in 5 cases. Type D2 and D4 damage was not observed during the study.

The development of the fruits was monitored from their formation (late September 2021) until ripening, which took approximately 11 months. The flowers protected with nylon bags successfully developed fruits, even after being damaged and without contact with floral visitors (Figure 5). Out of the 79 flowers that bloomed, 72 fruits initially formed, 11 of which abscised, leaving 61 fruits that matured. The number of fruits formed that experienced florivory by *T. torquatus* remained relatively stable from October 2021 (72 fruits) to December 2021 (71 fruits). However, a gradual decrease was observed starting in January 2022, with 68 fruits, followed by a consistent reduction in February (64 fruits) and March (61 fruits). The count stabilized at 61 fruits from March to August 2022, corresponding to the number of fruits that matured.

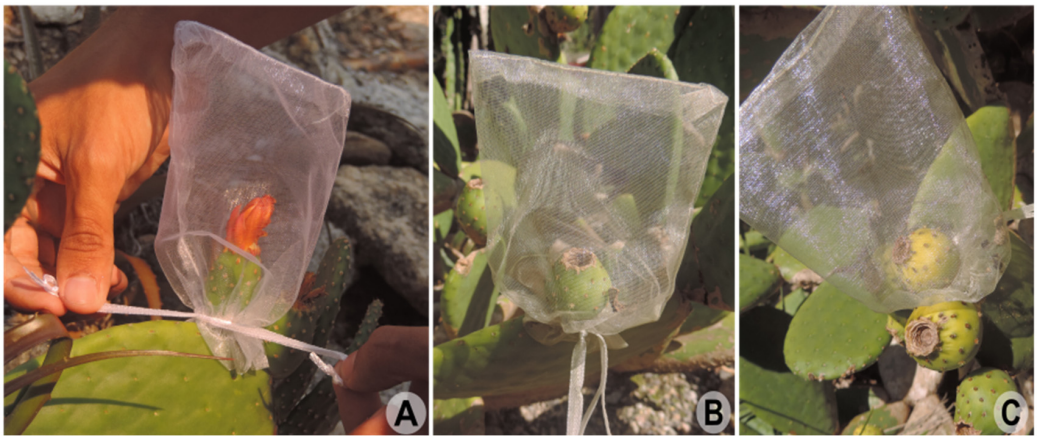

Figure 5. Damaged flower (**A**) and fruits wrapped for protection and development. (**B**) Green fruit; (**C**) ripe fruit. Photos by Diego R. Gonzaga.

4. Discussion

Tacinga inamoena has been described in the literature as primarily ornithophilous, with potential pollination by various species of hummingbirds, though the strength and exclusivity of this association remain uncertain [25–27]. In our study, only five visits by the hummingbird species *Thalurania glaucopis* were recorded during the observation period. In contrast, 136 visits by bees (both solitary and social) were observed, making them the predominant group of floral visitors, along with 45 visits by the lizard *Tropidurus torquatus*. While our observations focused on floral visitors, and did not confirm pollination, these results suggest more complex reproductive interactions than previously assumed. This study offers a unique perspective by presenting ex situ observations of floral visitation in *T. inamoena*, contributing to a broader understanding of its pollination ecology and highlighting the importance of considering cultivated environments as complementary systems for studying plant-animal interactions. It is important to note that the basic floral biology of *T. inamoena* was not the focus of our study, and further investigations are necessary to deepen our understanding of its reproductive mechanisms. Additionally, considering the probable autogamy observed and reports of potential apomixis in related taxa, further research is warranted to clarify the reproductive strategies of *T. inamoena*, including experiments that could more conclusively determine the roles of animal-mediated pollination, potential self-reproduction mechanisms, and their correlation with pollen release timing. Understanding these complexities in both natural and ex situ environments is crucial to advancing knowledge of the species' pollination dynamics (Table 1).

While the high number of fruits produced despite infrequent visits by hummingbirds suggests that *T. inamoena* may be self-compatible and autogamous—similar to findings with *Tacinga palmadora* (Britton & Rose) N.P. Taylor & Stuppy [28]—florivory in other cactus species, such as *Echinopsis rhodotricha*, has been shown to negatively impact fruit formation by directly damaging reproductive organs and indirectly reducing floral attractiveness and pollinator rewards [17].

