

ORCHID DIVERSITY AND ACCLIMATIZATION OF GIANYAR BOTANIC GARDEN AND ITS SURROUNDING AREAS

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Abstract

Orchids' remarkable diversity and threatened state warrant conservation efforts for this plant group. In Indonesia, ex-situ conservation in botanic gardens has proven an effective conservation strategy. However, ex-situ conservation success strongly relies, among other things, on plant diversity data of the targeted area and the effectiveness of the collected specimens' acclimatization process. This study seeks to document orchid diversity in the Gianyar Botanic Garden and its surrounding areas, while also assessing the effectiveness of the Bali Botanic Garden's orchid acclimatization process using collected specimens. Fieldwork was carried out in the Gianyar Botanic Garden, Banjar Seming, and Banjar Penyabangan in Bali. Literature reviews were also carried out to understand the uses of the recorded species. The acclimatization process was monitored by assessing the survival of orchid specimens over specific time intervals in the Bali Botanic Garden. This study documented 30 orchid taxa, both epiphytes and terrestrials, from the collection sites. Species composition varied notably between sites, as reflected in the low Jaccard similarity index. A high survival rate was also observed among orchids introduced to the Bali Botanic Garden, with terrestrial orchids performing better than epiphytes. This study advances our understanding of orchid diversity on Bali Island, particularly in the Gianyar Botanic Garden and surrounding areas. It also highlights the effectiveness of Bali Botanic Garden's orchid acclimatization procedure in supporting ex-situ conservation efforts.

Keywords: Acclimatization; Conservation; ex-situ; Orchid

Introduction

Ex-situ conservation, including botanic gardens, is essential for plant conservation efforts (Kovacs *et al.*, 2021; Neves, 2024). In Indonesia, ex-situ conservation has proven effective, with the number of threatened plant species under protection increasing since the establishment of several new

botanic gardens (Purnomo *et al.*, 2015). This situation emphasizes the necessity of establishing new botanic gardens to improve the country's plant conservation efforts.

Gianyar Botanic Garden is one of these newly established botanic gardens. Situated on the island

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of Bali, it complements the already-established Bali Botanic Garden. This botanic garden is one of two new botanic gardens on the island, alongside Jagatnatha Botanic Garden. Gianyar Botanic Garden harbors unique species, such as the endemic palm of *Pinanga arinasae* (Kuswanto *et al.*, 2018; Yudaputra *et al.*, 2021). A vegetation analysis conducted prior to the development of the botanic garden also recorded the presence of terrestrial orchid species (Kuswanto *et al.*, 2018). However, a specialized study documenting orchid diversity in this new botanic garden site and its surrounding areas is still missing.

The lack of orchid diversity data in conservation areas such as Gianyar Botanic Garden is regrettable. Orchids are one of the flagship plants for global biodiversity conservation efforts (Zhan *et al.*, 2024). This condition is due to the orchid's high diversity and numerous benefits for humans (Saavedra & Pitogo, 2021; Kumar *et al.*, 2024) while facing enormous threats in the face of anthropogenic disturbances, climate change, and specific conservation needs (Wraith *et al.*, 2020; Saavedra & Pitogo, 2021; Kindlmann *et al.*, 2023). This condition also warrants the study of orchid acclimatization. Ex-situ conservation relies on plants, including orchids, being displaced from their original habitat to an ex-situ site. The acclimatization period is important in determining the success of ex-situ conservation as it determines the number of available plant specimens for the next stage of conservation effort (Lestari *et al.*, 2018). However, this stage also needs particular attention as plant specimens might develop stress symptoms due to the collection and adaptation processes.

In Bali, orchid diversity studies were conducted in various areas, such as the west Bali forests (Dodo & Hartini, 2019) and a secret area of Mount Batukau (Wibowo *et al.*, 2015). However, a study regarding orchid diversity in Gianyar Botanic Garden and its surrounding area is still absent. The same condition was also applied for the acclimatization study of orchid species in the Bali Botanic Garden. Despite the mention of orchid acclimatization effort alongside other plant specimens acquired from Kayang Mentarang National Park, Indonesia (Lestari *et al.*, 2018), specialized records in this area are still absent, unlike the presence of a specialized acclimatization study of Araceae specimens collected in the garden (Asih *et al.*, 2018). The absence of data on the efficiency of the Bali Botanic Garden orchid acclimatization technique is unfortunate, as the botanic garden is the oldest botanic garden on the island and in the eastern part of Indonesia, and has served as a conservation reference for newly established botanic gardens in the region.

