Chapter

Redefining Parasitic Plants: An Analysis of Economically Important Balanophoraceae Species in Argentina

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Abstract

The main objective of this work is to conduct a review of the uses of parasitic plants of the family Balanophoraceae present in Argentina. This study attempts to change the perspective on parasitic plants, shedding light on their inherent value and economic importance in certain communities in Argentina. Rather than adhering to the prevailing bias that all parasitic plants are harmful or simple weeds, this study aims to redefine such perceptions. It highlights the fact that some parasitic plants play fundamental roles as sources of livelihood, traditional medicine, or ornamental elements among local populations. In addition, this study highlights the importance of certain parasitic plant species that face conservation threats. Their prioritization stems from the global commitment to biodiversity conservation. The exploration of these unique plants and their functions within ecosystems highlights the intricate interaction between species and their environment. Taken together, this research contributes to a more nuanced understanding of parasitic plants, recognizing their multifaceted contributions, economic potential, and crucial role in the broader context of biodiversity conservation.

Keywords: economic significance, *Lophophytum*, *Ombrophytum*, biodiversity, conservation

1. Introduction

Biodiversity possesses intrinsic value and constitutes the foundation of natural heritage. It is a strategic resource as it underpins a wide array of essential environmental goods and services crucial for national development. To conserve it, it is imperative to maintain environments that harbor the genetic diversity of each species, communities, and ecosystems in each ecoregion. Consequently, conserving and sustainably utilizing biodiversity is the way to uphold the stability of ecosystems from which we derive essential services [1, 2]. Plants are the bedrock of civilization; we rely on the oxygen and the food and medicine they provide. However, from our daily lives, not everyone perceives that the majority of our culture and economy are rooted in plants [3].

Conservation involves managing biodiversity's use to obtain benefits while maintaining its potential for future generations. Conservation encompasses preservation, maintenance, sustainable use, and restoration of natural environments. Generally, the most effective strategy for biodiversity conservation is to keep it within its natural environment where it evolves. The key lies in preserving its interactions, ecological processes, and natural evolution [2, 4].

The conservation of genetic diversity is a globally assumed commitment. It can be carried out ex situ and in situ. In situ conservation involves maintaining species in their natural environments, and in the case of cultivated species, in environments where they have developed specific properties. Ex situ conservation refers to conserving resources outside their natural habitat, such as germplasm banks and botanical gardens, through propagation and cultivation (Convention on Biological Diversity, 1992 [CBD]). Successful conservation protocols require comprehensive studies encompassing taxonomic, morphological, population, and environmental interaction aspects.

From various governmental levels, at the very least, there is a need to "promote the development of sustainable biodiversity utilization plans, fostering alternatives for sustainable utilization of products and byproducts with high added value at the local level; applying an ecosystem-based approach grounded in scientific information; and involving communities in the development and monitoring of these plans. Promote economic alternatives based on the conservation of natural ecosystems, thereby safeguarding the ethnobiological knowledge associated with traditional and sustainable use of biodiversity" (taken from: National Biodiversity Strategy: Action Plan 2016–2020. Argentina).

In all of this, the often overlooked regional Herbaria, now regaining due significance, represent one of the most valuable sources of information, not only strictly concerning the flora of a region but also regarding the characteristics of the location where it was found, the type of environment, the community it belongs to, its relationship with fauna, and anthropic uses. This makes them indispensable for the conservation of biodiversity from the broadest perspective [5].

The vast majority of green plants are autotrophic, producing their own food through photosynthesis. Parasitic plants, on the other hand, have adopted a heterotrophic lifestyle, obtaining all or some of their nutrients from other plants on which they establish an organic connection with a host plant from which they are dependent. The most extreme manifestation of parasitism is seen in holoparasitic, plants entirely lacking chlorophyll, which acquire all their nutrients from the host, upon which they are entirely dependent. Most holoparasitic plants parasitize the roots of their hosts, with the majority of their life cycle spent underground. Due to this, many organs are highly reduced, modified, or even absent, as in the case of leaves and stomata in Balanophoraceae [6]. In many cases, their flowers are highly reduced, although embryological processes seem to follow general patterns among Angiosperms [7].