Studies on the floral biology of *T. inamoena* in the Caatinga phytogeographic domain recorded visits from two species of hummingbirds, three species of butterflies, and only one species of bee (*Trigona* sp.) [29]. In contrast, our study at the Rio de Janeiro Botanical Garden (JBRJ) documented a greater diversity among floral visitors, including seven bee species, four butterfly species, two fly species, one moth species and one wasp species. However, we recorded fewer hummingbird species and visits. Costa et al. [29] also conducted pollination tests that indicated self-compatibility and autogamy in this species, which is further supported by our findings, particularly through the successful fruit formation from bagged flowers that had no contact with visitors or pollinators. The higher diversity of floral visitors observed at JBRJ may be linked to its proximity to a forested area within the Atlantic Forest phytogeographic domain, differing from the species' native Caatinga environment.

Furthermore, the flowering of *T. inamoena* was recorded as continuous during the dry season, from August to December, in the Caatinga in São José dos Cordeiros, Paraíba [25]. It was also reported to bloom year-round in three municipalities of Paraíba and in natural areas of Raso de Catarina, Bahia [29,30]. At the JBRJ Cactarium, however, we recorded flowering only from late July to September, consistently over five consecutive years (2018–2023). These differences may also be related to environmental variations resulting from ex situ cultivation in a biome that is not the species' natural habitat, or to adaptation to the specific cultivation conditions within the botanic garden [31]. The adaptation of wild species to local environmental conditions can simultaneously cause the loss of adaptations to their natural origins and the need for new adaptations for survival in cultivated settings [32,33]).

The genus *Tropidurus* Wied-Neuwied comprises 23 species of lizards native to South America, ranging from Venezuela to northern Argentina [34], and inhabiting various environments [35]. In the state of Rio de Janeiro, only two species are found (*T. torquatus* Wied and *T. hispidus* Spix), with the former being the only species present in the cultivated area of the Cactarium at the Rio de Janeiro Botanical Garden. This species is saxicolous or arboreal, exhibits pronounced sexual dimorphism, and relies on visual orientation [36]. It employs a sit-and-wait foraging strategy, primarily feeding on mobile and active prey [37].

Florivory in *Tacinga inamoena* in its natural habitat by the lizard species *Tropidurus hispidus* (Spix, 1825) was reported, with cases of complete flower consumption, including the pericarpel [18]. In our study, no consumption of the pericarpel was recorded, possibly due to the presence of a different lizard species with distinct body morphology, as well as the abundance of food resources at the botanical garden, which contrasts with the Caatinga, where prolonged periods of food and water scarcity are common. The pericarpel is a rigid structure, lacking attractive coloration and bearing glochids, which make it difficult and unappealing to consume, unlike the petals and other floral structures, which are visually appealing, flexible, and palatable.

On rainy days at JBRJ, a decrease in foraging activity by these lizards was observed, as they sought shelter and hid in rock crevices and artificial refuges, not visiting the flowers of *T. inamoena*.

In addition to *T. inamoena* flowers, the consumption of flowers and fruits from other Cactaceae species (*Echinopsis calochlora* K.Schum., *Xiquexique gounellei* (F.A.C.Weber) Lavor

& Calvente) by *T. torquatus* lizards was observed within the Cactarium environment [38]. Two species of the genus *Tropidurus* were reported as key dispersers of *Melocactus lanssensianus* P.J. Braun seeds in the Caatinga, with seed germination rates increasing after passage through their digestive tracts [39]. This highlights the importance of lizards of this genus as seed dispersers for certain Cactaceae species.

In studies linking living collections with herbarium specimens, the RB herbarium (JBRJ) holds two samples of *Tacinga inamoena* from ex situ collections. One of these specimens originates from JBRJ's living collection, collected by Campos Porto in 1934 (RB 28382) from the state of Bahia. The specific cultivation location within JBRJ is not mentioned, so it is uncertain whether it was in the Cactarium, whose establishment dates back to 1934–1938 [24]. This indicates that cultivation records of this species at JBRJ date back approximately 90 years.