The condition mentioned above leaves the knowledge gaps that need to be addressed by this study. This study aims to document orchid diversity in Gianyar Botanic Garden and two surrounding areas while describing the wider aspects of the orchid species, i.e., its use for human beings through a literature study. The study also seeks to document the effectiveness of the orchid acclimatization effort conducted in the Bali Botanic Garden using orchid specimens collected from Gianyar Botanic Garden and surrounding areas. This study will enhance the data on the island's orchid diversity and ex-situ conservation efforts, enabling the island stakeholders to preserve the island's highly popular natural uniqueness.

Materials and Methods

This study field trip was conducted from 5-7 May 2019 at Kerta Village, Gianyar Regency, Bali province, Indonesia. The trip was conducted in three sites within the village, namely the Gianyar Botanic Garden, Banjar Seming, and Banjar Penyabangan (Figure 1). These three sites were purposively chosen to document the orchid diversity in Gianyar Botanic Garden and its surrounding areas.

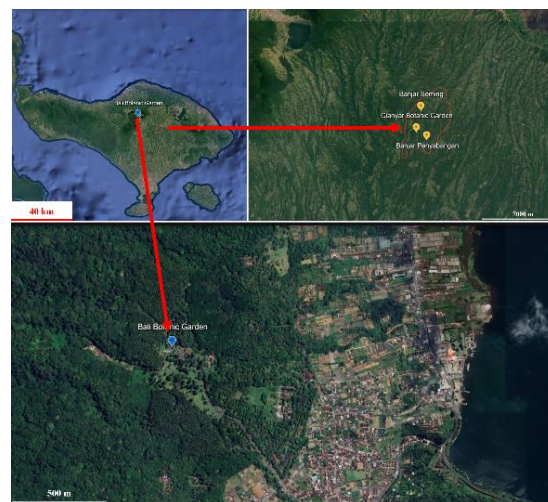


Figure 1. The study site map shows the collection sites in Kerta Village, Gianyar, and the Orchid acclimatization house at Bali Botanic Garden, Bali

Orchid collection was carried out by surveying each site over the course of a day. While the exact size of the sampling area was not recorded, the climate conditions were found to vary between sites. The Gianyar Botanic Garden site is located at

727-774 meters above sea level (m asl) with soil pH of 6-6.8 and relative humidity (Rh) of 82%-86%, the air temperature and relative humidity were 26.3-26.5°C and 80%. Meanwhile, Banjar Seming has soil pH and Rh of 7 and 55% air Rh and temperature of 34.4°C and 24.4°C, and located at 800 m asl. Banjar Penyabangan, on the other hand, was located at about 722 m asl with an air Rh of 79% and a temperature of 28.20°C.

The encountered orchid specimens were then collected. The number of collected orchid specimens was dependent on the number of encountered specimens; usually, no more than five specimens were collected for each collection number. The collection team conducted orchid identification at the site. Data regarding the orchid life form was also collected during this field trip.

At the end of each collection day, collected orchid specimens were sorted and repacked. The terrestrial orchid's root was wrapped in plastic with its growing medium, leaves trimmed and packed in open sacks. Meanwhile, the epiphytic orchids were surface-dried using tissue papers before being stacked delicately into cardboard boxes. Newspapers were placed between each stack to absorb excess water. To minimize plant stress and promote growth, the plant was carefully sprayed with plant growth hormone solution (Atonic) and plant B1 Vitamin (Liquinox). The plants were kept indoors until they were transported to the Bali Botanic Garden, with daily watering using the same plant growth hormone solution conducted during this waiting period.