Preserving biodiversity, understanding sustainable resource utilization, and fostering new research have propelled parasitic plants beyond being merely harmful to crops or a curiosity in the botanical world. It is well known that parasitic plants often represent significant losses for agriculture, especially root holoparasites causing severe damage to cereals and legumes [7, 8–10]. Conversely, others are listed as threatened or endangered, such as Balanophoraceae [11, 12], and even in cases like Apodanthaceae and Hydnoraceae, their population levels are so low and their collections and herbarium reports are so minimal that their true risks are unknown, potentially putting them at risk of extinction. Compounded by their infrequent occurrence and lack of recognition, they might not feature on these lists or simply go unstudied and unaccounted for due to a lack of understanding about their habitats.

The majority of studies concerning parasitic plants are dedicated to finding solutions for weedy parasitic species, with less attention paid to those groups at risk of conservation or of local economic importance. Marvier and Smith [13] reported over 20 years ago that little progress had been made in conservation plans for lesser-known and threatened species, a situation that has improved today, although much remains to be done.

Among the species at risk of conservation or lesser-known are those with economic significance due to their value as food, medicine, or ornamentals, exacerbating their population decline due to increased exploitation in their natural habitats where cultivation techniques have not been developed. A concrete example in Argentina is the "Ankañoca" (*Ombrophytum subterraneum* (Aspl.) B. Hansen), an underground plant considered a "high-altitude fruit," where the axis of the inflorescence is edible. It grows in the Puna region at altitudes between 2500 and 4500 meters above sea level and is highly valued by local communities [14–16]. The mode of propagation or establishment of new host associations in this holoparasite is completely unknown.

A factor that hinders sustainability in the use of these species is the lack of knowledge about the mechanisms of propagule dispersal in the majority of holoparasitic species. In Balanophoraceae and Rafflesiaceae, this remains entirely unknown. The unique germination process described in *Balanophora abbreviata* Blume [17] involves the participation of endosperm cells in anchoring the parasite onto the host root. The uniqueness of the process raised doubts about the accuracy of the observation. In the few known cases, germination only occurs in response to chemical stimuli from host roots [18–20]. This also determines the most vulnerable stage of their life cycle [8]. Hence, experiments with positive results always involve the presence of a live host or extracts of their roots [21], (Roulet, pers. comm.).

2. The Balanophoraceae family

Among the more specialized holoparasitic plants are the species of the family Balanophoraceae L. C. Richard et A. Richard, which are devoid of chlorophyll and parasitize the roots of trees and shrubs. The best summary of the known characteristics of the family Balanophoraceae can be found in Kuijt & Hansen's work [22]. These plants develop a vegetative body called a tuber, which is partially or totally underground, of variable shape and color, from whitish-yellowish to yellow, orange to reddish-orange or brownish, or even purplish. It lacks the structures of the typical cormophytic organization, as the body is not differentiated into root, stem, and leaves [23–26].

A peculiarity of holoparasites is the tendency to acquire foreign genes from their host plants. It has recently been demonstrated that *L. mirabile* subsp. *bolivianum* not only harbors in its mitochondria a majority of genes from its host but also depends on them to carry out cellular respiration. Twenty-three of the 35 protein genes were obtained from Fabaceae. But what is most interesting is that these genes have replaced the native genetic material [27–28].

The Balanophoraceae family s.str. consists entirely of root holoparasites with 13 genera (*Exorhopala* has been placed within *Helosis*) [29] and 53 species distributed in tropical and subtropical regions. Unlike cormophytes, species of this family lack typical structures such as roots, stems, and leaves. Instead, they develop an underground vegetative body called a tuber [30, 31].