Botanical gardens play a vital role in fostering a deeper connection between humans and nature, serving not only as centers for plant conservation and research but also as spaces that inspire environmental stewardship. By highlighting the intricate relationships between species, such as those observed in this study, botanical collections can engage visitors in meaningful ways, encouraging observation, care, and a sense of responsibility towards biodiversity. Educational initiatives, interactive displays, and community outreach programs centered around these living collections can amplify public awareness and promote a culture of appreciation and respect for the natural world, ultimately contributing to broader conservation efforts.

Our study emphasizes the need for research across different biological groups to better understand their behaviors in nature and in ex situ collections. The significant records of interactions between *Tacinga* and *Tropidurus*, along with other floral visitors, provide a strong research model for ex situ collections. These insights can help develop conservation strategies for botanical species, including those not yet classified as threatened.

Author Contributions: Conceptualization, D.R.G. and A.L.P.; methodology, D.R.G.; validation, R.M.T. and D.R.G.; formal analysis, R.M.T.; investigation, R.M.T.; data curation, R.M.T. and D.R.G.; writing—original draft preparation, D.R.G. and R.M.T.; writing—review and editing, T.M.H.d.A. and A.L.P.; supervision, A.L.P.; project administration, D.R.G.; funding acquisition, A.L.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) through a PIBIC research grant from the Instituto de Pesquisas Jardim Botânico do Rio de Janeiro to R.M.T. (Process: 122050/2021-5).

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Dataset available on request from the authors.

Acknowledgments: We thank the researchers who assisted with animal identification: Junia Y.O. Carreira (butterflies and moths), João L. Lobo (bees), and Bruno Correa Barbosa (bees and flies). Additionally, we appreciate the assistance of JBRJ photographer Alexandre Machado with the photographic records.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. IUCN Species Survival Commission. *Guidelines on the Use of Ex Situ Management for Species Conservation, Version 2.0*; IUCN Species Survival Commission: Gland, Switzerland, 2014. Available online: https://portals.iucn.org/library/sites/library/files/documents/2014-064.pdf (accessed on 20 September 2024).
2. Byers, O.; Copsey, J.; Lees, C.; Miller, P.; Traylor-Holzer, K. Reversing the Decline in Threatened Species through Effective Conservation Planning. *Diversity* **2022**, *14*, 754. [CrossRef]