The specimens were unpacked and planted in the Bali Botanic Garden's orchid acclimatization house on the same day they arrived. The acclimatization house was located in the Bali Botanic Garden's orchid garden at an altitude of about 1200 m asl. While the planting procedure was followed as described by Lestari *et al.* (2018), the acclimatization house temperature and air relative humidity were recorded at 21°C - 24°C and 65%±10%. Epiphytic orchids were planted during this study by attaching them to the *kadaka* (tree fern's root) plate using *sphagnum* moss and metal wire. In contrast, terrestrial orchids were planted in pots using a mixture of fertile soil and chopped *kadaka* media (Figure 2). However, the orchid planting media in Bali Botanic Garden are varied. A previous study recorded that pot planting was applied for epiphytic orchids using a mixture of chopped *kadaka*, charcoal, charred rice husk and coconut husk media (Lestari *et al.*, 2018). In contrast, terrestrial orchids were planted in pots using charred rice husk (Lestari *et al.*, 2018).

During the acclimatization step, the number of orchid specimens was recounted, as it might have decreased or increased due to death or specimens that needed to be split into smaller specimens. This number was the initial collection number. The specimens' survival observation was conducted in June, September, and December 2019. This period was chosen following the garden standard operational procedure that divided the reporting period into three-month periods for each year. Throughout the observation period, we recorded the number of surviving specimens, we defining survival as the presence of clear signs of life, such as the growth of new leaves. The count of surviving specimens in the final observation was then taken as the final collection number.

After the data acquisition, information on orchid species use was acquired from a literature review at the World Checklist of useful plant species (Diazgranados *et al.*, 2020). Meanwhile, the study's Jaccard index value was calculated using PAST software version 4.03 (Hammer *et al.*, 2001). The data was analyzed using Microsoft Excel and presented descriptively as a picture and table in this paper.



Figure 2. Orchid acclimatization conditions at Bali Botanic Garden, Bali. (Photo by Gusti Kade Alit Mantra)

Results and Discussion

This study successfully collected thirty-two orchid specimens. These orchids belong to 30 taxa and 22 genera, with *Dendrobium* having the most taxa (four), followed by *Thrixspermum* (three). *Cymbidium*, *Vanda* and *Robiquetia* are the third most diverse genera, with two taxa each. Figure 3 shows the orchid genera recorded in this study along with the number of taxa within each genus.

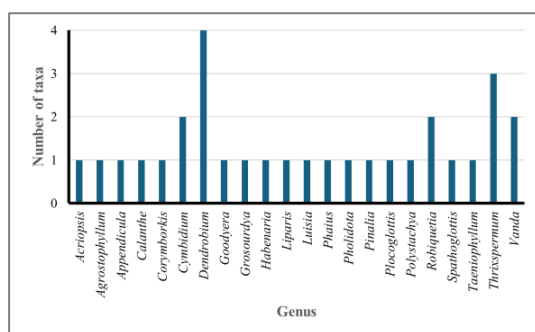


Figure 3. List of Orchid Genera and Number of Taxa for Each Genera Collected During the Study

Most of the orchids collected in this study were successfully identified to the species level (73%), while the remaining 27% could only be identified to their genus. In terms of life form, the majority of taxa (77%) were epiphytic orchids. Only 23% of the orchid taxa were terrestrial. Figure 4 displays the percentage of orchid taxa gathered for this study in terms of identification status and life form.

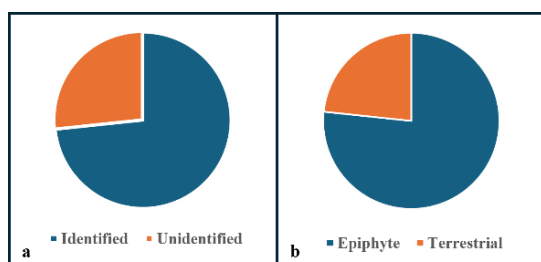


Figure 4. Percentage of Orchid Identification Level (a) and Life Form (b)

The results also show that the Gianyar Botanic Garden site hosts the largest orchid collection (14), followed by Banjar Seming (10) and Banjar Penyabangan (8). We also found that the

composition of orchid life forms varied between the collection sites. Terrestrial orchids were found in the Gianyar Botanic Garden and Banjar Seming, while absent in Banjar Penyabangan. Figure 5 presents a detailed list of the orchid life forms recorded in this study, while Table 1 provides the list of orchid taxa collected.