In this study, we will provide a detailed description of the information gathered from existing literature and observations made by our research team concerning the utilization and conservation of the following species: *Ombrophytum subterraneum*, *Lophophytum mirabile* subsp. *bolivianum* (Wedd.) B. Hansen, and *Lophophytum pyramidale* Eichler. These species have been selected for detailed examination due to their inclusion in Cantero [2]: "Plants of Economic Interest in Argentina."

3. Materials and methods

This study was based on an exhaustive literature review and numerous observations made since 2010, coinciding with the commencement of doctoral thesis of Sato, HA.

Ombrophytum subterraneum: For this species, observations were conducted between 2018 and 2023 through 10 trips to the following locations in Argentina: Jujuy: Yavi, Rodeo; Humahuaca, Palca de Aparzo; Humahuaca, Tres Cruces. These trips allowed the analysis of 67 specimens in situ for this species.

Lophophytum pyramidale: Observations were made from 2010 to 2018, with 14 study trips to the following locations in Argentina, Misiones: San Ignacio; Cainguás Salto Tabay; San Andrés. A total of 40 specimens were observed.

Lophophytum mirabile subsp. *mirabile*: Observations were made from 2010 to 2022, with 19 study trips to the following locations in Argentina: Jujuy: Ledesma, Parque Nacional Calilegua; Santa Bárbara, Santa Clara; San Pedro, Capital. A total of 23 specimens were observed.

Specimens collected from different species were deposited in the JUA and CTES herbaria. Open-ended interviews were conducted with inhabitants of the study areas during each visit. Field observations were complemented with the concepts and criteria that respondents pointed out about the species, along with information from bibliographic references.

Additionally, specimens and field labels of the studied species deposited in the following herbaria were examined: LIL; SI; LP; MCSN; JUA; CTES, LPB.

4. Results

4.1 "Ancañoka": *Ombrophytum* subterraneum

The Ancañoka grows in valleys and highlands between 2500 and 4000 meters above sea level in Argentina (Jujuy, Salta, Tucumán, and Catamarca), Chile, Bolivia, and the Galápagos Islands. Commonly known as "amañoke," "ancañoca," "amañoco," or "sicha" [14–16, 32–34], this achlorophyllous plant parasitizes the roots of trees, shrubs, and herbs. Its hosts documented by [24] include *Baccaris grisebachii* Hieron., *B. petiolata* DC., *Eupatorium bupleurifolium* DC., *Heterothalamus spartioides* Hook. & Arn., *Lepidophyllum quadrangulare* (Meyen) Benth. & Hook., *Scalesia pedunculata* Hook. f., *Tessaria absinthioides* DC., *Viguieria mollis* Gris. (Compositae), *Dioscorea megalantha* Gris. (Dioscoreaceae), *Medicago sativa* L. (Leguminosae), *Nicotiana glauca* Grah. (Solanaceae).

This taxon holds both food and medicinal potential. It is a valued resource among rural populations in the foothills, who have great appreciation for it as a fresh fruit they had access to in their childhood in areas where finding fruit products is challenging.

The axis of the inflorescence is consumed fresh, with the secondary rachises bearing unisexual flowers removed (**Figure 1A-B**). It usually has a sweet or slightly sweet taste. It serves as a useful means to quench thirst and hunger in rural areas. Recently, its use was proposed for creating a functional food nectar, easily accessible and with