3. Diaz-Martin, Z.; De Vitis, M.; Havens, K.; Kramer, A.T.; MacKechnie, L.M.; Fant, J. Species-specific effects of production practices on genetic diversity in plant reintroduction programs. *Evol. Appl.* **2023**, *16*, 1956–1968. [CrossRef]
4. Souza, C.S.; Aoki, C.; Ribas, A.; Pott, A.; Sigrist, M.R. Floral traits as potential indicators of pollination vs. theft. *Rodriguésia* **2016**, *67*, 309–320. [CrossRef]
5. Waser, N.M.; Chitkka, L.; Price, M.V.; Williams, N.M.; Ollerton, J. Generalization in pollination systems, and why it matters. *Ecology* **1996**, *77*, 1043–1060. [CrossRef]
6. Alves-dos-Santos, I.; Silva, C.I.; Pinheiro, M.; Kleinert, A.M.P. Quando um visitante floral é um polinizador? *Rodriguésia* **2016**, *67*, 295–307. [CrossRef]
7. Burgess, K.H. Florivory: The Ecology of Flower Feeding Insects and Their Host Plants. Ph.D. Thesis, Harvard University, Cambridge, MA, USA, 1991.
8. Cascante-Marín, A.; Wolf, J.H.D.; Oostermeijer, J.G.B. Wasp florivory decreases reproductive success in an epiphytic bromeliad. *Plant Ecol.* **2009**, *203*, 149–153. [CrossRef]
9. Carper, A.L.; Adler, L.S.; Irwin, R.E. Effects of florivory on plant-pollinator interactions: Implications for male and female components of plant reproduction. *Am. J. Bot.* **2016**, *103*, 1061–1070. [CrossRef]
10. APG IV; Chase, M.W.; Christenhusz, M.J.M.; Fay, M.F.; Byng, J.W.; Judd, W.S.; Soltis, D.E.; Mabberley, D.J.; Sennikov, A.N.; Soltis, P.S.; et al. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Bot. J. Linn. Soc.* **2016**, *181*, 1–20. [CrossRef]
11. Hunt, D.R.; Taylor, N.P.; Charles, G. *The New Cactus Lexicon*; Text.dh Publications: Milborne Port, UK, 2006.
12. Korotkova, N.; Aquino, D.; Arias, S.; Eggli, U.; Franck, A.; Gómez-Hinostrosa, C.; Guerrero, P.C.; Hernández, H.M.; Kohlbecker, A.; Kohler, M.; et al. Cactaceae at Caryophyllales.org—A dynamic online species-level taxonomic backbone for the family. *Willdenowia* **2021**, *51*, 251–270. [CrossRef]
13. Jardim Botânico do Rio de Janeiro. Flora e Funga do Brasil. Available online: http://floradobrasil.jbrj.gov.br/ (accessed on 26 October 2024).
14. Lima, J.L.S. *Plantas Forrageiras das Caatingas—Usos e Potencialidades*; Embrapa-CPATSA: Petrolina, Brazil, 1996; p. 37.
15. Cavalcante, M.B.; Sampaio, A.C.P.; Duarte, A.S.; Santos, M.A.F. Impacts of climate change on the potential distribution of epiphytic cacti in the Caatinga biome, Brazil. *An. Acadêmica Bras. Ciências* **2023**, *95*, e20200904. [CrossRef]
16. Campbell, K.; Pham, D.; Zheng, L. Impact of beetle florivory on floral longevity and pollinator visitation in desert cacti: A comparative study of *Opuntia basilaris* var. *basilaris* and *Echinocereus engelmannii*. *Calif. Ecol. Conserv. Res.* **2024**, *8*, 1–10. [CrossRef]
17. Gomes, V.G.N.; Koroiva, R.; Araujo, A.C. Vertebrate florivory on the short-columnar cactus *Echinopsis rhodotricha* K. Schum. in the Brazilian Chaco. *Plant Ecol.* **2016**, *217*, 1481–1487. [CrossRef]
18. Paixão, V.H.F.; Gomes, V.G.N.; Venticinque, E.M. Florivory by lizards on *Tacinga inamoena* (K.Schum.) N.P.Taylor & Stuppy (Cactaceae) in the Brazilian Caatinga. *Biota Neotrop.* **2021**, *21*, e20201109.
19. Zappi, D.; Taylor, N.P.; Cactaceae in Flora e Funga do Brasil. Jardim Botânico do Rio de Janeiro. Available online: https://floradobrasil.jbrj.gov.br/FB1750 (accessed on 20 September 2024).
20. Seddon, A.W.R.; Macias-Fauria, M.; Long, P.R.; Benz, D.; Willis, K.J. Sensitivity of global terrestrial ecosystems to climate variability. *Nature* **2016**, *531*, 229–232. [CrossRef] [PubMed]
21. MapBiomas. Mapeamento Anual da Cobertura e Uso da Terra no Brasil de 1985 a 2021—Caatinga. 2022. Available online: https://brasil.mapbiomas.org/wp-content/uploads/sites/4/2023/10/MapBiomas_Caatinga_2022_10.10.pdf (accessed on 23 September 2024).
22. Gonzaga, D.R.; Reis, R.C.C. The importance of ex-situ conservation: The challenges of the Cactarium at Botanical Garden of Rio de Janeiro. In *Cacti: Ecology, Conservation, Uses and Significance*, 1st ed.; Santos, M.R., Ed.; Nova Science Publishers: New York, NY, USA, 2019; Volume 1, pp. 1–279.
23. Carra, A.; Catalano, C.; Pathirana, R.; Sajeva, M.; Inglese, P.; Motisi, A.; Carimi, F. Increased Zygote-Derived Plantlet Formation through In Vitro Rescue of Immature Embryos of Highly Apomictic *Opuntia ficus-indica* (Cactaceae). *Plants* **2023**, *12*, 2758. [CrossRef] [PubMed]
24. Almeida, T.M.H.; Gonzaga, D.R.; Peixoto, A.L. Cacti in distress: How to enhance ex situ conservation strategies through living collections. *Oryx* **2024**, *58*, 565–575. [CrossRef]
25. Quirino, Z.G.M. Fenologia, Síndromes de Polinização e Dispersão e Recursos Florais de Uma Comunidade de Caatinga no Cariri Paraibano. Ph.D. Thesis, Universidade Federal de Pernambuco, Recife, Brazil, 2006. Available online: https://repositorio.ufpe.br/bitstream/123456789/406/1/arquivo2142_1.pdf (accessed on 23 October 2024).
26. Lambert, S.M. *Tacinga*, the hummingbird pollinated prickly pear. *Cactus Succul. J.* **2009**, *81*, 156–161. [CrossRef]
27. Las-Casas, F.M.G. Guildas de Beija-Flores (Aves: Trochilidae) em Uma Área de Caatinga, no Estado de Pernambuco. Master's Thesis, Universidade Federal de Pernambuco, Recife, Brazil, 2009. Available online: https://repositorio.ufpe.br/bitstream/123456789/586/1/arquivo1226_1.pdf (accessed on 23 October 2024).