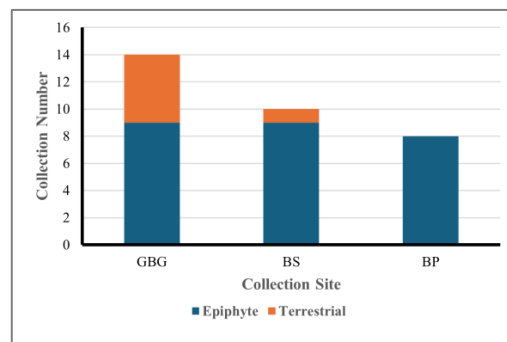


Figure 5. Number of Orchids Collected from Three Collection Sites During This Study and Their Life Form. Note: GBG= Gianyar Botanic Garden; BS=Banjar Seming; BP= Banjar Penyabangan

This study also found that each collection site is unique in terms of the orchid species they harbor. No orchid species were found in all three collection sites, while only two species were found in two of the collection sites. This site's uniqueness is also reflected in its Jaccard Similarity Index (JSI) value. The results of this study show that Gianyar Botanic Garden - Banjar Seming recorded the highest JSI value (0.048), followed by Gianyar Botanic Garden - Banjar Penyabangan (0.043). Meanwhile, Banjar Penyabangan and Banjar Seming show zero similarity values (Table 2).

This study recorded significantly fewer orchid taxa than the 81 species documented in the Batukau forest (Wibowo *et al.*, 2015). However, the collected taxa exceed the orchid diversity of the Dewasana Protected Forest reported in West Bali (Dodo & Hartini, 2019). The varied orchid diversity reported in these studies might be attributed to the different anthropological disturbances received by each study site. Diverse anthropological disturbances experienced at each collection site might also explain the variation in orchid species collected during this study period.

Table 1. List of Orchid Taxa Collected During This Study

Species	GBG	BS	BP	Habit
<i>Acropsis liliifolia</i> (J.Koenig) Ormerod	-	*	-	E
<i>Agrostophyllum javanicum</i> Blume	-	*	-	E
<i>Appendicula</i> sp.	-	-	*	E
<i>Calanthe sylvatica</i> (Thouars) Lindl.	*	-	-	T
<i>Corymborkis veratrifolia</i> (Reinw.) Blume	*	-	-	T
<i>Cymbidium bicolor</i> Lindl.	*	-	-	E
<i>Cymbidium</i> sp.	-	*	-	E
<i>Dendrobium crumenatum</i> Sw.	-	-	*	E
<i>Dendrobium linearifolium</i> Teijsm. & Binn.	-	*	-	E
<i>Dendrobium macrostachyum</i> Lindl.	*	-	*	E
<i>Dendrobium subulatum</i> (Blume) Lindl.	*	-	-	E
<i>Goodyera procera</i> (Ker Gawl.) Hook.	*	-	-	T
<i>Grosourdyia appendiculata</i> (Blume) Rchb.f.	-	*	-	E
<i>Habenaria</i> sp.	-	*	-	E
<i>Liparis</i> sp.	-	*	-	E
<i>Luisia javanica</i> J.J.Sm.	*	-	-	E
<i>Phaius</i> sp.	*	-	-	T
<i>Pholidota imbricata</i> Lindl.	-	*	-	E
<i>Pinalia djaratensis</i> (Schltr.) Schuit., Y.P.Ng & H.A.Pedersen	*	-	-	E
<i>Plocoglottis</i> sp.	*	-	-	T
<i>Polystachya concreta</i> (Jacq.) Garay & H.R.Sweet	-	-	*	E
<i>Robiquetia aberrans</i> (Schltr.) Kocyan & Schuit.	*	*	-	E
<i>Robiquetia minimiflora</i> (Hook.f.) Kocyan & Schuit.	*	-	-	E
<i>Spathoglottis plicata</i> Blume	-	*	-	T
<i>Taeniophyllum biocellatum</i> J.J.Sm.	*	-	-	E
<i>Thrixspermum</i> sp. 1	-	-	*	E
<i>Thrixspermum</i> sp. 2	-	-	*	E
<i>Thrixspermum subulatum</i> (Blume) Rchb.f.	*	-	-	E
<i>Vanda helvola</i> Blume	-	-	*	E
<i>Vanda tricolor</i> Lindl.	-	-	*	E

Note: GBG= Giayar Botanic Garden; BS=Banjar Seming; BP= Banjar Penyabangan; *= Present; -= Absent; T= Terrestrial; E= Epiphytes.