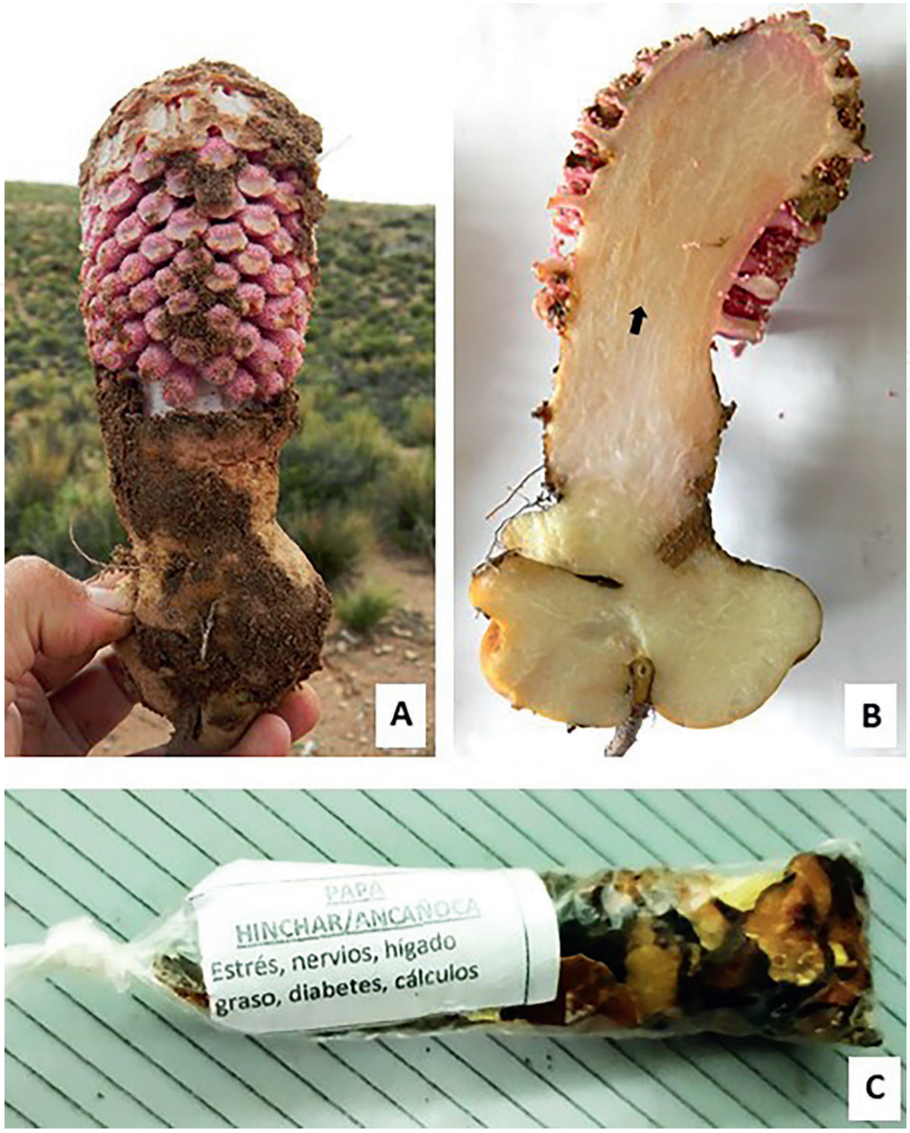

Figure 1.
Ombrophytum subterraneum*. A: Complete plant in bloom. B: Longitudinally sectioned plant, arrow points to the edible axis of the inflorescence. C: Plant remains dissected and packaged for sale.*

high nutritional value, based on the combination of *Ombrophytum subterraneum* and *Neowerdermannia vorwerckii* Frič, a cactus known colloquially as Achacana or Achakahana, found in the southern region of Bolivia and northern Argentina [35].

The tuber has a bitter taste and is consumed either fresh or as an infusion. To prepare the tea, it is sliced and dehydrated at room temperature under the sun, allowing it to be stored for months or even years. It is kept in polyethylene bags (**Figure 1C**). It is used in traditional medicine as an anti-inflammatory, analgesic, and antiseptic [16, 36]. Occasionally, dried tubers ready for infusion can be found in herbal stores or local markets.