28. Locatelli, E.; Machado, I.C.S. Comparative study of the floral biology in two ornithophilous species of Cactaceae: *Melocactus zehntneri* and *Opuntia palmadora*. *Bradleya* **1999**, *17*, 75–85. [CrossRef]
29. Costa, P.M.A. Biologia Floral de *Tacinga inamoena* (K. Schum.) NP Taylor & Stuppy (Cactaceae). Master's Thesis, Universidade Federal da Paraíba, Bananeiras, Brazil, 2021; p. 63. Available online: https://repositorio.ufpb.br/jspui/handle/123456789/22759 (accessed on 10 September 2024).
30. Bezerra, D.S.; Gonzaga, D.R.; Conceição, A.S. Flora da APA Serra Branca/Raso da Catarina (Estado da Bahia, Brasil): Cactaceae Juss. *Hoehnea* **2024**, *51*, e642023. [CrossRef]
31. Rauschkolb, R.; Szczeparska, L.; Kehl, A.; Bossdorf, O.; Scheepens, J.F. Plant populations of three threatened species experience rapid evolution under ex situ cultivation. *Biodivers. Conserv.* **2019**, *28*, 3951–3969. [CrossRef]
32. Vitt, P.; Havens, K. Integrating quantitative genetics into ex situ conservation and restoration practices. In *Ex Situ Plant Conservation: Supporting Species Survival in the Wild*; Island Press: Washington, DC, USA, 2004; pp. 286–304.
33. Ensslin, A.; Sandner, T.M.; Matthies, D. Consequences of ex situ cultivation of plants. Genetic diversity, fitness and adaptation of the monocarpic *Cynoglossum ofcinale* L. in botanic gardens. *Biol. Conserv.* **2011**, *144*, 272–278. [CrossRef]
34. Carvalho, A.L.G. On the distribution and conservation of the South American lizard genus *Tropidurus* Wied-Neuwied, 1825 (Squamata: Tropiduridae). *Zootaxa* **2013**, *3640*, 42–56. [CrossRef] [PubMed]
35. Harvey, M.B.; Gutberlet, R.L. Lizards of the genus *Tropidurus* (Iguania: Tropiduridae) from the Serranía de Huanchaca, Bolivia: New species, natural history, and a key to the genus. *Herpetologica* **1998**, *54*, 493–520.
36. Pinto, A.C.S.; Wiederhecker, H.C.; Colli, G.R. Sexual dimorphism in the Neotropical lizard, *Tropidurus torquatus* (Squamata, Tropiduridae). *Amphib. Reptil.* **2005**, *26*, 127–137. [CrossRef]
37. Huey, R.B.; Pianka, E.R. Ecological consequences of foraging mode. *Ecology* **1981**, *62*, 991–999. [CrossRef]
38. Gonzaga, D.R. (Coordenação de Coleção Viva, Diretoria de Operações, Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro, Rio de Janeiro, Brazil, and Instituto de Biodiversidade e Florestas, Universidade Federal do Oeste do Pará, Santarém, Pará, Brazil). Personal communication, 2024.
39. Gomes, V.G.N.; Koroiva, R.; Cassimiro, C.A.L.; Batista, F.R.C. Endangered globose cactus *Melocactus lanssensianus* P.J. Braun depends on lizards for effective seed dispersal in the Brazilian Caatinga. *Plant Ecol.* **2021**, *222*, 1375–1387. [CrossRef]