Table 2. Jaccard Similarity Index of Orchid Species Collected during This Study

	GBG	BS	BP
GBG	1.000	0.048	0.043
BS	0.048	1.000	0
BP	0.043	0	1.000

Note: GBG= Giayar Botanic Garden; BS=Banjar Seming; BP= Banjar Penyabangan.

Previous studies found that orchid diversity is adversely affected by human disturbances, including deforestation (Hussain *et al.*, 2024; Mirioba *et al.*, 2024). Human disturbance leads to drought stress, exposure, and reduced soil conditions that affect terrestrial orchid development while also disrupting epiphytic orchid recolonization by degrading habitat conditions and damaging host tree bark due to canopy opening (Besi *et al.*, 2019; Besi *et al.*, 2023).

While the Batukau forest is relatively pristine and safe from land degradation (Wibowo *et al.*, 2015), the Dewasana Protected Forest is a secondary forest (Dodo & Hartini, 2019), a condition that is also found in this study site, resulting in lower orchid diversity recorded in this study compared to that recorded from Batukau. Gianyar Botanic Garden's status as a sacred forest protects it from anthropological disturbance better than the Banjar Seming and Penyabangan, which are human settlements, allowing higher orchid diversity. The varying anthropogenic disturbance levels may also create distinct micro conditions between the collection sites, supporting unique orchid populations and resulting in the low similarity of orchid species between the collection sites.

Despite the relatively low recorded orchid diversity, our result provides better data regarding orchid diversity in Kerta village, Gianyar, compared to the previous study that only documented terrestrial orchids such as *Plocoglottis plicata*, *Goodyera procera*, and *Malaxis* sp. from Gianyar Botanic Garden (Kuswanto *et al.*, 2018). This study lists epiphytic orchids found in Gianyar Botanic Garden and its surrounding area.

The variation in anthropological influence at each collection site in this study might explain why terrestrial orchids were predominantly found in Gianyar Botanic Garden compared to Banjar Seming (1 species) and Penyabangan (0 species). Because of its status as a human settlement, wild terrestrial orchids are not likely to be abundant in Banjar Seming and Banjar Penyabangan due to extensive land conversion for human settlement in these areas, unlike Gianyar Botanic Garden, which was initially a secluded forest area. Although not

fully observing the epiphytic orchid host plant, particularly at the Banjar Seming site, this study discovered the epiphytic orchid in a Teak (*Tectona grandis*) tree in Banjar Penyangban. Simultaneously, epiphytic orchids were also discovered in unidentified fallen trees at the Gianyar Botanic Garden site.

In addition to the enhanced orchid biodiversity data, this study also identified orchid species in Gianyar Botanic Garden and its surrounding areas as valuable species. Among these four categories, medicine is the predominant use category among the listed taxa (five), followed by environmental uses (four) (Figure 6a). Furthermore, the results revealed that *Spathoglottis plicata* is an orchid species included in all of the listed use categories (Figure 6b).

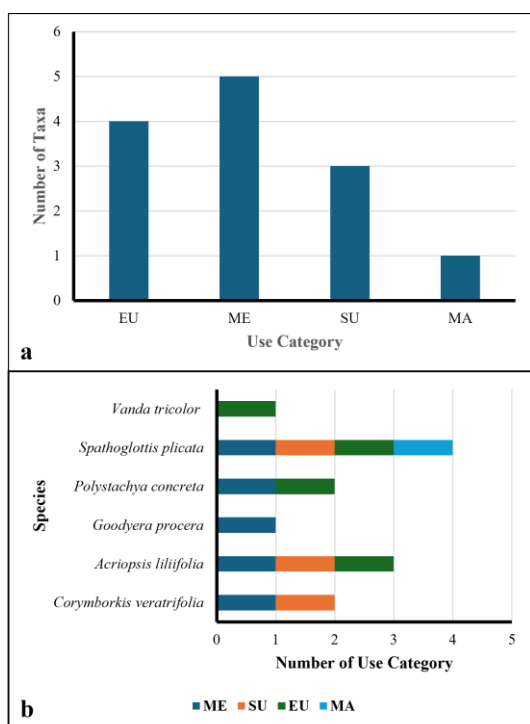


Figure 6. Number of Orchid Taxa in Each Use Category (a) and Orchid Species and Its Use Category. Notes: Environmental Uses (EU), Medicine (ME), Social Use (SU), and Material (MA)

The literature review result is supported by the previous research, which mentions the use of many orchids to fulfill various anthropological needs. Numerous orchid species are listed as medicinal plants (Wati *et al.*, 2023). Other orchid taxa, such as *Dendrobium*, are reported to be a culturally important part of the Mee tribe in Indonesian New

Guinea (Runtuboi *et al.*, 2023). Orchid including *Dendrobium*'s aesthetic features also made them popular as an ornamental species (Ketsa & Warrington, 2023; Kumar *et al.*, 2024).