The tuber is also used to dye wool with a brownish-yellow color and in ceremonies related to annual planting and harvest [37]. This plant exhibits specialized morphological and physiological adaptations that are of importance in providing us with a deep understanding of plant morphogenesis. It is entirely subterranean, including its flowers. Due to this characteristic, it is believed to reproduce asexually [17]. However, artificial multiplication has not yet been achieved, making its potential commercial use involve the extraction from its natural environment without the ability to reproduce it, potentially leading to a decrease in its population density. This is a critical aspect to consider when contemplating any form of commercial exploitation involving it, as a prerequisite would be to expand our understanding of it.

Little is known about the chemical composition of *Ombrophytum* species. Considering its potential for food, medicine, and even commercial uses, it is of great importance to characterize the compounds present in the tissues of its exploitable structures.

Studies on the morphology and anatomy of the tuber exist in this species [38], as well as studies on the morphology of staminate flowers [39] and pollen [24], along with various ethnobotanical works attributing it a high regional value (Vignale, personal communication). Regarding its chemical composition, studies have been conducted on quantification of mineral elements [40] and characterization of its metabolome focused on determining composition and richness of volatile compounds, including evaluation of its antioxidative activity [36, 41]. In other species of the family, such as *Lophophytum mirabile* subsp. *bolivianum* and *Lophophytum pyramidale*, studies have been carried out concerning their antioxidant properties and microhistochemistry [42], driven by their traditional medicinal uses.

4.2 "Flor de piedra": *Lophophytum pyramidale*

The species *Lophophytum pyramidale* Eichler, commonly known as "Flor de piedra" in Misiones and Corrientes, is being depleted by local populations of indigenous communities, who sell it as a botanical rarity among ornamental plants [21–27].

According to Spegazzini [43], *L. pyramidale* used to grow abundantly throughout the territories of the provinces of Misiones and Corrientes and in neighboring countries Paraguay and Brazil, with records dating back just over 100 years. Currently, the presence of the species in our country is limited to specific areas in Misiones and is very scarce in Corrientes. Much of the habitat of *L. pyramidale* has been altered due to anthropogenic activities, especially for agriculture, and the populations of *L. pyramidale* are being diminished by local people who sell them for medicinal and ornamental purposes [44].

In Argentina, this species is exclusively parasitic on specimens of *Parapiptadenia rigida*, and it has been verified that its entire life cycle is completed on this host. Very old and healthy *P. rigida* trees have been found parasitized by *L. pyramidale*, suggesting that it might not be harming the host and could potentially involve a symbiotic relationship between the two plants. The flowering of *L. pyramidale* occurs between August and September. During this period, the host is coming out of its winter dormancy, and it is observed with virtually no foliage and pods still attached to its branches. These pods open and release the seeds simultaneously with the flowering of *L. pyramidale*. During the flowering period (August–September) (**Figure 2A–C**), the parasite is mostly sold at craft fairs alongside other plants, such as orchids. Vendors advise tourists about the benefits of plant infusions for liver and kidney conditions. As an ornamental, they are sold in pots with sand, where they gradually dry out.

They are also collected in large quantities and sold by kilogram to homeopathy companies, and various websites offer tinctures made from these plants (See reference: Article from the Ministry of Environment of Misiones; personal observation). *L. pyramidale* is even listed as a homeopathic medicine for the treatment of liver and kidney conditions.

While the extraction of these plants from their natural environment is detrimental to species conservation, it serves as a source of income for local populations. It is a priority to establish an action plan for regulating their extraction and promoting the development of propagation techniques that can be adopted by local communities.

Figure 2.
Lophophytum pyramidale*. A: Inflorescences emerging from the ground next to their host. B: Ornamental plant vendor with a recently removed flowering specimen. C: Complete specimen with complete tuber and inflorescence.*

4.3 "Flor de piedra": *Lophophytum mirabile* subsp. *bolivianum*

In addition to *L. pyramidale*, another species of the same genus with the same common name grows in Argentina, although it is much less known and very rarely used. Nonetheless, it also possesses the same characteristics and potential for utilization, but it is in a better conservation situation. *Lophophytum mirabile* subsp. *bolivianum* inhabits Argentina in the provinces of Jujuy and Salta, descending from the north through the Phytogeographic Province of Yungas, generally between 600 and 800 meters above sea level (msm). It parasitizes *Anadenanthera colubrina* (Vell.) Brenan, a large tree. Nuñez et al. [45] determined that this plant contains starch, other carbohydrates, and no alkaloids, indicating its potential for use as food, similar to what has been demonstrated for *O. subterraneum*. However, there are no records documenting its consumption. The anatomy of the flowers, both male and female, and their processes of micro-macrosporogenesis and micro-macrogametogenesis of the *Lophophytum* species were studied [31–46]. Embryogenesis, endospermogenesis, and fruit development of *Lophophytum* species (Balanophoraceae) were studied [31].

The flowering period is from November to March, during which they can be located by the emergence of the inflorescences (**Figure 3A**-**C**). The study "Vegetative Anatomy of *Lophophytum mirabile* subsp. *bolivianum* (Balanophoraceae) and the Effect of its Parasitism on the Anatomy of the Roots of its Host *Anadenanthera colubrina*" [26] is also available. However, the germination and establishment processes have not yet been identified, although sufficient baseline information and preliminary germination tests with positive results have been conducted.

In both *Lophophytum* species, a similar germination process was observed in the initiation of in vitro cultivation [21- Roulet, pers. comm.]. In *L. pyramidale*, the germination process continues with the emergence of the haustorium (Roulet, pers. comm.).

The contrasting situation between the *Lophophytum* species in Argentina is striking. Both are very similar and possess the same medicinal and ornamental potential, yet one is much less known. The advantage of *L. mirabile* subsp. *bolivianum* is that its relative obscurity contributes to better conservation levels. However, the conversion of lands for agriculture poses a threat to both species equally.

Figure 3.
Lophophytum mirabile *subsp.* bolivianum. *A: Plant in vegetative stage attached to the root of its host. B: Inflorescence emerging from the ground with drooping scales. C: Fully emerged mature inflorescence.*

5. Conclusion

In this review, the Balanophoraceae family has been thoroughly explored, and specific species of economic and conservation importance in Argentina have been analyzed. Biological diversity, particularly encompassing parasitic plants, represents a rich source of knowledge and economic potential. As research delves deeper into these species, prejudices are challenged, and their roles in ecosystems and society are redefined.

The species studied in this work, such as *Ombrophytum subterraneum*, *Lophophytum mirabile* subsp. *bolivianum*, and *Lophophytum pyramidale*, have been shown to have intricate relationships with their environment and local communities. Beyond their initial appearance of parasitism, these plants reveal a complex web of interactions that span from their role in habitat ecology to their economic and cultural value for local populations.

The analysis of morphological, anatomical, and physiological characteristics of these species provides a deeper understanding of their biology and potential applications. The existence of potential food and medicinal uses in *Ombrophytum subterraneum* and *Lophophytum mirabile* subsp. *bolivianum* underscores the need for further exploration of their chemical components and properties. Moreover, the identification of potential uses in industry and medicine, alongside the conservation challenges they face, emphasizes the importance of considering sustainable management approaches and conservation strategies for these species.

In a context of global change and biodiversity loss, comprehending and valuing plant diversity, including parasitic ones, becomes fundamental for ecosystem conservation and human well-being. This work not only highlights the economic and conservation significance of the studied species but also invites us to reconsider our relationship with plants and explore new ways of coexistence and sustainable utilization.

The research presented here opens doors to greater knowledge and appreciation of parasitic plants in the Balanophoraceae family in Argentina. As we advance in understanding their biology, uses, and conservation challenges, we contribute not only to botanical science but also to the preservation of the natural and cultural wealth of our region.

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