Another example of the high usefulness of orchid species listed in this study was found in *Spathoglottis plicata*, the orchid species with the most use category. The species benefits for humans range from high commercial value as ornaments (Defiani *et al.*, 2024) to traditional medical usage (Dapar & Amoroso, 2022). The species is also a culturally important plant for the Yali people in Indonesian New Guinea (Milliken, 1994).

Our data found that orchid specimens collected during this study have high survivability at Bali Botanic Garden, with up to 50% survivorship across taxa, collection, and specimen numbers (Figure 7a). The data also suggest that terrestrial orchids show higher survivability compared to epiphytic orchids in all these categories (Figure 7a). The orchid survival data also indicates a decrease in the number of collected orchid specimens during the first and second observation periods, which then remained constant until the final observation period. This decline was driven by a reduction in the number of epiphytic orchid specimens, while the number of terrestrial orchid specimens remained constant from the initial collection to the final count, despite a decrease in the first observation period (Figure 7b).

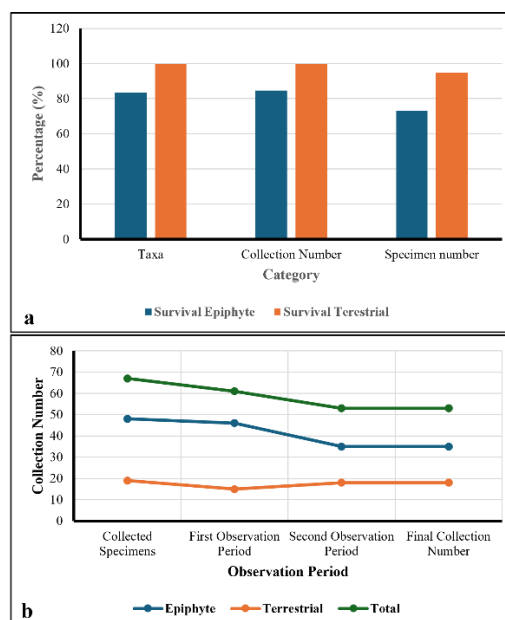


Figure 7. Survival Rate of Orchids Collected During This Study in Bali Botanic Garden (a) and Time Series Orchid Specimen Number Categorized by its Life Form (b)

The fluctuation in the number of terrestrial orchid collections in this observation is attributed to the loss of vegetative and generative organs, such as leaves and flowers, in terrestrial orchids during the initial observation period. This loss made the plants appear lifeless, almost as if they had withered. Yet, once they began to regrow, signs of vitality emerged, and by the second period they were observed as living specimens once again.

In contrast, epiphytic orchids exhibit lower survivorship compared to terrestrial orchids due to their specific characteristics for an epiphytic lifestyle. Epiphytic orchids show greater water regulation-related functional traits than terrestrial orchids, including for water loss regulation in their leaves, roots, and pseudobulbs (Zhang *et al.*, 2018). This specialization might cause a slight disruption to the epiphytic orchid organ, which is inevitable during collection, significantly impact its survival during acclimatization.

Conclusions

This study provides updated knowledge regarding orchid diversity in Bali Island by documenting 30 orchid taxa from Gianyar Botanic Garden and its two surrounding areas. This study also found that several orchid species are considered useful plants with diverse use categories ranging from environmental to social use. Along with the diversity data, the conservation and use data improve Gianyar Botanic Garden and its surrounding area's conservation value. On the other hand, this study's high survivability of collected orchids might be credited to the proper handling and acclimatization efforts in the Bali Botanic Garden. However, the high survivability also highlights the species high adaptability, an important trait for orchid domestication and breeding. The high survival rate also affirms that, with appropriate handling methods, ex-situ conservation of orchid species represents a feasible conservation strategy.

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